Agrociencia Uruguay 2023 | Volume 27 |Supplement |Article e1219
DOI: 10.31285/AGRO.27.1219
ISSN 2730-5066

I Jornada Técnica del Grupo de Protección Vegetal - EEMAC

Pre-emergent herbicides: benefits and restrictions for rational use

Herbicidas preemergentes: beneficios y restricciones para un uso racional

Herbicidas pré-emergentes: benefícios e restrições para um uso racional

Villalba, J.[1]

[1]*Universidad de la República, Facultad de Agronomía, Estación Experimental Dr. Mario A. Cassinoni (EEMAC), Paysandú, Uruguay*

Editor
Horacio Silva
Universidad de la República, Facultad de Agronomía, Paysandú, Uruguay

Received *20 Jun 2023*
Accepted *26 Jun 2023*
Published *11 Sep 2023*

Correspondence
Juana Villalba
villalba@fagro.edu.uy

1. Introduction

Weed interferences for resources such as water, nutrients and space are mentioned as direct causes of yield loss in agricultural crops. Grain losses are variable depending on crop potential, the magnitude of interference associated with weed density and identity, and the potential of the local environment in relation to available resources.

Currently, the most widely used method to avoid these losses is chemical control, but herbicide use is actually at the crossroads of weed resistance. The sustained increase in cases of herbicide resistance is a consequence of several factors, which could be summarized as weed management based exclusively on chemical control, high selection pressure due to the repeated use of herbicides with the same mode of action, and lack of rotation in production systems. In this context, the concept of integrated management has been revalued, because it is not possible to continue with agriculture based only on the use of herbicides. Even so, the use of pre-emergent herbicides is considered a very important tool to reduce initial crop interference as well as pressure towards the use of foliar herbicides.

At present, pre-emergent herbicides are widely used, and this responds to the increase of weed populations that express resistance to foliar herbicides. As an example, in our country, commercial importations of some of the pre-emergent herbicides used on soybean have increased more than 7 times in the last few years(1).

The general characteristics of pre-emergent herbicides are that they are absorbed through the soil solution by roots and/or hypocotyl or coleoptile, depending on the herbicide and the weed species. Herbicides behavior in soil is related to their physical-chemical characteristics as well as the interaction with soil characteristics such as organic matter content, texture, type and quantity of clays and soil moisture conditions.

2. Benefits of the use of pre-emergent herbicides

The main benefit of using these herbicides is to initiate the weed-free cultivation stage, free of interferences, because they control the first flushes of weeds, which are recognized as the most competitive[(2)].

On the other hand, many are the evidences that show that early weed control generates benefits for the crop, because of competition for resources. Even for high yielding crops, it has been proven that there is an additional restriction related to light quality[(3-4)]. This is due to the ability of plants to detect the quality of light, the presence of neighboring or nearby plants in the crop, and to determine changes in the wavelength received, associated with the far red/red ratio (R/RL). This perception generates morphological changes in plants, changes in the translocation of photosynthesis products, and photo-assimilates change in their translocation, being directed more to the aerial part than to the root part. These changes can generate unbalances with negative consequences in subsequent stages of the crop, such as tolerance to water stress conditions, and decreases in the capacity to absorb nutrients and water[(5-6)]. This process is called initialism[(6-7)], indicating the occurrence of the plant-plant interaction process. This includes not only light quality, but various signaling events in response to that sensing[(7-8)]. Although not all species or genotypes make such changes in responses to light quality[(7)].

In parallel, the use of pre-emergent herbicides in addition to the initiation of the crop cycle without competing weeds, in those cases of high weed infestations, allows a larger window period for the use of foliar herbicides. It is known that weed susceptibility is associated with plants of lesser development, therefore, effectiveness is conditioned by the state of the weed at the time of application. Additionally, in the case of summer weeds, they present higher growth rates, associated with higher photosynthesis rates and more effective use of resources[(9)].

