WSSA Liaison to EPA (Office of Pesticide Programs–OPP)
Interim Report to the WSSA Board of Directors–Quarter 3, 2010
Jill Schroeder
September 27, 2010

Schedule of third quarter activities:
August 2-5, 2010: hosted tour of NM agriculture and riparian areas (preparation time in July)
August 9-11, 2010: attended the NACD taskforce meeting on management of herbicide resistant weeds in conservation tillage agriculture in Little Rock, AR
September 13-16, 2010: visited OPP headquarters

Overview of Activities: I was active during the third quarter although I only visited the EPA-OPP headquarters in September. Instead of my August trip to headquarters, I hosted EPA colleagues in New Mexico for a tour of weed related issues in the semi-arid southwest. I had phone and email correspondence with EPA personnel during the quarter. In addition, I attended the NACD task force meeting in Arkansas and attended numerous teleconferences for the Herbicide Resistance Education Committee (S 71), the S71 subcommittee developing a table describing occurrences of herbicide resistance at the request of EPA, and the S71 subcommittee working on the herbicide resistance training modules. I have corresponded with John Jachetta and other officers as well as Lee Van Wychen during the quarter to keep them informed of my activities.

August 2-5: NM tour itinerary follows. My final report will be sent as soon as it is completed and reviewed.

EPA New Mexico Tour
August 2-5, 2010

Monday, August 2

4:00 p.m.	Introductions and agenda for tour – NMDA conference room
6:00	welcome at home of Jill Schroeder and Phil Banks

Tuesday, August 3

8:00 a.m.	Elephant Butte Irrigation District Headquarters, Las Cruces Hosts: Gary Esslinger (EBID Treasurer-Manager, www.ebid-nm.org) Leo Barrett, weed control, maintenance department EBID Presentation: description of water supply, allocation (water rights), and delivery system; discussion of issues related to weed management; field trip to see delivery system and weed management programs
Noon	lunch at Chope's cafe, La Mesa, NM
1:30 p.m.	Joe Nelson Farms – Anthony, NM Host: Carl Moore Integrated operation growing lettuce, onions and other row crops under furrow and drip irrigation. Carl Moore will discuss operations including crop rotations, pest management, pesticide application, and other specialty crop production issues.
3:30	Salopek Farms – North – Dońa Ana, NM Host: Brad Lewis (for Dick Salopek) NMDA/NMSU Pecan history and production in NM; water issues and pest management.
6:00 p.m.	dinner (St. Clair Bistro, Las Cruces)

Wednesday August 4

7:30 a.m.	BLM brush management program, Upham/Rincon, NM Host: Lane Hauser (Lane_Hauser@blm.gov), Operational officer for brush control projects, BLM Discussion of creosote and mesquite control projects on BLM lands; treatment preparation, application, and post-treatment monitoring of rangeland recovery (recovery of species diversity).
9:15 a.m.	BOR vegetation management programs, T or C, NM Aerial and carpet roller equipment, BOR equipment yard Arrey, NM Vegetation management program – Palomas, NM Host: Brent Tanzy (BTANZY@uc.usbr.gov), BOR Discussion of issues, BOR goals and strategies for managing saltcedar and other invasive species in and around the Elephant Butte and Caballo reservoirs.
12:00 p.m.	lunch Owl Café –San Antonio, NM

1:30 p.m.	Bosque del Apache National Wildlife Refuge (http://www.fws.gov/southwest/refuges/newmex/bosque) Host: John Vradenburg (John.Vradenburg@fws.gov) , lead biologist Presentation on the refuge and refuge vegetation management programs; restoration of native vegetation through control of saltcedar and program for growing crops for wildlife.
6:30 p.m.	dinner and discussion (Peppers Café)

