Zest®
Sustainable ICM

HTA

Herbicides approved for container-grown HNS, HRAGs and modes of action, approval specifics and restrictions

Selchuk Kurtev, Zest Sustainable ICM

What I will cover

- Herbicide Modes of Action (MoA)
- Approved herbicides for container-grown HNS
- Approval specifics and restrictions
- Weed susceptibility to herbicides
- Getting the best from herbicides

Sustainable ICM

TERMINOLOGY

- **'Herbicide resistance'** - *the ability of a weed biotype to survive an herbicide application, where under normal circumstances that herbicide applied at the recommended rate would kill the weed.*
- **'Plant tolerance'** - *the inherent ability of that plant species to survive and reproduce after treatment with that herbicide.*
- **'Target-site resistance'** - *inhibits herbicide action by: a change in structure of the target protein that decreases herbicide binding to its usual site of action; an increase in target protein expression; or an increase in copies of the gene containing the target site.*
- **'Non-target-site resistance'** - *includes decreased translocation of an herbicide to its site of action, increased metabolic detoxification of an herbicide, and sequestration or immobilization of an herbicide in a part of the plant so it cannot reach its site of action.*

Sustainable ICM

TERMINOLOGY

- **'Cross resistance'** - *occurs when a plant has one mechanism that enables plants to survive treatment with herbicides from different chemical classes or with differing modes or sites of action.*
- **'Multiple resistance'** - *refers to plants that have more than one mechanism that enables them to survive treatment with herbicides with differing modes or sites of action.*

Sustainable ICM

Mode of Action (MoA)

- 3 plant processes, 24 groups, 78 chemical classes, 79 active substances
- *in HNS containers* – ***30 active substances or 27 products (O+P)***

HRAC	Legacy HRAC	Mode of Action
1	A	Inhibition of Acetyl CoA Carboxylase (ACCase)
2	B	Inhibition of Acetolactate Synthase (ALS)
3	K1	Inhibition of microtubule assembly
4	O	Auxin mimics
5	C1,2	Inhibition of Photosynthesis at PS II - D1 Serine 264 binders (and other non-histidine 215 binders)
6	C3	Inhibition of Photosynthesis at PS II – D1 Histidine 215 binders
9	G	Inhibition of Enolpyruvyl Shikimate Phosphate Synthase (EPSPS)
10	H	Inhibition of Glutamine Synthetase (GS)
12	F1	Inhibition of Phytoene Desaturase (PDS)
13	F4	Inhibition of Deoxy-D-Xylulose Phosphate Synthase (DXPS)
14	E	Inhibition of Protoporphyrinogen Oxidase (PPO)
15	K3	Inhibition of Very Long-Chain Fatty Acid Synthesis (VLCFA)

HRAC	Legacy HRAC	Mode of Action
18	I	Inhibition of Dihydropteroate Synthase (DHPS)
19	P	Auxin transport inhibitors
22	D	PS I Electron Diversion
23	K2	Inhibition of microtubule organization
24	M	Uncouplers
27	F2	Inhibition of Hydroxyphenyl Pyruvate Dioxygenase (HPPD)
28	none	Inhibition of Dihydroorotate Dehydrogenase (DHODH)
29	L	Inhibition of cellulose synthesis
30	Q	Inhibition of Fatty Acid Thioesterase (FAT)
31	R	Inhibition of Serine Threonine Protein Phosphatase (STPP)
32	S	Inhibition of Solanesyl Diphosphate Synthase (SDPS)
33	T	Inhibition of Homogentisate Solanesyltransferase (HST)
Ø	Z	Unknown mode of action

