HERBICIDE RESISTANCE ACTION COMMITTEE

Global HRAC & EHRAC Update

EPPO Resistant Panel

Berlin, Sept.19th, 2017

HERBICIDE RESISTANCE ACTION COMMITTEE

Who We Are

A global leader on weed resistance

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Challenges of Herbicide Resistance

- Undermines sustainability
- Hurts our customers
- Limits return on investment

Challenges to Resistance Management

- Technical
- Economic
- Societal

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How Does Industry Meet These Challenges?

Technical

- Study resistant weeds to understand mechanisms
- Develop New technologies
- Evaluate integrated programs

Economic and Societal

- Education
- Stewardship programs
- Incentives

Individual Company Initiatives

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Many companies have actively promoted resistance management for years

- Research
- Education
- Farmer resources
- Farmer incentives

Enlist™ Ahead

Resistance Care LABORATORY

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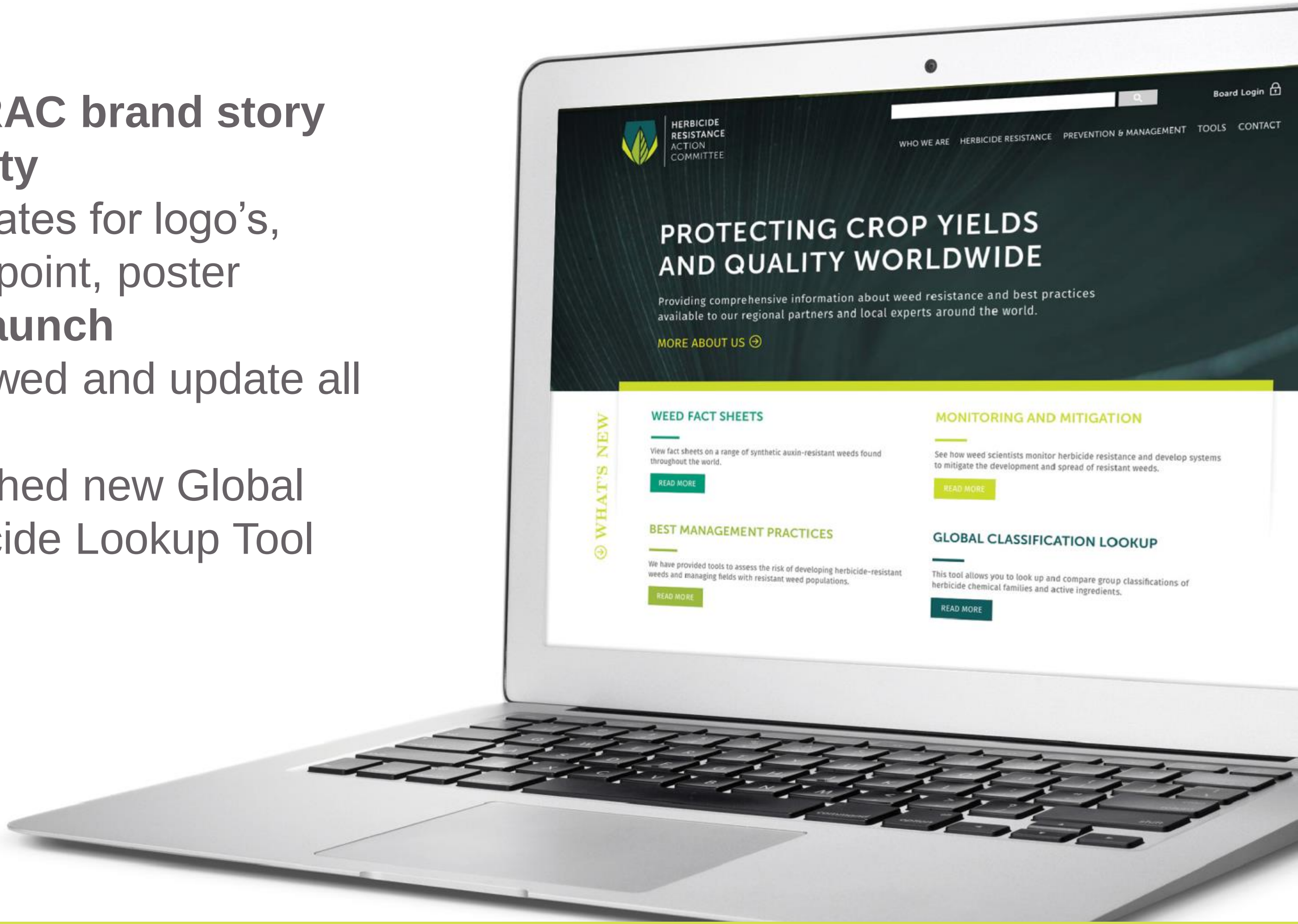
2016 Accomplishments:

