



HERBICIDE  
RESISTANCE  
ACTION  
COMMITTEE

2014 WSSA – Vancouver, British Columbia

# HPPD-inhibitor resistance stewardship: The perspective of the HRAC HPPD- inhibitor Working Group

Gordon D. Vail<sup>1</sup>, Roland S. Beffa<sup>2</sup>, William L. Patzoldt<sup>3</sup>, Peter J. Porpiglia<sup>4</sup>  
and Walter E. Thomas<sup>5</sup>

*<sup>1</sup>Syngenta - Greensboro, NC; <sup>2</sup>Bayer CropScience – Frankfurt, DE; <sup>3</sup>DuPont Crop Protection – Wilmington, DE; <sup>4</sup>AMVAC Chemical Corporation – Newport Beach, CA; <sup>5</sup>BASF Corporation – Research Triangle Park, NC*

# HPPD-inhibitor Working Group

HRAC Purpose: To facilitate the effective management of herbicide resistance by fostering understanding, cooperation and communication between industry, government and farmers.

Result: HPPD-inhibitor Working Group (WG) was initiated by HRAC to specifically address HPPD-inhibitor resistance matters.

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)

# HPPD-inhibitor Working Group

HPPD-inhibitor WG was formed in 2012 and held face-to-face and multiple teleconference meetings over the past two years.

While the scope of the HPPD-inhibitor WG is global, the WG agreed to focus on North America.

Company	Participants
AMVAC	Peter Porpiglia, Rich Porter
BASF	Greg Armel, Andreas Landes, Walter Thomas
Bayer	Roland Beffa, Arlene Cotie, Tom Kleven, Harry Streck
DuPont	William Patzoldt
Syngenta	Deepak Kaundun, Les Glasglow, Brett Miller, Gordon Vail

# HPPD-inhibitors: an important weed control tool

Very effective class of chemistry for control of important species including *Ambrosia*, *Amaranthus*, *Chenopodium*, *Kochia*, grasses and other weeds.

Herbicides that can be applied PRE or POST

- Greater utility and flexibility for growers

Excellent compatibility with other herbicides

- Allows growers to deploy effective weed management programs with multiple, effective modes of action

Excellent atrazine synergists for enhanced performance

Multiple registered active ingredients with this mode of action

- Isoxaflutole, mesotrione, pyrasulfotole, tembotrione and topramezone

# Background herbicide resistance to selected modes of action

Mode of action	Herbicide group	Number of resistant species globally	Number of resistant species in North America
ALS-inhibitors	2	135	54
Glutamine synthase inhibitors	10	2	1
Glycines	9	25	14
HPPD-inhibitors	27	2	2
Photosystem II inhibitors	5	71	12
Synthetic auxins	4	31	12

Source: Ian Heap, [weedscience.org](http://weedscience.org)

# Confirmed cases of HPPD-inhibitor resistance in North America

Confirmation of resistant population reported via one of the following:

- International Survey of Herbicide Resistant Weeds
- Published in a peer reviewed journal

Palmer amaranth (*Amaranthus palmeri*)

- Kansas (2009) and Nebraska (2011)

Waterhemp (*Amaranthus tuberculatus* syn. *rudis*)

- Illinois (2009), Iowa (2009, 2011) and Nebraska (2011)

Other populations under evaluation by industry and universities

# Current knowledge of *Amaranthus* HPPD-inhibitor resistance mechanism

- Mechanism of resistance studies are ongoing
  - Not known for all confirmed resistant populations
- All confirmed resistant populations are also resistant to other herbicide modes of action
- *Amaranthus* spp. Can be multiple/cross resistant to herbicides with diverse modes of action (Heap, 2013)
- Non-target site mechanisms (Reichers, et al, 2013)
  - Target site resistance has not been found in resistant populations tested
- Enhanced metabolism contributes to resistance (Reichers, et al, 2013)

# HPPD-inhibitor WG objectives

- 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

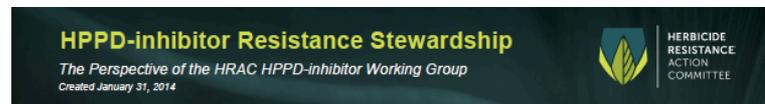
# Understanding the current resistance situation

The HPPD-inhibitor Working Group agreed to:

- Meet regularly (2 to 3 times per year)
- Review together and track the confirmed complaint cases