Sustainable ICM

HERBICIDE RESISTANCE ACTION COMMITTEE

HRAC Mode of Action Classification 2024

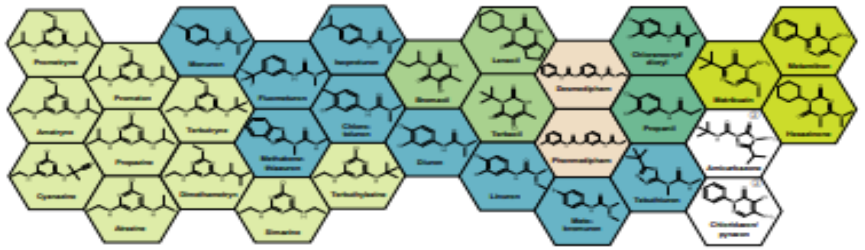
https://hracglobal.com/tools/2024-hrac-global-herbicide-moa-classification Here access the complete herbicide MoA classification excel database.

Light Activation of ROS[a]

5 Inhibition of Photosynthesis at PS II

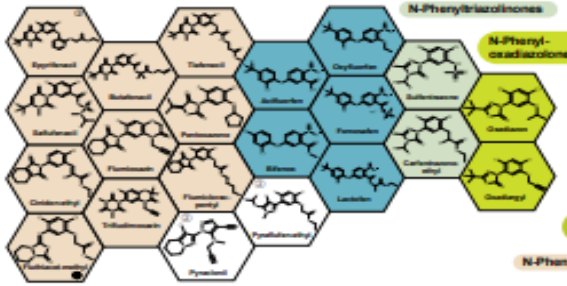
D1 Serine 264 binders (and other non-histidine 215 binders)

Triazines | Ureas | Uracils | Phenylcarbamates | Amides | Triazinones



14 Inhibition of Protoporphyrinogen Oxidase (PPO)

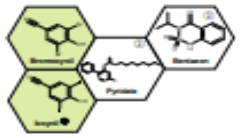
N-Phenylimides | Diphenyl ethers | N-Phenyltriazolinones | N-Phenyl-oxadiazolones



6 Inhibition of Photosynthesis at PS II

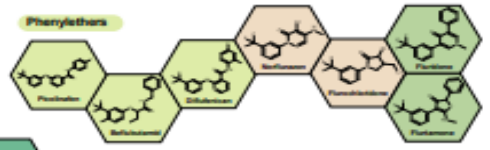
D1 Histidine 215 binders

Nitriles also uncouplers



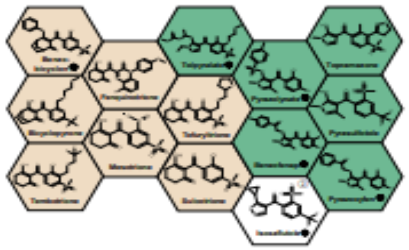
12 Inhibition of Phytoene Desaturase (PDS)

N-Phenyl heterocycles | Diphenyl heterocycles | Phenylethers

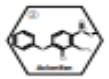


27 Inhibition of Hydroxyphenyl Pyruvate Dioxygenase (HPPD)

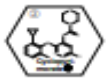
Triketones | Pyrazoles



32 Inhibition of Solanesyl Diphosphate Synthase (SDPS)

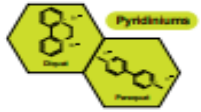


33 Inhibition of Homogentisate Solanesyltransferase (HST)



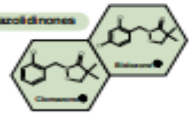
22 PS I Electron Diversion

Pyridiniums



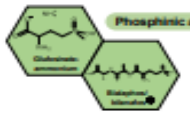
13 Inhibition of Deoxy-D-Xylulose Phosphate Synthase (DXPS)