- **Global HRAC brand story and identity**
  - Templates for logo’s, powerpoint, poster
- **Website launch**
  - Reviewed and update all info
  - Launched new Global Herbicide Lookup Tool



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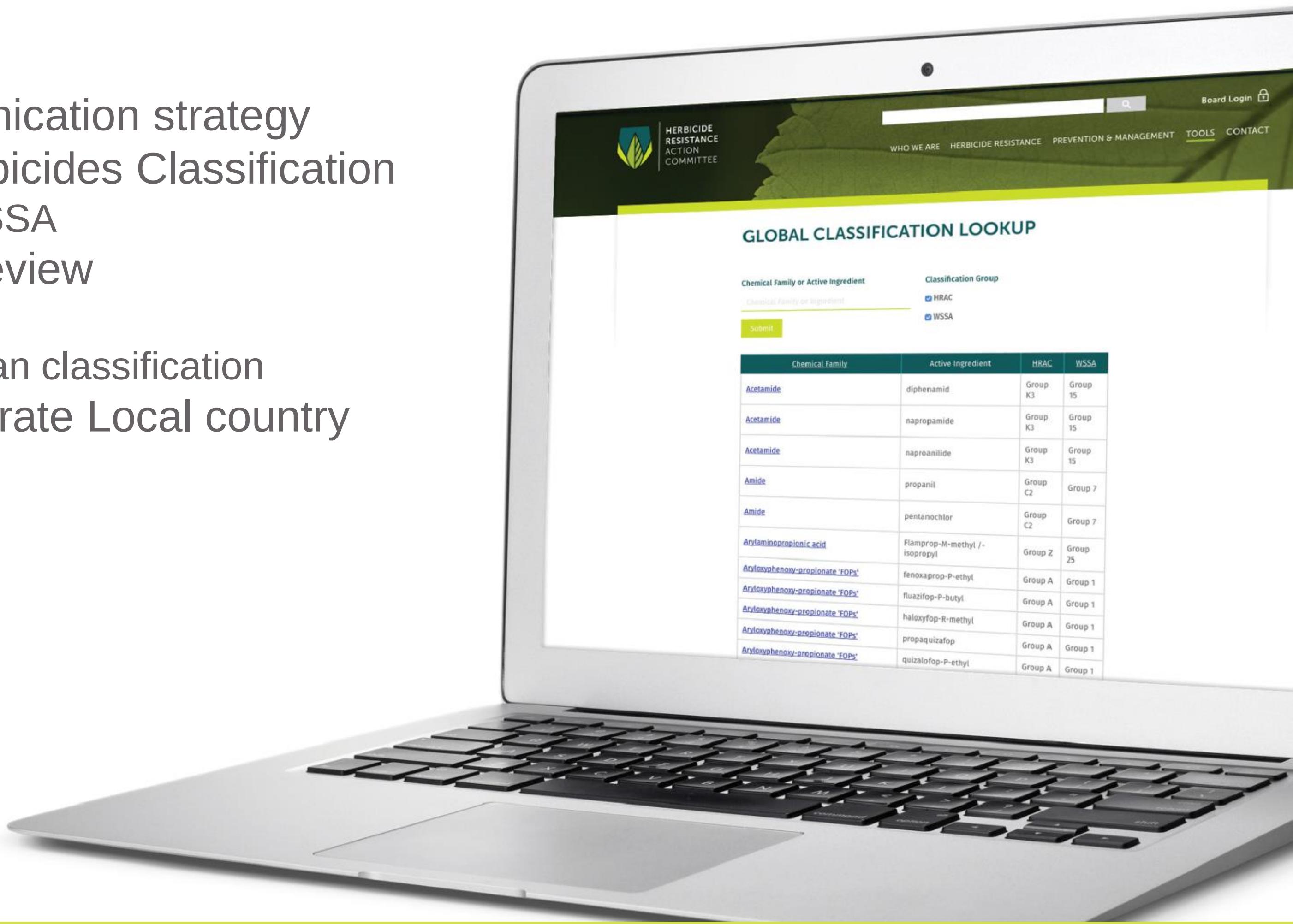
2017 – 2018 Initiatives:

- Building a communication strategy
- Request New Herbicides Classification
  - aligned with WSSA
- Website content review
  - update BMP’s
  - include Australian classification
- EHRAC to incorporate Local country RAC’s