Thursday August 5 Depart Las Cruces

List of participants

OPP/RD			
Dan Kenny	kenny.dan@epamail.epa.gov	Susan Stanton	Stanton.susan@epamail.epa.gov
Mindy Ondish	ondish.mindy@epa.gov	Beth Benbow	benbow.bethany@epa.gov
OPP/BEAD			
Skee Jones	Jones.Arnet@epamail.epa.gov		
Office of Water			
Jack Faulk	Faulk.Jack@epamail.epa.gov	Prasad Chumble	chumble.prasad@epa.gov
Region 6 - EPA			
Greg Weiler	weiler.gregory@epa.gov		
WSSA			
Jill Schroeder	jischroe@nmsu.edu	Lee VanWychen	lee.vanwychen@wssa.net
NMSU			
Kirk McDaniel	kmcdanie@nmsu.edu	David Thompson	dathomp@nmsu.edu
Phil Banks	marathonag@zianet.com	Cheryl Fiore	cfiore@nmsu.edu
James Hill	jhill@nmsu.edu		
NM Dept. of Ag.			
Bonnie Rabe	brabe@nmda.nmsu.edu	David Lucero	DLucero@nmda.nmsu.edu

August 9-11, 2010: I attended the National Association of Conservation Districts (NACD) herbicide resistant weed task force meeting in Little Rock, AR along with other members of the S71 Herbicide Education Committee; this meeting was a follow-up meeting to the one David Shaw and I attended in Beltsville in January 2010 (see First Quarter Report). The meeting attendees included NACD members, NRCS staff, HRAC members, and university weed scientists. The agenda included a field tour of Arkansas production and university research fields and concluded with a group discussion of best management practices for herbicide resistant weeds. The product of the meeting is a NACD white paper discussing the impact of the evolution of herbicide resistant weeds on conservation programs and best management practices for herbicide resistant weeds. John Soteres (HRAC chair) and I drafted the section on best management practices based on information presented on the HRAC website and the group discussion in Arkansas. The document was reviewed by the S71 committee, task force participants, and HRAC members and is attached to this report. I provided the document to NACD for inclusion in the white paper.

September 13-16, 2010: The week offered many opportunities for interaction on a number of topics and with a number of individuals. I spent time with Drs. Thomas 'Gene' Reagan (Entomology SME representing ESA) and Frank Wong (Plant Pathology SME representing APS) during the week. The trip was Gene's first to OPP while Frank has spent some time at the agency. We plan on working together in our respective roles at the office.

I met with Dan Kenny and members of the Herbicide Branch on a number of topics; I continue to learn more about how the Registration Division interacts with other divisions of OPP, in particular how the Divisions work together to make sure that herbicide risk is minimized while preserving product use. I also listened to portions of the FIFRA Science Advisory Panel meeting on "Reevaluation of the Human Health Effects of Atrazine: Review of Noncancer Effects and Drinking Water Monitoring Frequency" that were held September 14-17.

I met with David Shaw, Bill Vencill, Lee Van Wychen, and Harold Coble, USDA/OPMP, for meetings with NRCS (set up by David Shaw), regarding the NACD white paper; Farm Bureau and Crop Life (Lee Van Wychen set up this meeting), for updates on spray drift (Bob Wolf, KSU, also attended) and herbicide resistance; and the EPA resistance management workgroup. Outcomes of the meetings included providing NRCS and EPA with a copy of the Best Management Practices document that will be part of the NACD white paper (attached) and providing the EPA resistance workgroup (Bill Chism, BEAD, chair) with a table of occurrences of herbicide resistant weeds (attached; drafted by Bill Vencill, John Soteres, John Jachetta, and Jill Schroeder (S71 subcommittee) and reviewed by S71 members and HRAC). The subcommittee had many discussions about the table of occurrences requested by the EPA resistance workgroup and made note of the fact that the table does not address economic impact or acreage affected by each occurrence; the table simply tabulates the number of species identified with resistance as related to herbicide site of action.