Isoxazolidinones



10 Inhibition of Glutamine Synthetase (GS)

Phosphinic acids



Cellular Metabolism

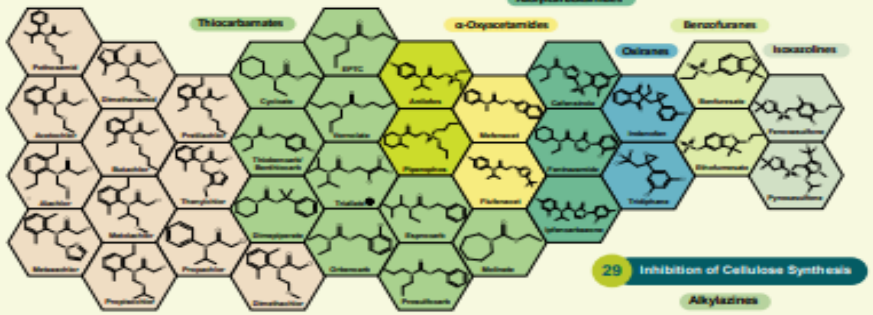
2 Inhibition of Acetolactate Synthase (ALS)

Pyrimidinylbenzoates | Triazolopyrimidine – type 2 | Imidazolinones | Sulfonylureas | Triazolopyrimidines – type 1 | Triazolinones

Sulfonanilides

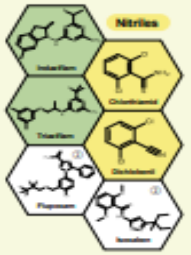
15 Inhibition of Very Long-Chain Fatty Acid Synthesis (VLCFA)

α-Chloroacetamides | α-Thioacetamides | Acylcarboxamides | Thiocarbamates | α-Oxyacetamides | Benzofurans | Oxiranes | Isoxazolines



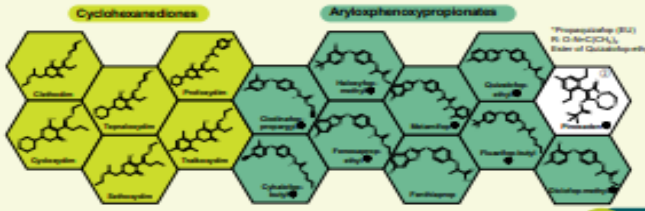
29 Inhibition of Cellulose Synthesis

Alkylazines | Nitriles



1 Inhibition of Acetyl CoA Carboxylase (ACCase)

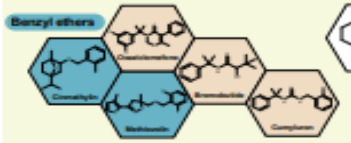
Cyclohexanediones | Aryloxyphenoxypropionates



9 Inhibition of Enolpyruvyl Shikimate Phosphate Synthase (EPSPS)

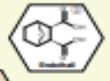
30 Inhibition of Fatty Acid Thioesterase (FAT)

Benzyl ethers

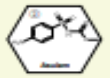


gem-Dimethylbenzamides

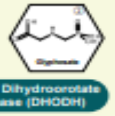
31 Inhibition of Serine Threonine Protein Phosphatase (STPP)



18 Inhibition of Dihydropteroate Synthase (DHPS)



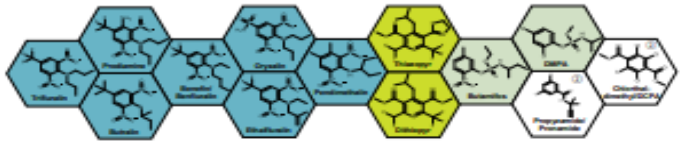
28 Inhibition of Dihydroorotate Dehydrogenase (DHODH)



Cell Division and Growth

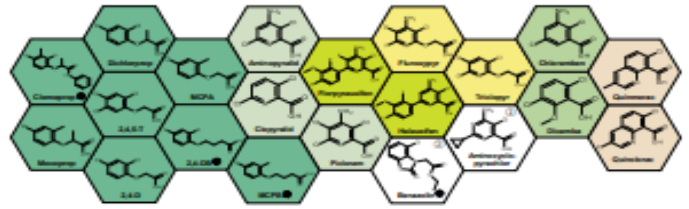
3 Inhibition of Microtubule Assembly

Dinitroanilines | Pyridines | Phosphoroamidates



4 Auxin Mimics

6-Chloropicolinates | Pyridyloxycarboxylates | Quinolinecarboxylates | Phenoxycarboxylates | 6-Arylpicolinates | Benzoates