Although it is not a benefit, another aspect that can be taken as a facility is that there are no requirements for its application. This implies that their effectiveness does not depend on the technologies used for their application and they can be applied with those technologies that present the lowest risk of losses to the environment. An example of this would be that it is not necessary to achieve large spray coverages, they can be applied with low application rates, and with coarse and very coarse droplet sizes. The results of greater reach to the soil of the solution applied with fine droplets, although it can be associated to the technology itself, respond more to the lack of rainfall than to the technology used[(10)]. Pre-emergent herbicides in our conditions did not show greater effectiveness at 20 days post-application in sorghum crop, by use of fine and/or extremely coarse drops, and neither by application volumes of 74 or 153 L.ha^{-1}[(11)].

3. Restrictions on the use of pre-emergent herbicides

The main restriction for the activity of pre-emergent herbicides is the need for soil moisture[(12)] to remain in the soil solution from where they are absorbed by weeds in the germination process. Although the development recommendations of most products mention the need of 10 mm of rainfall for these to be activated, for some herbicides the amount of rainfall needed for good control can be higher. This is reported for the control of *Euphorbia heterophylla* with flumioxazin[(13)].

On the other hand, the presence of straw on the surface, in zero tillage systems or herbicides used in second crops or after service crops that are dried out no more than 40-60 days in advance, ensures that they are applied on plant material remains. This material may be just beginning to dry out, but there may be desiccated remains from previous periods that are in an advanced period of decomposition. These situations make the activity of pre-emergent herbicides even more complex, because they have the capacity to be retained in this straw. The level of retention is associated with the species that make up the straw and the degradation time[(14)]. Straw modifies the soil environment also in the temperature generated, which in turn will generate changes in the degradation rates of the straw and, therefore, interacts with the arrangement of the straw on the ground[(15)].

The presence of straw, even when it can inactivate the pre-emergent, presents benefits in weed suppression[(16-17)]. In *Amaranthus* spp. a delay in emergence was observed due to the presence of 3000 kg.ha^{-1} of straw[(18-19)]. Even though this effect was only initial, the benefit implies a larger window for the application of foliar herbicides and also generates a complementary effect of straw with the use of pre-emergent herbicides.

The inactivation caused by the straw determines that the occurrence of rain after the application is crucial for it to be leachate from the straw and reach the soil solution, before its degradation by light, chemical or microbial. This implies that the time of occurrence of rain since the application is transcendental. The inactivation generated by the straw, therefore, is associated with the quantity, type, arrangement, distribution of the straw, the degradation processes to which it is subject, the amount of rainfall and time of occurrence, and the type of herbicide.

The research carried out by the Malherbology team of the School of Agronomy has focused on the study of the effectiveness of the herbicides s-metolachlor, sulfentrazone, flumioxazin, metribuzin and pyroxasulfone, varying the amount and the type of straw, and variables of amount and moment of rain simulation, on the emergence of *Amaranthus* spp. as one of the summer weeds of greatest interest at present.

In relation to the interception of s-metolachlor herbicide by the straw, there were no differences for 2500 or 5000 kg.ha^{-1} of dried straw. Subsequent rains that enabled the transfer of the herbicide from the straw showed interaction with the time of occurrence of these rains. Parallel studies of herbicide effectiveness in the control of *Amaranthus* spp. indicated that rainfall on day 14 post-application resulted in 3 times more emergence than when it occurred on the following day or 7 days post-application.

On the contrary, the herbicide sulfentrazone was not inactivated by the straw, regardless of the amounts (3000 vs. 6000 kg.ha^{-1}), as evidenced by the emergence of *Amaranthus* spp. whenever the label dose was used[19], and neither did it show differences in the control of the mentioned weed for subsequent rains of 20 or 80 mm[20].