A highlight of the week was introducing the seminar on sprayer technology presented on Tuesday September 14 by Dr. Bob Wolf, Kansas State University (http://www.bae.ksu.edu/faculty/wolf) . I worked with Bob to schedule the seminar, Dan Kenny facilitated the organization at the agency, and Mike Walsh, HB/RD, made the arrangements for the presentation including making arrangements for Bob to bring a spray chamber/table onto the premises for the presentation. The seminar was very well attended by 55 staff from all the divisions in the Office of Pesticide Programs. Drs. David Shaw and Lee Van Wychen attended as representatives of WSSA. I received very positive feedback during the rest of the week at the agency. The agency deals with how to reduce off target movement of spray with each registration; the seminar was very timely and addressed many of the issues faced by the agency. The seminar abstract follows:

Robert Wolf Abstract "Update on Application Technology for Agricultural Boom Sprayers": The latest sprayer technology involves the incorporation of various electronic controls designed to improve the efficiency of the application process. GPS technology is allowing for the incorporation of various components including auto-steer, automatic boom height control, automatic boom swath control, and field mapping for prescription/variable rate applications. In addition, over the last several years there has been an increased emphasis by nozzle manufacturers to engineer spray nozzles that will effectively reduce the volume of driftable fines found in spray droplet spectrums. Concern has been expressed that this increased emphasis in designing nozzles to minimize drift is compromising field efficacy for some herbicide products. Most recently, nozzle manufactures have introduced nozzle types that while maintaining a drift reduction theme, are providing better coverage. More information about how to use the latest equipment and nozzle technologies to apply crop protection products is paramount for achieving optimum control of undesired pests while minimizing drift. This presentation will provide information on the latest nozzle designs as well as the research done in evaluating field performance. The latest information on calibrating sprayers for label directed droplet size specifications to meet the droplet spectra classification standard will also be presented. As future application guidelines regarding increased efficacy and spray drift minimization are established, more technologies will be developed and adapted regardless of cost. These developments will require sound research to support adaptation.

Other activities: I plan to continue to work as part of the S71 committee on Herbicide Resistance Education. I am a member of the committee and a subcommittee working on developing training modules on herbicide resistance management. I also plan on developing a one-page document that outlines talking points related to herbicide resistance management at the request of Harold Coble; this will be reviewed by the committee.

I have been invited to the November meeting of the Washington State Weed Control Conference in Yakima, Washington (Dr. Tim Miller) to present a general session talk on the SME program. I will also work with Dan Kenny and others to schedule one more trip to the agency this fall.

Respectfully submitted,
Jill Schroeder
WSSA SME/liaison to EPA

BEST MANAGEMENT PRACTICES FOR WEED MANAGEMENT (adapted from the Herbicide Resistance Action Committee (HRAC) guidelines www.hracglobal.com)–drafted for inclusion in the NACD White Paper"**NACD Herbicide Resistance Task Force Report "*Zero Tolerance, Unlimited Conservation, Infinite Possibilities, A Comprehensive, Industry Wide Weed Management Program* "**

GENERAL PRINCIPLES (www.hracglobal.com):

The general principles of herbicide resistance management are:

1. Apply integrated weed management practices. Use multiple herbicide mechanisms-of-action with overlapping weed spectrums in rotation, sequences, or mixtures. (Integrated weed management practices include the combination of cultural, mechanical, and chemical weed control practices such that selection pressure from one method or any one herbicide is minimized.)

2. Use the full recommended herbicide rate and proper application timing for the hardest to control weed species present in the field.

3. Scout fields after herbicide application to ensure control has been achieved. Avoid allowing weeds to reproduce by seed or to proliferate vegetatively. (Scouting fields regularly to identify weeds and map their distribution will assist in developing management strategies.)

4. Monitor site and clean equipment between sites.

For annual cropping situations also consider the following:

- Start with a clean field and control weeds early by using a burndown treatment or tillage, in combination with a preemergence residual herbicide, as appropriate.

- Use cultural practices such as cultivation and crop rotation, where appropriate.

- Use good agronomic principles that enhance crop competitiveness.

DISCUSSION:

Integrated Weed Management (IWM) is defined as a diversified weed management approach that uses information on the biology and ecology of the weed(s) to select from available control techniques, embracing cultural, chemical and/or mechanical methods in an integrated fashion without excessive reliance on any one strategy. (Note: Weed Scientists also use the term diversified weed management to describe this approach.)

