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Technical Note

Modifications on Labels and Leaflets of Herbicides for Preventing and Managing Resistance

Modificação em Rótulo e Bula de Herbicidas para Prevenção e Manejo da Resistência

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ABSTRACT - The challenge of managing herbicide-resistant weeds is an agricultural reality in Brazil that shall not be neglected. In this sense, Ministério da Agricultura, Pecuária e Abastecimento (MAPA) published Act No. 45 on July 14, 2017, provides the inclusion of a code system on labels and leaflets of insecticides, fungicides and herbicides, in order to demonstrate the mode of action of the active ingredient present in the product. In case of mix formulations, both molecules must be discriminated, adopting the same "Herbicide Resistance Action Committee – HRAC" international reference code. The Act No. 45 facilitates the process to choose and adopt products by all those involved in the chain production. It also collaborates with the possible to standardize the mixture of the products, since the need to mix products from different chemical groups to correct handling the resistance cases and avoiding potential new cases. In summary, the process of recognizing the mode of action and classification of herbicides was facilitated, as well as its practical adoption by technicians, growers and the chain production.

Keywords: mode of action, mixtures, pesticides, label, leaflets.

RESUMO - O desafio de manejo de plantas daninhas resistentes a herbicidas é uma realidade agrícola no Brasil que não pode ser negligenciada. Nesse sentido, o Ministério da Agricultura, Pecuária e Abastecimento (MAPA) publicou o Ato nº 45, em 14 de julho de 2017, o qual prevê a inclusão de um sistema de códigos em rótulos e bulas de inseticidas, fungicidas e herbicidas, no intuito de evidenciar o modo de ação do ingrediente ativo presente no produto. Em caso de misturas formuladas, ambas as moléculas devem ser discriminadas, adotando-se o mesmo código de referência internacional do Herbicide Resistance Action Committee – HRAC. O Ato nº 45 facilita o processo de escolha e adoção de produtos por todos os envolvidos na cadeia produtiva, além de colaborar com a possível normatização de misturas de produtos em tanque, visto a necessidade de utilizar produtos de diferentes grupos químicos para o correto manejo de plantas daninhas resistentes e evitar potenciais novos casos. Em síntese, foi facilitado o processo de reconhecimento dos modos de ação e classificação de herbicidas, bem como sua adoção prática por parte dos técnicos, produtores e cadeia produtiva.

Palavras-chave: modo de ação, misturas, defensivos, rótulo, bula.

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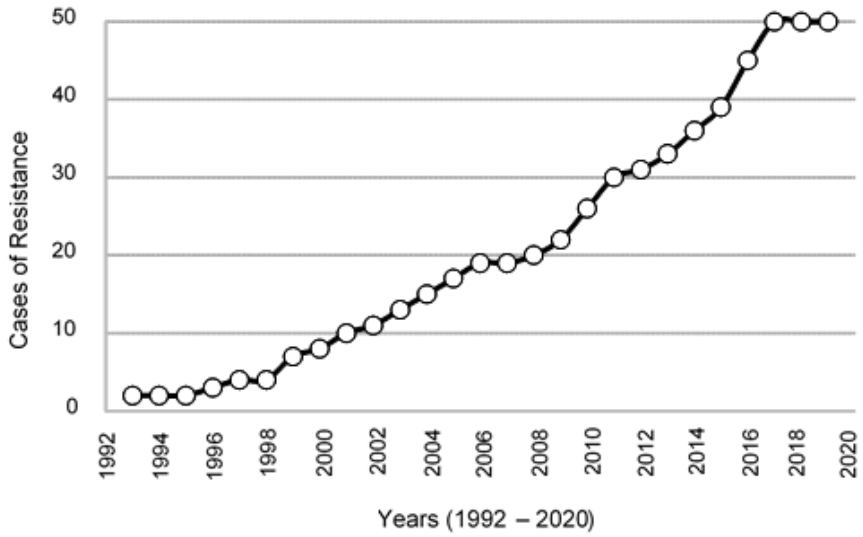
BRIEF HISTORY

In Brazil, the first reports of weed biotypes resistant to herbicides were registered in 1993, involving hairy beggarticks (*Bidens pilosa*) and wild poinsettia (*Euphorbia heterophylla*) resistant to ALS inhibitor herbicides. Since then, new cases of resistance are reported annually, related to the most varied modes of action, including some cases of multiple resistance (resistance of the same plant to more than one mode of action). As of May 2019, there were 50 reported cases of herbicide resistant weed biotypes registered in Brazil (Figure 1).