Regional/Local HRAC Objectives and Actions

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An objective of Global HRAC is to support and coordinate with regional HRACs

- Provide technical information in support of local initiatives
- Assist with organizational questions and setup
- Provide a means to share experiences, initiatives, and challenges

Weed Resistance Action Group

WRAG

CPRH

Comité de Prevención de Resistencias a Herbicidas

Grupo de trabajo de la SEMh

Our Working Groups:

Key objectives for Working Groups:

Auxin	HPPD	PPO

- Consolidate and communicate information for specific MOAs
- Monitor research
- Support intellectual dialogue
- Customize BMPs for a given MOA
- Address specific resistance topics (e.g. Monitoring)

Communications	Issues Engagement	MOA Classification
Providing current technical information about weed resistance to target audiences	Evaluate resistance-related discussions in the public domain and develop science-based information	New Herbicides Classification aligned with WSSA and Australian classification

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Our Working Groups:

Auxin

Facilitating the exchange of information and BMPs related to auxin-resistant weeds among technical stakeholders

The symposium, "*Weed Resistance to Synthetic Auxin Herbicides: Current State of Knowledge and Knowledge Gaps*," on May 15, 2017, Denver (USA)

The symposium presentations :

- Overview of the current knowledge of synthetic auxin herbicide resistance;
- Description of case studies of weed species with confirmed resistance to synthetic auxin herbicides; and
- Perspectives about how to manage resistance in synthetic auxin herbicide-tolerant crops.

Synthetic Auxin Resistance in Corn Poppy

Available from the HRAC website: hracglobal.com

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Synthetic Auxin Resistant Corn Poppy

Corn poppy is the most important broadleaf weed of winter wheat in southern Europe. Synthetic auxins, particularly 2,4-D, have been used to control corn poppy in winter wheat for over 60 years. Synthetic auxin resistant corn poppy was first identified in Spain in 1993, and subsequently in Italy and France. Synthetic auxin resistance in corn poppy is now widespread in both of these countries.

Levels of Resistance and Cross-Resistance

herbicides used for corn poppy control. Seven mutant ALS alleles, Ala197, Arg197, His197, Leu197, Ser197, Thr197 and Leu574 that have been identified that confer ALS inhibitor resistance in corn poppy populations. Combinations of these mutant ALS alleles have sometimes been found in the same population, and indeed in the same plant. The different mutant ALS alleles give different patterns of cross resistance to ALS inhibitors however all appear to confer resistance to sulfonylureas such as tribenuron. These mutations are dominant and spread rapidly throughout fields through pollen and seed dispersal.

Multiple Resistance

Synthetic Auxin Resistance in Lambsquarters

Available from the HRAC website: hracglobal.com

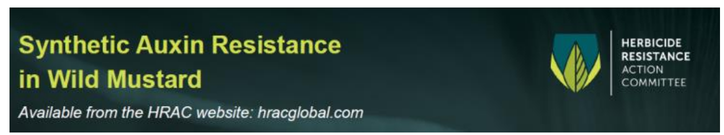
Synthetic Auxin Resistant Common Lambsquarters

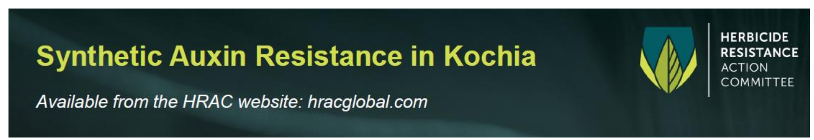
Common lambsquarters is a rapidly growing summer annual weed found in many agricultural systems. Synthetic auxins have long been used for control of common lambsquarters throughout the world. They became particularly important for control of triazine resistant common lambsquarters in the 1970's. In 2005 synthetic auxin resistant common lambsquarters was reported in maize (corn) fields in New Zealand. Growers had been using dicamba for over 10 years to control triazine-resistant common lambsquarters.

Levels of Resistance and Cross-Resistance

Mechanism of Resistance

The mechanism of synthetic auxin





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Our Working Groups:

HPPD

Facilitating the exchange of information and BMPs related to HPPD-resistant weeds among technical stakeholders

HPPD-inhibitor Resistance Stewardship

The Perspective of the HRAC HPPD-inhibitor Working Group

Created January 31, 2014

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Working Group Objectives

Since 2009, waterhemp (Amaranthus tuberculatus) and Palmer amaranth (Amaranthus palmeri) have been identified with resistance to hydroxyphenylpyruvate dioxygenase (HPPD)-inhibitor chemistries used in several agronomic production systems in North America. HPPD-inhibitors can be found in multiple products (Table 1) and have become valuable tools for managing weeds resistant to other herbicides. The objectives of the HPPD-inhibitor Working Group are to develop stewardship recommendations and implement key actions to support the use of HPPD-inhibitors with the intent of prolonging their efficacy in providing weed control solutions for agricultural producers. The objectives will be accomplished by understanding the current resistance situation and providing communication and education tools, consistent stewardship recommendations to stakeholders, and guidance on potential research objectives.

