Future Challenges to Agriculture and its Impact on Weed Science

Workshop held on 19 June at the 6th International Weed Science Congress, 17-22 June 2012, Hangzhou, China

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This document endeavours to summarise the discussions held on the day with the various contributors and delegates. The recommendations, however, were personally drafted by the organizers after the conference and workshop, thus they could not be tested or validated with the workshop participants.

Introduction

When the Scientific Committee of the congress decided to have a Main Topic dealing with the "Future of Weed Science", we felt that the format of a normal session with oral presentations only, would not be adequate for this theme and we would need more time to discuss this important subject. Our idea was to start with introductory lectures on the future of agriculture in order to prepare the ground for a World-Café workshop where we wanted to elaborate the consequences from what we expect from future agriculture for the three topics: weed problems, weed control and research in weed science. After this World-Café we would have a panel discussion and if the whole activity would run successfully, we would publish the outcome of the workshop on the Congress website to be made available for all participants of the Congress and IWSS. This concept was approved and we can now present the outcome of the workshop and our recommendations.

We started with four introductory lectures. For the presentations and summaries of the lectures please see attached files.

Changes in agricultural structure and globalization of production systems: The view of an agronomist
R.E. Blackshaw, Agriculture and Agri-Food Canada, Canada

The future of agriculture and requirements for the food industry
H.P. Reust, Star Farm Consulting, China

Future Information and Communication Technology (ICT) and future agriculture
S. Wolfert and C. Kempenaar (presenter), Wageningen University, The Netherlands

Sustainability and weed management
D. Sammons, Monsanto, USA

The structure of our documentation is as follows:

1. Key trends derived from the invited lectures and own views considered in the workshop

2. Summary of the World-Café discussions and the outputs:
   - Topic: Evolution of weed related problems
   - Topic: Control of weeds and management in the future
   - Topic: Research in weed science in the future

3. Recommendations for future weed science

1. Key trends derived from the invited lectures and own views considered in the workshop

A growing world population along with an increasing middle class triggering an increase of meat consumption in the diets and competing demands for non-food uses require large increases in agricultural production in the coming decades (**Blackshaw)**.

On top of the increase in demand, the nature of the demand will also change. The needs of the society will have greater influence on what and how food is produced at the farm level, compounded by the requirements of the large food

retailers for greater uniformity in food production along with full transparency and low production costs (**Blackshaw**, **Reust**).

A move towards global food products with specified crop cultivars and production practices can also be identified as well as a need to supply previously considered “seasonal foods” more and more throughout the entire year.

These developments have and will continue to drive tremendous changes in the structure of agricultural operations such as:

- Larger farm size to attain economics of scale
- Farm specialization to simplify operations
- Population drift from rural to urban environments, depleting the labor pool for hand-weeding
- Reduced political influence of the few(er) remaining farmers
- Fewer and larger multinational companies with considerable vertical integration such as food retailers, seed-, pesticide- and fertilizer companies
- Increasing demand in the market (consumer and retailer) for a safe, healthy, sustainable/fair, traceable and by that fully transparent food supply (**Reust**)
- Growing importance of Information and Communication Technology (ICT) to enable precision agriculture and traceability in the food supply chain (**Wolfert & Kempenaar**)
- Growing participation of globally operating corporate farms with a tendency to standardize farming practices
- Governments and sovereign wealth funds leasing / purchasing land in land-rich regions
- Still growing adaptation of global technologies such as GM crops, precision agriculture and agricultural mechanization in general

Along with these structural changes, additional challenges for agriculture will result from adverse resource and environmental trends:

- Loss of productive soils / areas to erosion and urban and industrial development

- Declining water resources triggering the need for cropping systems with increased water use efficiency
- More expensive energy impacting manufacturing and use of farm machinery, production of fertilizers and pesticides and transportation costs
- Changes in climate, with some regions becoming hotter and drier and others more wet and an overall increase in extreme weather events – all impacting the occurrence and severity of weed and pest problems

These challenges require agricultural scientists and extension services to develop and promote the adoption of highly productive but more sustainable production systems including the widespread adoption of conservation tillage and the implementation of integrated crop management practices with more diverse crop rotations on one farm or across farming operations and the incorporation of new technologies **(Sammons)** when and where appropriate (**Blackshaw**).