Source: (Heap, 2019).

Figure 1 - Evolution of the number of accumulated cases of herbicide resistant weeds reported in Brazil between 1993 and 2019.

PREVENTION AND MANAGEMENT

Due to the increasing number of new cases of herbicide resistant weeds, prevention and management measures must be implemented by growers, aiming to protect the herbicides and their use in production systems, guaranteeing sustainability. In this sense, the "Ministério da Agricultura, Pecuária e Abastecimento" (MAPA), through the "Secretaria de Defesa Agropecuária, Coordenação Geral de Agrotóxicos e Afins", issued NORMATIVE INSTRUCTION NO. 16, of May 18, 2017 - Article 3, Paragraph 3, duly regulated by Atc No. 45, on June 9, 2017, published in the "Diário Oficial da União" on June 14, 2017 (Brasil, 2017).

Normative Instruction 16, regulated by Act No. 45, provides for the inclusion of a system of codes in labels and leaflets of insecticides, fungicides and herbicides, in order to evidence the mode of action of the active ingredient present in the product. In case of formulated mixtures, both molecules should be listed on the label and leaflet, using the same HRAC international reference code. As for herbicides, the code nomenclature was stipulated in Table 1.

According to Act No. 45, "symbols should be arranged in rectangles divided into three parts, proportional to each other, below the name of the active ingredients in the central column of the label and in the leaflet, in a legible and space-saving manner of the rectangle". In the first segment of the rectangle, the word GROUP ("GRUPO") must be included; in the central part, includes the international product nomenclature (Table 1); and in the third segment, the agronomic class of the active ingredient should be included; e.g.: HERBICIDE ("HERBICIDA"). The standard of information provision, as well as the formatting, follows the following example:

GRUPO	**A**	**HERBICIDA**

Table 1 - Correspondence between letter codes, mode of action and chemical groups of herbicides

Group	Mode of action	Chemical group	Active ingredient
A	Inhibition of lipid synthesis (ACCase Inhibitors)	Aryloxyphenoxypropionates (FOPs)	Cyhalofop-butyl
			Clodinafop-propargyl
			Diclofop-methyl*
			Fenoxaprop-P-ethyl
			Fluazifop-P-butyl
			Haloxyfop-P-methyl
			Propaquizafop
			Quizalofop-P-ethyl
			Quizalofop-P-tefuril
		Cyclohexanodion (DIMs)	Alloxydim*
			Butroxydim*
			Cycloxydim*
			Clethodim
			Profoxidim
			Setoxydim
			Tepraloxydin
			Tralkoxydim*
		Phenylpyrazolines (DENs)	Pinoxaden*
B	Acetolactate synthase inhibitors (ALS) (branched chain amino acid synthesis)	Imidazolinones	Imazamethabenz-methyl*
			Imazamox
			Imazapic
			Imazapyr
			Imazaquin
			Imazethapyr
		Pyrimidinil (thio) benzoates	Bispyribac-sodium
			Pyribenzoxim
			Pyriftalid
			Pyriminobac-methyl*
			Pyrithiobac-sodium
		Sulphonylaminocarbonyl - -triazolinones	Flucarbazone-sodium*
			Propoxycarbazone sodium*
		Sulfonylurea	Amidosulfuron*
			Azimsulfuron
			Bensulfuron-methyl*
			Cyclosulfamuron*
			Cinosulfuron*
			Chlorimuron-ethyl
			Chlorosulfuron*
			Ethoxysulfuron
			Flazasulfuron
			Flupyrsulfuron-methyl-sodium*
			Foransulfuron*
			Halosulfuron-methyl
			Imazosulfuron*
			Iodosulfuron
			Mesosulfuron*
			Metsulfuron-methyl
			Nicosulfuron
			Oxasulfuron*
			Pyrazosulfuron-ethyl
			Primisulfuron-methyl *
			Prosulfuron*
			Rimsulfuron *
			Sulfometuron methyl
			Sulfosulfuron *
			Thifensulfuron-methyl*

To be continued ...

Table 1, cont.