The goal of integrated/diversified weed management is to manage weeds in a sustainable way in order to maximize crop productivity, prevent weed escapes, and ultimately reduce the size of the soil seed bank. Therefore, growers should start with weed-free fields, and maintain them as weed-free fields, to reduce the potential for herbicide resistance to evolve and to reduce weed seed-production, including fields with suspected herbicide resistant weed biotypes. Regular scouting and proper weed identification are critical elements of effective IWM programs which cannot be over-emphasized. It is important to recognize that weed populations will adapt to any weed management tactic that is used recurrently and where it is the only tactic used to manage weeds.

IWM programs need to be developed based on understanding the weed life cycle, growth characteristics, and population densities of the weed species identified in the field. Preventing the evolution of herbicide resistant biotypes by using a combination of cultural, herbicide, and mechanical tactics is generally easier and more economical than managing a confirmed herbicide resistance situation. Experience has shown that simply changing herbicides after resistance has evolved to a product or mechanism of action (MOA) is not enough to create a long-term sustainable weed management system; thus a diversified approach must be adopted which is appropriate for the farm in question. Better still is to adopt IWM proactively, prior to the evolution of herbicide resistant weed biotypes. Examples of each method follow:

(1) Cultural practices: manage the crop to enhance productivity and competitiveness;
    a. control weeds around fields, maintain and clean field equipment
    b. remove weeds that establish in a field after harvest
    c. carefully monitor fields during the growing season and remove weeds prior to setting seed
    d. use cover crops, crop rotation, and rotate planting dates
    e. remove weeds with post harvest stubble burning (where allowed).
(2) Herbicide practices: apply herbicides with different mechanisms of action in mixtures, sequential timings (pre followed by post) or alternating products with different MOAs across a crop rotation.
(3) Mechanical practices: preplant, in-crop, and/or post harvest tillage.

The following is additional information on key weed management practices that may be used in an integrated/diversified approach to reduce the selection pressure from recurrent tactics on any weed species– hence significantly reducing the chance of survival of herbicide resistant weeds. Growers should consult their local extension recommendations and Natural Resources Conservation Service (NRCS) office to develop a management plan that will provide effective weed management without compromising conservation programs.

ROTATION OF CROPS

Crop rotation as a resistance management tool allows one to: (1) integrate different cultural practices which can influence weed population diversity and density, and (2) facilitate the use of alternative herbicide mechanisms of action for control of the same weed species across multiple cropping seasons.

Crop rotation allows the following options:

- Different crops will allow rotation herbicides with different mechanisms of action.
- The growth season of the weed can be avoided or disrupted when crops with different planting/harvest dates are grown.
- Crops with different sowing times and different seedbed preparation can facilitate use of a variety of cultural techniques to manage a particular weed problem.
- Crops also differ in their inherent competitiveness against weeds. A highly competitive crop will have a better chance to restrict weed seed production.

HERBICIDE MIXTURES, SEQUENCES AND ROTATION

Herbicide rotations, sequences or mixtures should include herbicides with different mechanisms of action that are each active against identified target weed species. Experience has shown that simply changing herbicides after herbicide resistant biotypes have evolved does not provide a long-term sustainable weed management system. A diversified (IWM) approach specifically developed for the farm or field in question that includes herbicide rotation or mixtures as well as other tactics must be adopted.

The Weed Science Society of America (WSSA) has prepared a table that classifies herbicides according to mechanism of action (www.WSSA.net). When planning a weed control program, proper weed identification is the key to success of the program. After consulting with state extension personnel or qualified advisors, herbicides should then be chosen from different mechanism of action groups to control the same weed with sequential applications or mixtures of these herbicides, unless otherwise directed. Classification of herbicides according to mechanism of action is in itself NOT a recommendation of which herbicide to use. This system does not account for efficacy on individual weed species or on herbicide resistance risk assessment, but is solely based on chemical mechanism of action. This mechanism of action table should be used as a tool to help select herbicides from different mechanism of action groups, so that appropriate mixtures or rotations can be included within an IWM system.