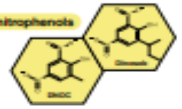


23 Inhibition of Microtubule Organization

Carbamates

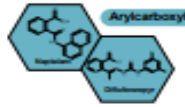
24 Uncouplers

Dinitrophenols



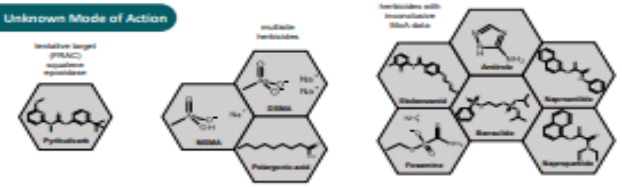
19 Auxin Transport Inhibitors

Arylcarboxylates



HRAC	Legacy HRAC	Mode of Action	HRAC	Legacy HRAC	Mode of Action
1	A	Inhibition of Acetyl CoA Carboxylase (ACCase)	18	I	Inhibition of Dihydropteroate Synthase (DHPS)
2	B	Inhibition of Acetolactate Synthase (ALS)	19	P	Auxin transport inhibitors
3	K1	Inhibition of microtubule assembly	22	D	PS I Electron Diversion
4	O	Auxin mimics	23	K2	Inhibition of microtubule organization
5	C1,2	Inhibition of Photosynthesis at PS II - D1 Serine 264 binders (and other non-histidine 215 binders)	24	M	Uncouplers
			27	F2	Inhibition of 'Hydroxyphenyl Pyruvate Dioxygenase (HPPD)
6	C3	Inhibition of Photosynthesis at PS II – D1 Histidine 215 binders	28	none	Inhibition of Dihydroorotate Dehydrogenase (DHODH)
9	G	Inhibition of Enolpyruvyl Shikimate Phosphate Synthase (EPSPS)	29	L	Inhibition of cellulose synthesis
10	H	Inhibition of Glutamine Synthetase (GS)	30	Q	Inhibition of Fatty Acid Thioesterase (FAT)
12	F1	Inhibition of Phytoene Desaturase (PDS)	31	R	Inhibition of Serine Threonine Protein Phosphatase (STPP)
13	F4	Inhibition of Deoxy-D-Xylulose Phosphate Synthase (DXPS)	32	S	Inhibition of Solanesyl Diphosphate Synthase (SDPS)
14	E	Inhibition of Protoporphyrinogen Oxidase (PPO)	33	T	Inhibition of Homogentisate Solanesyltransferase (HST)
15	K3	Inhibition of Very Long-Chain Fatty Acid Synthesis (VLCFA)	Ø	Z	Unknown mode of action

Ø Unknown Mode of Action



*Reactive oxygen species

●Indicates pro-herbicide

② HRAC's recommendation is not to include a chemical family name when there is one active in the family. Actives without chemical family names are indicated with a white background

③New actives which are still in the process of registration at the time of release of the current poster version

A free copy of this poster can be downloaded at www.hracglobal.com

Mode of Action (MoA) and regulations

- Key regulatory challenge
- Many active substances from same chemical class
- Perennial cropping a significant risk
- Short cycle crops medium risk
- Adoption of ICM
- Environmental impact
- Non-target organisms
- Water pollution
- Pollinators
- ED concerns
- Many others ….