# Provide additional communication and education tools

1. Post this HPPD-inhibitor WG presentation on HRAC website at [hracglobal.com](http://hracglobal.com)
2. Distribute HPPD-inhibitor WG fact sheet
3. Recommend incorporating resistance management recommendations into HPPD-inhibitor containing product labels



## 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 site 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 Arnel  
 Bayer CropScience: Roland Beffa, Harry Strek, Tom Kieven and Ariene Cotle  
 DuPont: William Palzoldt  
 Syngenta: Gordon Vall, Deepak Kaundin, 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 Rimsulfuron	Corn	DuPont
Corvus®	Isoxaflutole plus Thienencarbazone-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
Ream® 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 Thienencarbazone-methyl	Wheat	Bayer CropScience
Laudis®	Temboltrione	Corn	Bayer CropScience
Capreno®	Temboltrione plus Thienencarbazone-methyl	Corn	Bayer CropScience
Impact®	Topramezone	Corn	AMVAC
Armezon® Herbicide	Topramezone	Corn	BASF

\*Product names registered in the United States

ALWAYS READ AND FOLLOW PESTICIDE LABEL DIRECTIONS. Balance® Flexx, Corvus®, Huskie®, Wolverine®, Laudis® and Capreno® are registered trademarks of Bayer. Callisto®, Zemax®, Lumax®, Lexar® and Halex® are registered trademarks of a Syngenta Group Company. Armezon® is a registered trademark of BASF. Impact® is a registered trademark of AMVAC Chemical Corporation. Prequel®, Instigate™ and Ream® are trademarks or registered trademarks of E.I. DuPont de Nemours and Company. Balance® Flexx, Corvus®, Huskie® Complete, Callisto® Xtra, Lumax® EZ, Lexar® EZ and Prequel are Restricted Use Pesticides.

HPPD-inhibitor fact sheet

# Provide consistent stewardship recommendations to stakeholders

The Working Group is developing and recommending a common language for HPPD-inhibitor stewardship which can be used in:

- Education programs (step 1)
- Labels (step 2)

Include mode of action labeling on all HPPD-inhibitor containing products

In order to reduce the development of resistance, always use the full labeled rate for all applications PRE and POST

Follow explicitly the recommendations for application volume(s), recommended nozzle(s) and other application parameters

# Provide consistent stewardship recommendations to stakeholders

In order to avoid the development of resistance, require PRE and POST HPPD-inhibitors to always be used in tank mix or premix

- When appropriate a residual herbicide should be used
- Use at least two compounds with efficacy against the target species

Applications should be made to small, actively growing weeds

- Recommend targeting weeds less than four inches in height

A recommendation to limit the number of HPPD-inhibitor applications is under consideration as additional research is completed

# **Provide consistent stewardship recommendations to stakeholders – label alignment**

- Strengthen and align recommended resistance management language on all HPPD-inhibitor containing product labels
- Incorporate recommendations made by HPPD-inhibitor WG into product labels during label revisions
- Optimize product rate and weed size recommendations for post-emergence HPPD-inhibitor labels to be consistent with resistance management stewardship
- Recommend the use of tank mixtures or premixtures with a minimum of two effective modes of action against driver weeds

# Provide guidance on potential research objectives

Continued investigation into resistance mechanisms

What is an effective tank mix partner(s)?

- Which herbicides work best as tank mix partners that would be least prone to metabolic degradation?
- Should tank mix partners have similar length of residual and soil behavior?
- Should sequential applications contain herbicides with multiple, different modes of action?

Is there an impact from limiting the number of applications?

- Within a season or between seasons
- How will this impact resistance evolution?

Does weed growth stage at application influence resistance evolution?

Encourage research collaboration

# Conclusions and perspectives

- HPPD-inhibitor WG will continue with a goal of prolonging the useful life of HPPD-inhibitor herbicides
- HPPD-inhibitor WG needs the support of industry and university research and extension
- HPPD-inhibitor WG focus is on HPPD-inhibitor resistance but this is a larger issue encompassing all modes of action
- Key WG stewardship activities:
  - Understand the current resistance situation
  - Provide additional communication and education tools
  - Provide consistent stewardship recommendations to stakeholders
  - Provide guidance on potential research objectives

**Thank you for  
your attention**



**HERBICIDE  
RESISTANCE  
ACTION  
COMMITTEE**