Working Group Stewardship Recommendations to Stakeholders

1. In order to avoid the development of resistance, require HPPD-inhibitors applied preemergence (PRE) and postemergence (POST) to always be used in combination with other products, either in tank mixtures or pre-mixtures.
2. Make applications to small, actively growing weeds.
3. In order to reduce the development of resistance, always use full labeled rate for all applications PRE or POST.
4. Follow explicitly the recommendations for application volume(s), nozzle(s), and other application parameters.

Working Group Recommendations for Label Alignment

1. Include mode-of-action labeling on all HPPD-inhibitor containing products.
2. Strengthen and align resistance management language on HPPD-inhibitor labels.
3. Adopt recommendations made by the HPPD-inhibitor Working Group and incorporate into products labels during revision.
4. Optimize product rate and weed size recommendations on POST applied HPPD-inhibitor labels
5. Emphasize tank mixtures or pre-mixtures with a minimum of two effective modes of action on product labels for driver weeds.

HRAC HPPD-inhibitor Working Group Members

AMVAC: Peter Porpiglia and Richard Porter
BASF: Walter Thomas, Andreas Landes and Gregory Armel
Bayer CropScience: Roland Beffa, Harry Strek, Tom Kleven and Arlene Cotie
DuPont: William Patzoldt
Syngenta: Gordon Vail, Deepak Kaundun, Brett Miller and Les Glasgow

Table 1. Current herbicide products* containing HPPD-inhibitors

Product Name	Active Ingredients (HPPD-inhibitor in bold)	Market Segment Use	Manufacturer*
Balance® Flexx	**Isoxaflutole**	Corn	Bayer CropScience
Prequel®	**Isoxaflutole** plus Rimsulfuon	Corn	DuPont
Corvus®	**Isoxaflutole** plus Thiencarbazone-methyl	Corn	Bayer CropScience
Callisto®	**Mesotrione**	Corn	Syngenta
Callisto® Xtra	**Mesotrione** plus Atrazine	Corn	Syngenta
Callisto® Ultra	**Mesotrione** plus Glyphosate	Corn	Syngenta
Instigate™	**Mesotrione** plus Rimsulfuron	Corn	DuPont
Realm® Q	**Mesotrione** plus Rimsulfuron	Corn	DuPont
Zemax®	**Mesotrione** plus *s*-Metolachlor	Corn and Grain Sorghum	Syngenta
Lumax® EZ	**Mesotrione** plus *s*-Metolachlor plus Atrazine	Corn and Grain Sorghum	Syngenta
Lexar® EZ	**Mesotrione** plus *s*-Metolachlor plus Atrazine	Corn and Grain Sorghum	Syngenta
Halex® GT	**Mesotrione** plus *s*-Metolachlor plus Glyphosate	Corn	Syngenta
Huskie®	**Pyrasulfotole** plus Bromoxynil	Cereals and Grain Sorghum	Bayer CropScience
Wolverine®	**Pyrasulfotole** plus Bromoxynil plus Fenoxyprop-p	Wheat and Barley	Bayer CropScience
Huskie® Complete	**Pyrasulfotole** plus Bromoxynil plus Thiencarbazone-methyl	Wheat	Bayer CropScience
Laudis®	**Tembotrione**	Corn	Bayer CropScience
Capreno®	**Tembotrione** plus Thiencarbazone-methyl	Corn	Bayer CropScience
Impact®	**Topramezone**	Corn	AMVAC
Armezon® Herbicide	**Topramezone**	Corn	BASF