2. Summary of the World-Café discussions and the outputs

Topic: Evolution of Weed Related Problems

Weeds are becoming more global and herbicide resistant (*e.g. Conyza, Amaranthus, Lolium*) as production systems in broad-acre crops (corn, soybeans, wheat, rice, cotton, sunflower, rapeseed) are becoming more standardized around the globe (some managed by globally operating corporate farms of several hundred thousand hectares) with a limited spectrum of effective herbicides. Global trade and a changing climate add to the continued spread of weeds.

Key trends identified:

- Still more herbicide resistant weeds, including multi-herbicide resistant species like the *Amaranthus* complex in corn and soybeans and the grass weeds in cereals and cereal based rotations
- Increase in weediness/plasticity of key weed species, *e.g.* season-long germination, increased metabolic capacity

- More crop related weed species, *e.g.* weedy rice in drill seeded rice, cruciferous weeds in rapeseed, johnsongrass in sorghum, including gene flow from HR (Herbicide Resistant) crops to weedy relatives
- Potential difficulties controlling HR volunteer crops in the rotation, *e.g.* corn in soybeans, oilseed rape/canola in sugar beets
- Weed shifts driven by a change from hand-weeding to chemical control triggered by labor shortage and increasing labor costs. The limited spectrum of registered herbicides will subsequently also increase the risk of herbicide resistance
- Increase of surface germinating weeds (small seeded dicots and grasses) due to increased adoption of conservation tillage practices
- Climate change leads to altered distribution, *e.g.* appearance of waterfern (*Marsilea* sp.) under wetter conditions in rice in India
- Water scarcity drives the move to seeded rice promoting grass weeds, including weedy rice
- Increasing problems with parasitic weeds (*e.g. Striga, Orobanche*) under continuous cultivation of host crops combined with low soil fertility, *e.g.* maize, sorghum, rice, sunflower, legumes, vegetables
- General weed problems in specialty crops/vegetables due to the disappearance of old herbicides and the lack of new compounds developed and registered for minor crops

Additional remarks related to weed problems have been made in the discussion following the workshop and the feedback to the session plenum such as: The general public having no idea about the impact of weeds on crop yield and the food chain and supply. The industrialized nations have plenty of food and think the problem of weeds is taken care of – wrong, as the weed problem is chronic, it never goes away. Thus, weeding is “the second oldest profession in the world”, but the willingness to do hand weeding, often carried out by women and children, is rapidly declining, therefore new tools need to be applied in an integrated approach.

Topic: Control and Management of Weeds in the Future

Limiting the impact of weeds on crops is fundamental to the success of high yielding intensive agriculture. During the second half of the 20th century the introduction of plethora of synthetic chemical herbicide products, ushered in an era where farmers could achieve unprecedented levels of weed control,

with greater simplicity and cost-efficacy than ever before. Latterly, the combination of herbicide tolerant crop plants (both naturally selected and genetically modified) has led to increased opportunities to use existing herbicide products and simplified the concept and practice of weed control in these crops still further. However, these advances are not without consequences.

Just as weed populations adapted to early control methods (*e.g.* tillage) so they have adapted ("shifted") in composition in response to herbicide pressure. Beyond that, in certain weed species, the use of herbicides has led to the enrichment of genes that confer resistance to the product, rendering it and sometimes related products, no longer effective. This process will continue as pointed out in the previous topic.

In the face of resistance, shifting to an alternative product can bring the weed back under control, but unfortunately once established at a high level in the population, the resistance to the failed product is rarely significantly diminished (*e.g.* through fitness penalties) and never eliminated.