With respect to flumioxazin, the results indicated interaction with straw, determining lower controls of *Amaranthus* spp. This was evident from early stages and for 6000 kg of straw.ha^{-1}[18]. Differences were found in the magnitude of the flumioxazin-straw interaction[20], perhaps in response not to the amount of straw, but to the type related to its degradation. Although the amount of lignin in the straw used was not quantified, it is known that interception is linked to this component[21].

Regarding metribuzin herbicide, it was not retained by the straw, regardless of the type, in the control of *Amaranthus* spp. In the same weed, pyroxasulfone did not present differences in control due to the presence of straw; the control was excellent with 6000 kg.ha^{-1} of oat stubble and even when the simulated rain was 14 days after the application. These results were contradictory to those obtained with 4000 kg.ha^{-1} of straw, where herbicide retention resulted in less control of ryegrass[22].

Even when generalizations or classifications of herbicide inactivation by straw are intended, depending on the type of products and their solubility properties or kow (ratio between the concentration in the lipid and aqueous phase), our results indicate that it depends on each product, because the interactions are varied.

4. Final considerations

In the current agricultural weed situation, we cannot dispense with the use of pre-emergents, despite the restrictions on their effectiveness. The interactions are varied and complex, and, therefore, more knowledge on the effects for each herbicide and for the weeds of interest is transcendental to predict their behavior.

Although water deficit conditions restrict the effectiveness of pre-emergents and are aggravated by the presence of straw and in summer crops, we believe that it is vital to consider that these conditions also affect the effectiveness of foliar herbicides. Water stress conditions generate changes in weed cuticles, hindering the retention and absorption of foliar herbicides[23]. Therefore, in such conditions, pre-emergents are even more necessary, because they allow a larger application window period.

Beyond that and in all cases, it is essential to deepen the implementation of integrated management practices. Isolated measures or basing management on chemical control will not allow an economically and environmentally sustainable agriculture, because resistance problems will gradually worsen. In this regard, in agricultural areas of Uruguay, populations of ryegrass with resistance to four herbicides have been found[24]. Integrated management is essential for rational management and for the sustainability of production systems.

Keywords: straw, herbicides, pre-emergent

Palabras clave: rastrojo, herbicidas, preemergente

Palavras-chave: palha, herbicida, pré-emergente

Transparency of data

Available data: The entire data set that supports the results of this study was published in the article itself.

Author contribution statement

Some of the results were part of the work of the Malherbologia group.

JV: Conceived and designed the analysis, Contributed to data or analysis tools, performed the analysis, wrote the paper.

References

1. Ministerio de Ganadería, Agricultura y Pesca (UY). Importaciones de productos fitosanitarios [Internet]. Montevideo: MGAP; 2020 [cited 2023 Jun 29]. Available from: https://bit.ly/3hiLrTN

2. Green-Tracewicz E, Page ER, Swanton CJ. Light Quality and the Critical Period for Weed Control in Soybean. Weed Sci. 2012;60:86-91.

3. Page ER, Tollenaar M, Lee EA, Lukens L, Swanton CJ. Does the shade avoidance response contribute to the critical period for weed control in maize (*Zea mays*)? Weed Res. 2009;49:563-71.

4. Page ER, Tollenaar M, Lee EA, Lukens L, Swanton CJ. Shade avoidance: an integral component of crop–weed competition. Weed Res. 2010;50:281-8.

5. Rajcan I, Swanton CJ. Understanding maize-weed competition: resource competition, light quality and the whole plant. Field Crops Res. 2001;71:139-50.

6. Vidal RA, Merotto A, Bergamashi H, Portes ES. Initialism: a new term to describe the first mechanism of negative interaction between weeds and crops. J Plant Dis Protec. 2008;21(1):95-8.

7. Vidal RA, Trezzi MM, Kozlowski LA, Prates MVB, Cieslik LF, Merotto A. Initialism as a mechanism of weed interference: can a crop plant be blinded? Planta Daninha. 2012;30(3):469-75.

8. Ballare CL. Illuminated behaviour: phytochrome as a key regulator of light foraging and plant anti-herbivore defence. Plant Cell Environ. 2009;32(6):713-25.