General guidelines for managing herbicide uses are:

- Avoid continued use of the same herbicide or herbicides having the same mechanism of action in the same field, in a single growing season or across years, unless it is integrated with other weed control strategies (including the use of herbicides with different mechanism(s) of action and/or mechanical methods of weed control).
- Where using herbicide mixtures, sequential treatments or rotation of herbicides having a different mechanism of action, it is important that each is active on the same target weeds.
- Use non-selective or selective herbicides to control early flushes of weeds (prior to crop emergence) and/or weed escapes.
- Follow herbicide label use instructions carefully. This especially includes the use of recommended rates and application timing for the target weeds.
- Routinely monitor results of herbicide applications, and note any trends or changes in the weed populations present.
- Maintain detailed field records so that crop and herbicide history is known. Records should also include a history of weed identification, population density and distribution; along with a record of treatment effectiveness.

Identification of the problem

A herbicide may not provide acceptable control for a number of reasons besides the presence of resistant weed species. Ensure that the proper rate was applied and the environmental conditions and weed growth stage were appropriate for that application. Herbicides may fail due to application to drought-stressed weeds, due to rain soon after application, lack of rainfall for incorporation, or other factors. Work with a weed scientist at your land grant university to verify the presence of herbicide-resistant weed species.

What to do in cases of confirmed herbicide resistance

In cases where a control failure has been confirmed as a herbicide resistant biotype, immediate action is recommended to limit further seed production. The degree of the action will depend on the crop developmental stage in the field and the density and distribution of the problem weed.

Some options to consider:

- Destroy and remove the remaining weeds from the field, particularly if the population is growing in patches, and limit build-up and spread of seed in the soil.
- Limit the field-to-field movement of herbicide resistant weed populations by cleaning all equipment to avoid transfer of the herbicide resistant weed seed.
- Avoid using the herbicide to which resistance has been confirmed, unless used in conjunction with additional herbicides that have different mechanisms of action and demonstrated efficacy on the herbicide resistant weed population.
- Select fields with confirmed herbicide resistant weeds for rotation to another crop or set these fields aside for the following cropping season.
- Seek advice from the local cooperative extension office for assistance in long term planning of weed control in these fields.

Once herbicide resistant weed numbers are reduced, implementation of a diversified weed management system as outlined in this document, will ensure that crops can continue to reach high levels of productivity in the fields in question.

A case study analysis carried out in England (ref. Orson and Harris, 1997) identified that the evolution of herbicide resistance can be categorized into stages, each stage requiring a new intensity of management. These management levels naturally carry a cost over that which is considered as the standard farming practice. An example cited in the case study is the option of delayed planting. While this is a very effective tool for managing weed numbers, the cost of doing so, if yield is reduced, can be significant.

The possible increased costs incurred to manage herbicide resistant weed populations must be measured against the impact of NOT applying these measures. In extreme cases, the rapid increase of herbicide resistant weeds will also severely affect crop yields and may eventually impact land value itself.

Key to the measurement of the cost of herbicide resistant weed management is the inclusion of several variables such as, but not limited to, crop yield potential, commodity prices, local costs of various techniques such as tillage, the weed species, and the soil type, among other issues. This means that a cost evaluation can only be accurate on a local level, and extrapolation from or to other situations can offer principles but not the specific detail.

Notes: This paper was prepared by Jill Schroeder and John Soteres September 17, 2010. It was reviewed by members of Global HRAC, members of WSSA S-71 Committee and other university weed scientists attending a NACD hosted symposium in Little Rock, AR in August, 2010.

If you have questions, contact Jill Schroeder (jischroe@nmsu.edu) or John Soteres (john.k.soteres@monsanto.com).

Table of Incidences of Herbicide Resistance:

Bill Vencill, John Soteres, John Jachetta, Jill Schroeder; S71 Herbicide Education Committee

Background

At the request of the Bill Chism, EPA Biological and Economic Analysis Division, a sub-committee of the Weed Science Society of America (WSSA) Herbicide Resistance Education Committee was formed to develop an herbicide resistance model that would characterize the evolution of herbicide resistant weed biotypes in relation to herbicide classes and weed species. The sub-committee evaluated a number of different approaches to fulfill this request and determined that the best approach would be to evaluate available data on occurrence of resistance. The database used was the information recorded on the International Survey of Herbicide Resistance website (http://www.weedscience.org/In.asp; Heap 2010).