Group	Mode of action	Chemical group	Active ingredient
B	Acetolactate synthase inhibitors (ALS) (branched chain amino acid synthesis)	Sulfonylurea	Triasulfuron*
			Tribenuron-methyl*
			Trifloxysulfuron sodium *
			Triflusulfuron-methyl *
			Tritosulfuron*
		triazolopyrimidines	Chloransulam-methyl
			Diclosulam
			Florasulam*
			Flumetsulam
			Metosulam*
			Penoxsulam
			Piroxsulam
C1	Inhibition of photosynthesis in photosystem II	Phenylcarbamates	Desmedipham*
			Phenmedipham*
		Triazines	Ametryne
			Atrazine
			Cyanazine*
			Desmethryne*
			Dimethametrine*
			Prometon*
			Prometryne
			Propazine*
			Simazine
			Simetryne*
			Terbumeton*
			Terbuthylazine*
			Terbutryne*
			Trietazine*
		Triazinones	Hexazinone
			Metamitron
			Metribuzin
		Triazolinones	Amicarbazone
		Uracils	Bromacil
			Lenacil*
			Terbacil*
C2	Inhibition of photosynthesis in photosystem II	Amides	Propanil
		Ureas	Chlorobromuron*
			Chlorotoluron*
			Chloroxuron*
			Dimefuron*
			Diuron
			Ethidimuron*
			Fluometuron (see F3)*
			Isoproturon*
			Isourom*
			Lefenurom*
			Linuron
			Methabenzthiazuron*
			Metobromuron*
			Metoxuron*
			Monolinuron*
			Neburon*
			Siduron*
			Tebuthiuron
C3	Inhibition of photosynthesis in photosystem II	Benzothiadiazinones	Bentazon
		Phenyl-pyridazines	Pyridafol*
			Pyridate*

To be continued ...

Table 1, cont.

Group	Mode of action	Chemical group	Active ingredient
C3	Inhibition of photosynthesis in photosystem II	Nitriles	Bromofenoxim*
			Bromoxynil*
			Ioxinyl octanoate
D	Inhibitors of photosystem I (free radical formers)	Bipiridiliuns	Diquat
			Paraquate
E	Inhibition of protoporphyrinogen oxidase (PPO)	Diphenyl ethers	Acifluorfen sodium
			Bifenox*
			Chlomethoxifen*
			Fluoroglycofen-ethyl*
			Fomesafem
			Halosafen*
			Lactofen
			Oxyfluorfen
		Phenylpyrazoles	Fluazolate*
			Pyraflufen-ethyl*
		N-phenylphthalimides	Cinidon-ethyl*
			Flumiclorac-pentyl
			Flumioxazin
		Others	Flufenpyr-ethyl *
			Pyraclonil*
			Profluazol*
		Oxadiazoles	Oxadiargyl*
			Oxadiazone
		Oxazolidinediones	Pentoxazone*
		Pyrimidinones	Benzfendizone*
			Butafenacil*
			Saflufenacil
		Tiadiazoles	Flutiacet-methyl *
			Thidiazimin*
		Triazolinones	Azafenidin*
			Carfentrazone-ethyl
			Sulfentrazone
F1	Inhibition of carotenoid biosynthesis in phytoene desaturase (PDS)	Others	Beflubutamid*
			Fluridone*
			Flurochloridone*
			Flurtamone*
		Pyridazinones	Norflurazone*
		Pyridinecarboxamides	Diflufenicam*
			Picolinafen*
F2	Inhibition of carotenoid biosynthesis in 4-hydroxyphenyl-pyruvate-dioxygenase (4-HPPD)	Isoxazoles	Isoxachlortole*
			Isoxaflutole
		Others	Benzobicyclon*
		Pyrazoles	Benzofenap*
			Pyrazolynate*
			Pyrazoxyfen*
		Triketones	Mesotrione
			Sulcotrione*
			Tembotrione
F3	Inhibition of carotenoid biosynthesis (unknown target)	Diphenyl ethers (Bleaching)	Aclonifen*
		Triazoles	Amitrole (*in vivo* inhibition of lycopene cyclase)
		Urea (Bleaching)	Fluometuron (see C2) *
F4	Inhibition of DOXP synthase	Isoxazolidinones	Clomazone
G	Inhibition of EPSP synthase	Glycines	Glyphosate
			Sulfosate*
H	Inhibition of glutamine synthetase	Phosphinic acid	Bialaphos (=Bilanaphos)*
			Glufosinate - ammonium salt

To be continued ...

Table 1, cont.