Sustainable ICM

Resistance risk management

Cropping System Evaluation - Risk of Resistance

MANAGEMENT OPTION	LOW RISK	MODERATE RISK	HIGH RISK
Herbicide mix or rotation in cropping system	> 2 modes of action	2 modes of action	1 mode of action
Weed control in cropping system	Cultural*, mechanical and chemical	Cultural and chemical	Chemical only
Use of same mode of action per season	Once	More than once	Many times
Cropping system	Full rotation	Limited rotation	No rotation
Resistance status to mode of action	Unknown	Limited	Common
Weed infestation	Low	Moderate	High
Control in last three years	Good	Declining	Poor

Sustainable ICM

Approved herbicide actives

PROTECTED

	Active Substance
1	Bentazone
2	Carfentrazone-ethyl
3	Clethodim
4	Clopyralid
5	Cycloxydim
6	Ethofumesate
7	Fatty acids: pelargonic acid
8	Florasulam
9	Flufenacet
10	Fluroxypyr
11	Glyphosate
12	Isoxaben
13	Metamitron
14	Metazachlor
15	Metribuzin
16	Napropamide
17	Nicosulfuron
18	Picloram
19	Propyzamide
20	Prosulfocarb

OUTDOOR

	Active Substance
1	2,4-D
2	Amidosulfuron
3	Bentazone
4	Carfentrazone-ethyl
5	Clethodim
6	Clomazone
7	Clopyralid
8	Cycloxydim
9	Diflufenican
10	Dimethenamid-P
11	Ethofumesate
12	Fatty acids: pelargonic acid
13	Florasulam
14	Fluazifop-P-butyl
15	Flufenacet
16	Flumioxazine
17	Fluroxypyr
18	Glyphosate
19	Imazamox
20	Isoxaben
21	Lenacil
22	Metamitron
23	Metazachlor
24	Metobromuron
25	Metribuzin
26	Napropamide
27	Nicosulfuron
28	Pendimethalin
29	Phenmedipham
30	Picloram
31	Propyzamide
32	Prosulfocarb
33	Rimsulfuron
34	S-metolachlor
35	Triflusulfuron-methyl

HTA

zest®
Sustainable ICM

Approved example products

PROTECTED
Shark – contact, total
Centurion Max – contact, selective
Shield Pro – contact, selective
Laser – contact, selective
Efeckt - contact
Finalsan – contact, total
Sunfire – pre-emergence
Glyphosate – contact, total
Flexidor – pre-emergence
Goltix – pre-emergence
Butisan – pre-emergence
Sencorex – pre-emergence
Devrinol – pre-emergence
Fornet – pre-emergence
Defy – pre-emergence
Laser – contact, selective

OUTDOOR	
Eagle – pre-emergence	**Nirvana** – pre-emergence
Shark – contact, total	**Stomp Aqua** – pre-emergence
Centurion Max – contact, selective	**Dual Gold** – pre-emergence
Shield Pro – contact, selective	**Debut** – pre-emergence
Laser – contact, selective	**Starane XL** – contact selective, pre-emergence
Effeckt - contact	**Centium** – pre-emergence
Finalsan – contact, total	
Sunfire – pre-emergence	
Glyphosate – contact, total	
Flexidor – pre-emergence	
Goltix – pre-emergence	
Butisan – pre-emergence	
Sencorex – pre-emergence	
Devrinol – pre-emergence	
Fornet – pre-emergence	
Defy – pre-emergence	
Titus – pre-emergence	
Hurricane – pre-emergence	
Springbok – pre-emergence	
Fusilade – contact, selective	
Paramount/Boxer – pre-emergence	