The model can only be used as a summative tool for where past cases of herbicide resistance have occurred. It cannot be used as a predictive tool for future occurrences of herbicide resistance. In addition, the table cannot be relied upon to predict evolved resistance to existing herbicides or herbicide classes, since there are many factors that can influence the evolution of herbicide resistance and the interaction between the factors for all herbicide classes has not been adequately defined.

The model is based on a matrix of factors that have affected the evolution of herbicide resistance. These include 1) herbicide mechanism of action (MOA), 2) the genus and/or species since certain weeds are apparently more prone to herbicide resistance evolution than others; and 3) best management practices. The ranking of the herbicide mechanism of actions (Table 1) and weeds (Table 2) was based upon an assessment of the International Survey of Resistant Weeds database (http://www.weedscience.org/In.asp) For weed management practices, there is a focus on specific management practices that cause the greatest selection pressure for herbicide resistance evolution. A weed management system that relies on a single herbicide mechanism of action with no other weed management practices will exert the greatest selection pressure for resistance development (Diggle et al 2003, Gressel and Segel 1990, and Jasieniuk et al 1996). If a grower uses herbicide mixtures, sequences or rotates herbicide mechanisms of action, but does not use other weed management practices, this will lower the selection pressure but not as much as if the grower uses an integrated weed management system where a combination of cultural (e.g. crop rotation, cover crops, planting date, fertility, row spacing, etc.), mechanical (e.g. tillage, flooding, etc.), and chemical weed control practices are used.

Regarding the International Survey of Resistant Weeds database used as the basis for this analysis; it must be acknowledged that there are known limitations to the interpretation of data coming from this database. The website and database is managed by Dr. Ian Heap on behalf of WSSA, HRAC (Herbicide Resistance Action Committee), and NAHRAC (North American Herbicide Resistance Action Committee), and is generally regarded as the best source of information on when herbicide resistance is first confirmed in a new weed species, new country and, to a lesser extent, new U.S. state. Before an herbicide resistant weed report is posted on this website, the weed in question must be tested to meet specific technical requirements specified by WSSA and HRAC to show proof that it is truly resistant to that herbicide. Thus, most public and private weed scientists will not declare a weed to be resistant to a specific herbicide until it has been posted on this site. However, these testing requirements limit the utility of the website as a tracking tool once resistance within a species has been reported. In many cases after the first-reported incidence, a weed scientist may not consider it a value-added process to document all future cases of herbicide resistance for a previously identified species. In addition the need to provide proof of herbicide resistance before information is posted to the site usually results in a delay between the first observation and posting.

References:

Diggle, A.J., P.B. Neve, and F.P. Smith. 2003. Herbicides used in combination can reduce the probability of herbicide resistance in finite weed populations. Weed Res. 43:371-382.Gressel, J. and L. A. Segel. 1990. Modeling the effectiveness of herbicide rotation and mixtures as strategies to delay or preclude resistance. Weed Technol. 4:186-198.

Heap, I. 2010. International Survey of Herbicide Resistance. (http://www.weedscience.com).

Jasieniuk, M., A. Brule-Babel, and I.N. Morrison. 1996. The evolution and genetics of herbicide resistance in weeds. Weed Sci. 44:176-193.

