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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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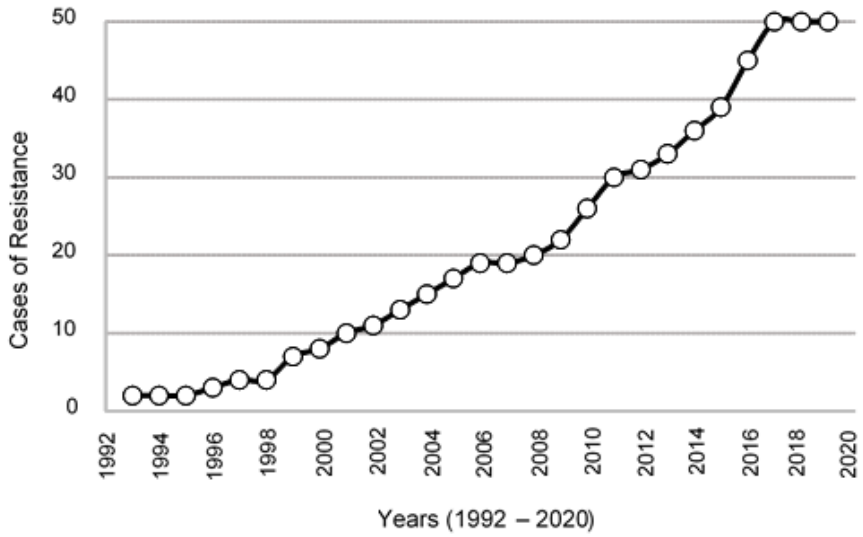
## BRIEF HISTORY

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.

## REFERENCES

Brasil. Ministério da Agricultura. Ato nº 45, de 9 de Junho de 2017. Diário Oficial da União. Seção 1. Publicado em 14 de Junho de 2017. n.113, p.1-3, 2017.

Heap I. International Sourvey of Herbicide Resistant Weeds. [acessado em: 30 maio de 2019]. Disponível em: http://www.weedscience.org/Summary/Country.aspx.

Associação Brasileira de Ação a Resistência de Plantas Daninhas aos Herbicidas - HRAC – BR. Rótulo com mais informação: mais eficiência no manejo da resistência. [acessado em: 19 fev. 2019]. Disponível em: http://www.modosdeacao.com.br.

López-Ovejero RF, Carvalho SJP, Christoffoleti PJ. Recomendações gerais para manejo integrado de plantas daninhas resistentes a herbicidas. In: Christoffoleti PJ, coordenador. Aspectos de resistência de plantas daninhas a herbicidas. Piracicaba: HRAC-BR; 2008. p.109-20.