HTA

zest®
Sustainable ICM

Approved example products

Example Product	Type of Herbicide	Approval situation	Notes
Butisan	Pre-emergence	O/P	Extensive use
Centurion Max	Contact, selective	O/P	Some use
Debut	Pre-emergence	O	Not used
Defy	Pre-emergence	O/P	Not used
Devrinol	Pre-emergence	O/P	Extensive use
Dual Gold	Pre-emergence	O	Extensive use
Eagle	Pre-emergence	O	Not used, some non-cropped areas
Efeckt	Contact	O/P	Not used
Finalsan	Contact, total	O/P	Some use
Flexidor	Pre-emergence	O/P	Extensive use
Fornet	Pre-emergence	O/P	Not used
Fusilade	Contact, selective	O	Not used
Glyphosate	Contact, total	O/P	Extensive use on non-cropped areas
Goltix	Pre-emergence	O/P	Some use mainly non-cropped areas
Hurricane	Pre-emergence	O	Some use in non-cropped areas
Laser	Contact, selective	O/P	Some use
Nirvana	Pre-emergence	O	Some use in non-cropped areas
Paramount/Boxer	Pre-emergence	O	Not used
Sencorex	Pre-emergence	O/P	Some use
Shark	Contact, total	O/P	Extensive use on non-cropped areas
Shield Pro	Contact, selective	O/P	Some use
Springbok	Pre-emergence	O	Extensive use
Starane XL	Contact selective, pre-emergence	O	Not used
Stomp Aqua	Pre-emergence	O	Some use on non-cropped areas
Sunfire	Pre-emergence	O/P	Some use
Titus	Pre-emergence	O	Not used

Herbicides approved for container-grown crops

Product	Active ingredient	HRAG	Solubility	Dose rate, L/ha	Water volume, L	On/off label	№ of applications	Herbicide type	Protected use	Expiry date
Devrinol (MAPP19358)	Napropamide – 45%	Z	Mod	7.0L/ha	1,000-2,000	0168/20	1	R	✓	31/12/2025
Dual Gold (MAPP14649)	S-metolachlor – 96%	K3	Mod	0.78L/ha	200-400	0501/12	1	R	×	31/01/2031
Flexidor 500 (MAPP18902)	Isoxaben – 50%	L	Low	0.50L/ha	600	✓	1	R	✓	31/07/2029
Butisan S (MAPP16569)	Metazachlor – 50%	K3	Mod	1.5L/ha	400-600	✓	1	R	✓	30/04/2029
Sencorex Flow (MAPP20710)	Metribuzin 60%	C1	High	1.15 – 1.0L/ha	400-600	2113/2108/23	1	C,R	✓	15/08/2027
Venzar 500 (MAPP18799)	Lenacil – 50%	C1	Low	0.40L/ha	100-200	4263/19	2.5	R	×	15/02/2028
Sunfire (MAPP16745)	Flufenacet - 50%	K3	Mod	0.48L/ha	200-400	1065/17	1	R	✓	15/12/2027
Springbok (MAPP16786)	dimethenamid-P 20% and metazachlor 20%	K3+ K3	High + Mod	2.5/ 1.6L/ha	200-400	2108/15 3006/14	1	R	×	09/09/2099
Wing-P (MAPP15425)	dimethenamid-P and pendimethalin – 21.25% + 25%	K3+ K1	High + Low	3.5L/ha	400-600	0253/13	1	R	×	09/09/2099

Sustainable ICM

Approval specifics

We will now look at the print outs!

Weed susceptibility to herbicides CONSIDERATIONS

- Type of weed and its growth stage
- Route of entry into crop
- Time of the year
- Dose rates, concentrations, and weed coverage (which parts of the weed?)
- Cropping situation (indoor/outdoor)
- Irrigation management and growing media
- Presence or lack of mulch
- Weather conditions post-treatment – rain fastness

Sustainable ICM

Herbicide result failures

- Not reading or understanding product label and EAMUs
- Disruption to the herbicide layer
- Wrong choice of herbicides
- Not incorporating the herbicide where it's needed
- Overwatering or underwatering of the herbicide layer
- Use of lower rates
- Lack of crop husbandry
- Use of granular fertiliser at the wrong time
- Sprayer calibration issues
- Incorrect timing of herbicide applications

Sustainable ICM

NURSERY PRODUCTION

Zest-ICM

0333 005 0167

nurseryproduction@hta.org.uk

Sustainable ICM

Sustainable ICM