Certain weed species with a high propensity to develop resistance (*e.g. Lolium, Amaranthus*), can evolve to resist multiple products, either by "stacking" different resistance genes or by using mechanisms (*e.g*. metabolism), which confer resistance to herbicides irrespective of the mode of actions, which therefore may include compounds not even invented yet!

This inevitable and inexorable trend towards more resistance is compounded by two factors leading to attrition of the chemical tool-set available to growers:

- Regulatory hurdles increasing, leading to the de-registration of formerly approved products
- Reduced industry productivity in bringing new herbicides to the market

The commercial success of herbicide tolerant crops and subsequent over-reliance on single weed control tools, has led to the emergence of serious and high profile problems with resistant "super weeds". This has led to a clamor for a quick-fix from industry based on new product solutions. While this spike of publicity has sparked a resurgence of interest in herbicide research, new products are increasingly hard to discover and costly to develop. Further, it takes a long time (8-10 years) to bring a new product to market.

What does this all mean for the future of weed control?

The potential irreparable failure of modern herbicides in the world's major food, fiber and energy crops threatens to undermine progress in mankind's development and prosperity, making weed resistance one of the biggest drivers for change when considering weed control in the world's agriculture in the future.

Discussions therefore centered on two imperatives and their implications:

1. The necessity to maximize the useful life of the existing commercial herbicides, effectively by reducing selection pressures on weeds and therefore preserving the genes for susceptibility. To do this implies the need for:

    - New and better strategies for use of herbicides (*i.e.* use of full rates, mixtures, rotations and emphasis on early season weed management)
    - More emphasis on the development and use of non-chemical means of managing weeds and the integration of these methods with chemical programs
    - Smarter use of products, increasing efficiency and effectiveness, from the development and adoption of precision application technology to maximize delivery to the target and to minimize wastage and environmental impact
    - A change in attitude, approach and ultimately behaviors, from the control of weeds today to the management of weed populations on a sustainable long-term basis

2. Intensify efforts to find alternative and better ways to manage weeds, such as:

    - Invention of new herbicides that can control both susceptible and resistant weed populations
    - Development of new herbicide tolerance traits and the extension of existing traits to different crops, to provide enhanced utility from existing chemical solutions
    - Development and commercialization of completely new non-chemical technologies (*e.g.* bio-controls, RNAi – RNA interference)
    - More holistic research and development on the best practices for sustainably managing weed populations over multiple seasons

Whatever industry, government and academia can contribute to the above, the reality is that weed control takes place on the farm and therefore is largely in

the hands of the grower. This raises another major challenge to the successful ongoing management of weed problems, how to communicate and influence growers to adopt the best strategies, technologies and practices to combat weeds.

Topic: Research in Weed Science in the Future

As one would expect, the discussion was mainly focused on research related to weed control and management as a response to the ongoing developments in the weed flora. Other areas were the critical issue of funding of research in weed science, the need for future oriented education in weed science and the need for improving the profile of weed science in academia and the public.

Key issues identified:

- There is a critical lack in the knowledge on weed biology (including biochemical, molecular biological and genetic aspects), weed ecology, local and global distribution and population dynamics of weed species for the development of a more knowledge-based weed management
- Elaborate and merge the above information in a comprehensive knowledge base for major weed species
- Need for weed surveys and mapping to understand changes in species composition and geographic distribution
- Need for long-term management strategies in addition to short-term control solutions
- Develop Decision Support Systems (DSS) to aid farmers in weed control
- Improve knowledge about the mechanisms of the development, spread and stability of herbicide resistance
- Need for more diversity in weed control – develop Integrated Weed Management (IWM) systems – applying agronomic practices including cover crops for sustainable weed management
- Need for current data on crop yield loss due to weeds
- Develop precision weed control systems to optimize the use of herbicides and lowering the risk of herbicide resistance development
- Develop weed thresholds as part of precision weed control
- Explore the potential utility of field robots for weed control
- More research based on farmers' needs – farmers to be integrated in weed control related research