Summary of the State of Herbicide Resistance Knowledge

Herbicide MOA (WSSA code)	Rank of influence on occurrence[c] (Table 1)	Ranking of Herbicide Resistance[b]			Rank of influence on occurrence	Influence of Weed Management Strategy
High – ALS (2), ACC (1), PS II (5),	3	3	6	9	1 (High)	Single herbicide MOA
		1.5	3	4.5	0.5 (Moderate - Low)	Multiple herbicide MOA only
		0.75	1.5	2.25	0.25 (Low)	Integrated Pest Mgmt[a]
Moderate –Auxin (4,), , PS I (22), PS-II (7), EPSP (9)	2	2	4	6	1 (High)	Single herbicide MOA
		1	2	3	0.5 (Moderate - Low)	Multiple Herbicide MOA only
		0.5	1	1.5	0.25 (Low)	Integrated Pest Mgmt
Low – VLCFA (15), GS (10), Cellulose Inhibitor (20) PPO (14) , PDS inhibitors (12), DOXP (11), fatty acid inhibitor (8), mitotic (3), oxidative uncoupler (24), dihydropteroate synthesis (18) HPPD inhibitors (27)	1	0.5	1	3	1 (High)	Single herbicide MOA
		0.25	0.5	1.5	0.5 (Moderate - Low)	Multiple Herbicide MOA only
		0.125	0.25	0.75	0.25 (Low)	Integrated Pest Mgmt
		1	2	3		
		CHEAL, SORHA, KOCXX, EUPXX BROXX / STEXX SETXX EPHXX RAPXX PHAXX SINXX	AVEFA, ERICA, DIGXX, ELEIN, AMBXX,	AMAXX, LOLXX, POAXX, ECHCG, ALOXX		
		Ranking of Weed[d] (Table 2)				

[a] Integrated Pest Management refers to the combination of cultural, mechanical, and chemical weed control practices such that selection pressure from one method is minimized.
[b] Ranking of resistance is a numerical value product of multiplying herbicide MOA rank (1-3) by weed rank (1-3) by weed management strategy (0.25-1). (For all 3 criteria the higher the number the higher the known incidence of resistance.) Blue indicates the highest frequency (>6); orange indicates a high frequency (4.5-6); yellow refers to moderate frequency (3-4); and green refers to low frequency (<3).
[c] Ranking of herbicide MOA results from frequency of resistance by herbicide MOA (Heap 2010). WSSA MOA codes are in parentheses.
[d] Ranking of weed results from frequency of weed genus or species resistance with top 20 resistant weed genus or species listed worldwide (Heap 2010). Bayer code of weed genus or species is displayed. Where only genera are presented (AMAXX), the resistance frequency has been aggregated for all members in the genera (e.g. AMAXX is an aggregation of *Amaranthus palmeri*, *hybridus*, *retroflexus*, *tuberculatus*, *rudis*, *powelli*, *blitoides*, and *lividus*).

Table 1: Frequency of herbicide-resistant weeds by site of action. Source: I. Heap 2010

WSSA #	Name	# of Global Species with Resistance	Proposed Rank of influence on Occurrence
2	ALS	107	3
5	PS II	68	3
1	ACC	37	3
4	Auxin	28	2
22	PS 1	24	2
7	Ureas and amides	21	2
9	EPSP synthase inhibitors	19	2
3	Mitotic	10	1
8	Fatty acid inhibitors	8	1
14	PPO inhibitors	4	1
12	PDS Inhibitors	2	1
15	VLCFA	4	1
11	DOXP	4	1
17	Organoarsenicals	1	1
6	Nitriles and others	3	1
24	Oxidative Uncoupler	0	1
18	Dihyropteroate synthesis	0	1
27	HPPD inhibitors	1	1
10	GS	0	1
20	Cellulose Inhibitor	1	1

Table 2: Top 20 Global genus x MOA

Global-Genus (Code)	**# MOA (HRAC)**	**Proposed Rank of influence on Occurrence**
Lolium (LOLXX)	11	3
Echinochloa (ECHXX)	10	3
Amaranthus (AMAXX)	8	3
Alopecurus (ALOXX)	6	3
Poa (POAXX)	6	3
Avena (AVEXX)	5	2
Ambrosia (AMBXX)	5	2
Conyza (ERIXX)	5	2
Digitaria (DIGXX)	5	2
Eleusine (ELEXX)	5	2
Bromus (BROXX)	4	1
Euphorbia (EPHXX)	4	1
Kochia (KOCXX)	4	1
Chenopodium (CHEXX)	4	1
Raphanus (RAPXX)	4	1
Phalaris (PHAXX)	4	1
Setaria (SETXX)	4	1
Sorghum halepense (SORHA)	4	1
Stellaria (STEXX)	3	1
Sinapis (SINXX)	3	1