Group	Mode of action	Chemical group	Active ingredient
I	Inhibition of DHP (dihydropteroate synthase)	Carbamates	Asulam
K1	Inhibition of microtubule formation	Benzamides	DCPA (=chlorthal-dimethyl)*
			Propyzamide = pronamide
			Tebutam
		Dinitroanilines	Benefin (=Benfluralin)
			Butralin*
			Dinitramine*
			Ethalfluralin*
			Orizalina*
			Pendimethalin
			Trifluralin
		Phosphoramidates	Amiprofos-methyl*
			Butamifos*
		Pyridines	Dithiopyr*
			Thiazopyr*
K2	Mitosis Inhibitors	Carbamates	Carbetamide*
			Chlorpropham*
			Propham*
K3	Inhibition of cell division (VLCFA)	Acetamidas	Difhenamid*
			Naproanilide*
			Napropamide*
		Chloroacetamides (V1)	Acetochlor
			Alachlor
			Butachlor*
		Chloroacetamides (V2)	Dimethachlor*
			Dimethenamid*
			Metazachlor*
			Metolachlor
			Pethoxamid*
			S-metolachlor
		Chloroacetamides (V3)	Pretilachlor*
			Propachlor*
			Propisochlor*
			Thenylchlor*
		Inhibitor of long chain fatty acids	Pyroxasulfone*
		Others	Anilofos*
			Cafenstrola*
			Piperophos*
		Oxyacetamides	Flufenacet*
			Mefenacet*
		Tetrazolinones	Fentrazamide*
L	Inhibition of cellulose synthesis (cell wall)	Quinolinocarboxylic acid	Quinclorac (for monocotyledons) (also group O)
			Quinmerac (also group O)*
		Alkyzines	Indaziflam
		Benzamides	Chlorthiamid*
			Dichlobenil*
			Isoxaben*
		Triazolecarboxamides	Flupoxam*
M	Oxidative phosphorylation decoupler (membrane disruptors)	Dinitrophenols	Dinoterb*
			DNOC*
N	Inhibition of lipid synthesis - different from ACCase inhibitors	Chlorocarbonic acid	Dalapon*
			Flupropanate*
			TCA*

To be continued ...

Table 1, cont.

Group	Mode of action	Chemical group	Active ingredient
		Benzofuran	Benfuresate*
			Ethofumesate*
		Phosphorodithioates	Bensulide*
		Thiocarbamates	Butilate*
			Cycloate*
			dimepiperate*
			EPTC (=S-ethyl-Dipropylthiocarbmate)*
			Esprocarb*
			Molinate*
			Orbencarb*
			Pebulate*
			Prosulfocarb*
			Thiobencarb (=Bentiocarb)
			Tiocarbazil*
			Triallate*
			Vernolate*
O	Auxin-Mimetic	Arilpicolinate	Florpyrauxifen-benzyl
			Halauxifen-methyl*
		Benzoic acid	Chloramben*
			Dicamba
			TBA*
		Phenoxycarboxylic acid	2,4-D
			2,4-DB*
			Aminopyralid
			Clomeprop*
			Clopyralid*
			Dichloropropene = 2.4-DP*
			Fluroxypyr
			MCPA
			MCPB*
			Mecoprop (=MCPP; CMPP)*
			Picloram
			Triclopyr
		Quinolinecarboxylic acid	Quinclorac (also group L)
			Quinmerac (also group L)*
		Others	Benazolin-ethyl*
P	Inhibitors of auxin transport	Phthalates semicarbazones	Diflufenzopyrsodium*
			Naptalam*
Z	Unknown mode of action	Arylaminopropionic acid	Flamprop-M-methyl/-isopropyl*
		Organoarseniacais	DSMA*
			MSMA (Monosodium methanearsonate)
		Other (Unknown)	Oleic acid*
			Pelargonic Acid*
			Bromobutide*
			Cinmetiline*
			Chloroflurenol*
			Cumiluron*
			Dazomet*
			Dimrone (=Daimuron)*
			Etobenzanide*
			Phosamine*
			Indanofan*
			Metam*
			Methyl-dimrone*
			Oxaziclomefone*
			Piributicarbe*
		Pirazoliuns	Difenzoquat*

Source: HRAC-BR (2019). *Active ingredients not registered in Brazil.