- Exploration of weeds as a source of useful genetic material for breeding into crop plants – flood, drought, salt and temperature stress tolerance
- Breeding weed tolerant crops (vigor) and allelopathic crops that
- suppress/kill weeds
- Ecological role of weeds in cropping systems relative to threshold levels for weed management

These issues above have some consequences for academia:

- Develop interdisciplinary curricula in weed science to learn more about the complexity of weeds in farming systems and discover and implement new solutions
- Economics of crop losses due to weeds and economics of weed control have to be part of the weed science curriculum
- Graduates in weed science should have more hands-on experience – crop protection industry should provide scholarships
- The intake of students in weed science is decreasing worldwide – reasons need to be identified
- More investment in weed research funding for long-term studies is needed

During the general discussion it was acknowledged that unfortunately the profile of weed science in academia and public is low and needs to be improved. In the discussion about why the perception of weed is low could finally not be determined. The other two main crop protection disciplines, phytopathology and entomology, have a far better reputation despite the critical role of weed control for crop production worldwide. It was agreed that long-term research funding is a prerequisite for successfully responding to the challenges that will confront the world's farmers as they wrestle with weeds to feed the growing world population. Interestingly, and thus worth mentioning, topics like eco-farming and herbicide resistant crops had not been an issue during the World-Café and the general discussion regarding future research in weed science.

3. Recommendations for future weed science

Based on the fact that the first and foremost objective of weed science is to serve agriculture by investigating weed crop-interactions and developing control methods and management strategies in order to avoid crop yield loss

by weeds and thereby improve both, reliability and economics of crop production, the following recommendations have been derived from the workshop:

Future Weed Problems

- It is recommended the IWSS (and affiliated weed societies), to co-ordinate the study of the world's "worst weeds" (*i.e.* a short list of those judged to have the biggest impact either in terms of economics, food security threat or socially). The idea would be to search and pool information, identify critical gaps and sponsor necessary research in order to build up a knowledge base, upon which better intervention and management strategies can be based. Consideration should be given to the creation/designation of research "centers of excellence" and support for global "networks" of concerned scientists, extension workers etc.

Future of Weed Control

- Notwithstanding the possibility that industry might meet the challenge to invent and develop new effective herbicides, it is essential to develop better ways to deploy and protect/extend the lifetime of the tools we have today. It is recommended that the IWSS consider what steps can be taken to promote and accelerate the adoption of technology relating to integrated weed management, precision agriculture and resistance management.

Future of Weed Research

- More in depth information about weed species is needed for the development of new control technologies. The control of weeds in the field has to be put on a more sustainable footing and the reality is that this implies a change in farmer behavior, with an increased emphasis on long-term management with better integration of chemical, non-chemical and cultural control methods. The role of extension services in the transformation of new scientific evidence is critical in driving and supporting this behavior change. However, there has been a sustained decline in the provision of this essential service. It is recommended that the IWSS (and affiliated weed societies) develop an agenda and implement a campaign to lobby governments, NGOs, crop associations to garner support and funding for extension activities.

About the workshop itself:

The workshop with introductory lectures followed by the World-Café type discussion of the three topics: weed problems, management and research as well as the feedback to the auditorium was well attended. Between 60 and more than 100 colleagues were present during the whole day.

This successful workshop would not have been possible without the help of a number of people. In that context we would like to thank Bob Blackshaw, Hanspeter Reust, Corné Kempenaar and Doug Sammons for their lectures and providing us with their presentations. We also thank Ahmet Aludag, Lammert Bastiaans, Pedro Christoffoleti, Stephen Duke, Samunder Singh, and Bernal Valverde for their help in moderating the World-Café.

For a future workshop we recommend to include a sizeable portion of young scientists, grad students and colleagues from other disciplines in order to elaborate on and to create the future.