9. Escalante Cárdenas L, Trejo Calzada R, Esquivel Arriaga O, Arreola Avila JG, Flores Hernández A. Comparación de tasas fotosintéticas en algunas plantas cultivadas y malezas. Rev Chapingo ser zonas áridas. 2008;7(2):165-72.

10. Contiero RL, Francischini AC, Santos G, Ita AG, Ruver A, Bucker EG. Deposição efetiva do produto pulverizado sobre cobertura vegetal de aveia-preta por diferentes pontas de pulverização. Planta Daninha. 2012;30(4):891-7.

11. Orsi MV, Soria LI. Tecnologías de aplicación asociadas al control de malezas en sorgo [grade's thesis]. Montevideo (UY): Universidad de la República, Facultad de Agronomía; 2017. 46p.

12. Pacanoski Z, Mehmeti A. Pre-emergence grass weed control in winter wheat (*Triticum aestivum* L.) with soil applied premixed herbicides influenced by precipitations. Agron Res. 2019;17(6):2386-98.

13. Da Silva PV,Tronquini SM, Barbosa GC, Carvalho Dias R, Soto Veiga JP, Inacio EM. Eficácia de flumioxazin em *Euphorbia heterophylla* L. aplicado sobre diferentes tipos e quantidades de resíduos culturais e simulações de chuva. Rev de Ciências Agrárias. 2020;43(3):324-32.

14. Correia NM, Durigan JC, De Melo WJ. Envelhecimento de resíduos vegetais sobre o solo e os reflexos na eficácia de herbicidas aplicados em pré-emergência. Bragantia. 2007;66 (1):101-10.

15. Dao TH. Field Decay of Wheat Straw and its Effects on Metribuzin and S-Ethyl Metribuzin Sorption and Elution from Crop Residues. J Environ Qual. 1991;20:203-8.

16. Ferber C. Efecto de distintas coberturas invernales en la dinámica del enmalezamiento [grade's thesis]. Montevideo (UY): Universidad de la República, Facultad de Agronomía; 2016. 70p.

17. Buratovich MV, Acciaresi HA. Winter cover crops and dynamics of weeds in agricultural systems of the Argentine Rolling Pampas. Int J Pest Manag. 2022;68(4):414-22.

18. Ciceri T, Sanguinetti JF. Efecto del rastrojo y precipitaciones en la efectividad de flumioxazin en el control de *Amaranthus spp.* [grade's thesis]. Montevideo (UY): Universidad de la República, Facultad de Agronomía; 2021. 31p.

19. Riccetto MV. Efecto del rastrojo y precipitaciones en la efectividad del sulfentrazone en el control de *Amaranthus* spp. [grade's thesis]. Montevideo (UY): Universidad de la República, Facultad de Agronomía; 2022. 36p.

20. Collares M, Villalba J. Effect of Avena strigosa straw and rainfall on sulfentrazone and flumioxazin control effectiveness of *Amaranthus* spp. Int J Pest Manag. 2022;68(4):423-8.

21. Riggle BD, Penner D. Controlled release of three herbicides with the fraft lignin PC940C. Weed Sci. 1988;36:131-6.

22. Khalil Y, Flower K, Siddique KH, Ward P. Pyroxasulfone efficacy for annual ryegrass control is affected by wheat residue height, amount and orientation. Pest Manag Sci. 2020;76(3):861-7. Doi: 10.1002/ps.5590.

23. Sreekanth D, Pawar DV, Mishra JS, Naidu VSGR. Climate change impacts on crop–weed interaction and herbicide efficacy. Curr Sci. 2023;124(6):686-92.

24. Marques S. Caracterización de la Resistencia a herbicidas en poblaciónes de *Lolium multiflorum* Lam. del Uruguay [master's thesis]. Montevideo (UY): Universidad de la República, Facultad de Agronomía; 2021. 56p.