**Product names registered in the United States*

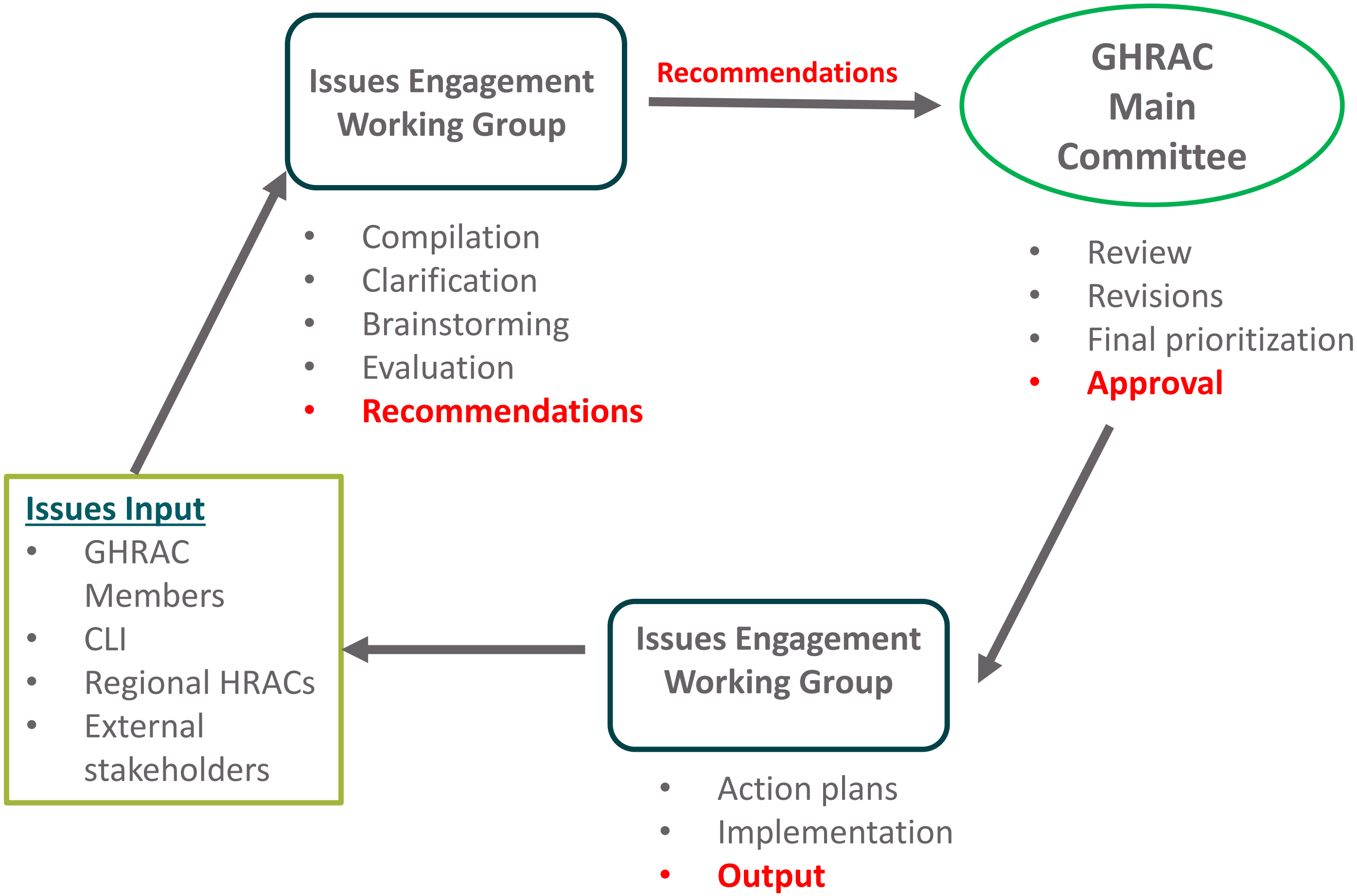
Objectives:

- Prolong useful life of HPPD-inhibitor herbicides
- Understand the current resistance situation
- Provide additional communication and education tools
- Provide consistent stewardship recommendations to stakeholders – including label stewardship alignment
- Provide guidance on potential research objectives
  - HPPD-inhibitor resistance understanding
  - HPPD-inhibitor stewardship recommendations (eg. weed size)

Our Working Groups: Process:

Issues Engagement

Evaluate resistance-related discussions in the public domain and develop science-based information



Recent Resistant cases in EU

www.weedscience.org

Weed species	Country	year	Site of Action
Apera spica-venti	Denmark	2016	Multiple Resistance: 2 Sites of Action (ACCase inhibitors (A/1), ALS inhibitors (B/2))
Lolium perenne	Denmark	2016	Multiple Resistance: 2 Sites of Action (ACCase inhibitors (A/1), ALS inhibitors (B/2))
Conyza canadensis	Hungary	2016	EPSP synthase inhibitors (G/9)
Stellaria media	Latvia	2016	ALS inhibitors (B/2)
Papaver rhoeas	France	2016	Multiple Resistance: 2 Sites of Action (ALS inhibitors (B/2), Synthetic Auxins (O/4))

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THANKS