If a product is a mixture formulated with two or more active ingredients, they should all be included on the label and leaflet by means of overlapping text boxes, according to the following example:

GRUPO	**A**	**HERBICIDA**
GRUPO	**G**	**HERBICIDA**

CHANGE IN PRACTICE

In general, when the presence of resistant weeds is identified in agricultural areas, the first modification of the management system adopted by growers is the replacement of the active ingredient, or its association with herbicides of other modes of action. However, for this measure to have maximum effectiveness, the effective rotation of the mode of action of the products is necessary. In this sense, Act No. 45 offers a great opportunity for farmers to implement this measure in their production system, because, even without having deeper knowledge about the mode of action of herbicides, a grower or applicator can easily recognize the group and replace it with another with different letter (code). That is, it is not enough to replace one Group A product by another Group A.

In this case, the grower's choice of options becomes simplified, since the need to replace a Group A product by a Group B, G, H product or vice versa (when recommended in leaflets and efficient in managing the same in the same crop). However, this replacement will only be valid if it meets the needs of the farmer, with herbicide options that offer similar efficacy and selectivity, even spectrum of controlled weeds, residual soil activity or not, and even cost feasibility.

Traditionally, the main measures related to chemical control that can be taken to prevent or control the selection of resistant weed biotypes are:

- Use the herbicide according to the manufacturer's recommendation, especially regarding the recommendation of leaflet doses and times of application.
- Improve herbicide application technology.
- Monitor the results of the applications and possible misapplicatioin in the areas.
- If possible, include control areas for evaluation of product efficacy.
- Apply herbicides only when necessary and as recommended.
- Reduce the frequency of application of the same herbicide or adopt combinations with herbicides of other mode of action (provided that they are efficient for the same weed or group of weeds to be controlled, but also that they are in the product registration leaflet).
- Avoid adopting herbicides with the same mode of action for which resistance was confirmed.
- Adopt the rotation of herbicides with different modes of action, if possible in association with crop rotation.

In this sense, Act No. 45 facilitates the process of choosing and adopting products by all those involved in the production chain. It also collaborates with the possible standardization of tank product mixtures, considering the need to associate products from different groups to better handle resistance cases. In summary, the process of understanding herbicide mode of action classification was facilitated, with greater possibility of adopting one of the important items for weed resistance management.

COMPLEMENTARY TECHNIQUES

It is worth noting that in addition to the replacement and/or rotation of the herbicides, other measures can be observed and implemented to avoid or reduce the selection

pressure imposed by the molecule, among which can be highlighted (López-Ovejero et al., 2008):

- The management of the seed bank: avoiding seed production by weeds is a key process for reducing the seed bank. Without the addition of new seeds to the soil, there is a population decline of the species and, consequently, lower selection pressure will be imposed by the herbicide.
- Ecological adaptability of the resistant biotype: if a resistant biotype has less ecological adaptability, its competitiveness within the population is impaired, influencing management techniques. In this case, by removing the selection factor (herbicide), the gene frequency of the resistant biotype can be reduced, due to its lower competitiveness.
- Crop rotation: crop rotation is the basis of the integrated management of resistant weeds, as it allows the growers to alternate herbicides with different modes of action and the use of non-chemical practices.
- Cultural method: set of measures that aims provide competitive advantage to crops for outgrowing the weeds. Thus, spacing, population density, soil fertility, adoption of hybrids and suitable varieties, suitability of the place to the culture etc. are measures that favor crops in relation to the weed flora.
- Mechanical method: the use of rotating hoes, brush cutters, harrows and plows may be an alternative to chemical management, since they have efficacy on weeds and on the seed bank. In some cases, plowing may be recommended, especially for perennial plants, as well as brushing in perennial crops and no-till areas.

FINAL CONSIDERATIONS

The challenge of herbicide resistant weeds is an agricultural reality in Brazil that increases year after year and cannot be neglected. Thus, all measures taken to facilitate the management and reduce the slection pressure on products should be seen as real gains to the agricultural environment and, above all, to be praised.

In this sense, it is necessary to implement a consistent educational process on Act No. 45, in order to clarify the importance of this information for farmers and responsible for agricultural sprays, so that, understanding the problem involved in the subject, begin to implement effective management measures and resistance control.

For this, the Resistance Action Committees (FRAC-BR, HRAC-BR and IRAC-BR) jointly established the “Modes of Action” campaign in August 2018, in partnership with ANDEF and SINDIVEG. This campaign aims to spread the labeling changes. The campaign materials (folders, illustrations and slides) are available on the website: www.modosdeação.com.br. It is of the utmost importance that this knowledge be disseminated within the academic environment so that, over time, it reaches the knowledge of the farmers.

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