Comunicata Scientiae
Horticultural Journal

ORIGINAL ARTICLE
published: 30 April 2024
https://doi.org/10.14295/CS.v15.4266

Are pyroxasulfone and pyroxasulfone plus flumioxazin options for application in transplanted onions?

Laura Bordignon[1]*, Dionatan Alan Amler[2], Alysson Dias Dalmas[3], Ricardo Pazinato[1], Mayra Luiza Schelter[4], Antonio Mendes de Oliveira Neto[4], Naiara Guerra[1]

[1]Universidade Federal de Santa Catarina, Curitibanos-SC, Brazil
[2]Instituto Federal Catarinense, Rio do Sul-SC, Brazil
[3]Universidade Estadual Paulista, Botucatu-SP, Brazil
[4]Universidade do Estado de Santa Catarina, Lages-SC, Brazil
*Corresponding author, e-mail: laurabordi19@gmail.com

Abstract

This study aimed to evaluate the efficiency and selectivity of the herbicides pyroxasulfone and pyroxasulfone plus flumioxazin for transplanted onion, which currently do not have registration for this crop in Brazil. The experiment was conducted in two commercial crops in Imbuia and Curitibanos, SC, Brazil, with four replications. The herbicides application was carried out pre-emergence of weeds, after onion transplanting in both experiments. The Imbuia experiment had eight treatments: T1: diuron (D) + pyroxasulfone (PYR) (500 + 50 g ha^{-1}), T2: D + PYR (500 + 75 g ha^{-1}), T3: D + PYR (500 + 100 g ha^{-1}), T4: D + PYR + flumioxazin (FLU) [500 + (60 + 40 g ha^{-1})], T5: D + PYR + FLU [500 + (75 + 50 g ha^{-1})], T6: D + PYR + FLU [500 + (90 + 60 g ha^{-1})], T7: Weed free check, and T8: Control. In Curitibanos, had an additional treatment, with application of diuron (500 g ha^{-1}). Evaluation consisted of identification and weed control, crop phytotoxicity, onion stand, and diameter and yield of bulbs. Pyroxasulfone and pyroxasulfone plus flumioxazin, with diuron, were effective in control of *Polygonum persicaria*, *Galinsoga parviflora*, and *Coronopus didymus*, regardless of the dose used. Diuron with pyroxasulfone at a dose of 100 g ha^{-1} and with pyroxasulfone plus flumioxazin (60 + 40.75 + 50, and 90 + 60 g ha^{-1}) were effective in *Raphanus* spp. control in boths experiments. The control showed losses in its total yield compared to the weed free check, decreasing by 81.7% in Imbuia and 90,3% in Curitibanos. The herbicides used were selective and are importante tools for weed management in transplanted onion.

Keywords: Allium cepa, herbicides, *Raphanus spp.*, selectivity, weed control

Introduction

Due to its slow initial growth and limited ground coverage (Resende & Costa, 2007), onion is highly susceptible to weed interference. Direct competition for resources and space can lead to drastic losses in crop yield and the percentage of marketable bulbs (Menezes Júnior & Marcuzzo, 2016; Soares et al., 2003), directly impacting the market value of onion bulbs.

In an attempt to reduce the culture's susceptibility, producers often resort to seedling transplanting system, where onions are introduced into the cultivation area at an advanced stage of development. Even with this advantage, the cultivation still is vulnerable to damage when proper control of infestation is not realized (Souza et al., 2015).

Onion low competitive capacity results with competition, especially in the early stages of crop growth being the most critical for production (Jangre et al., 2018), with a recommendation to keep the area weed-free for at least 60 days after transplanting (DAT), or longer, as late infestations interfere with the harvesting and bulbs curing (Menezes Júnior & Marcuzzo, 2016).

High weed density can cause yield losses, reduced average weight and bulb diameter (Soares et al., 2003), depending on the infesting and weed density species, and competition period (Qasem, 2006). To solve this problem, most producers resort to chemical control by applying pre and post-emergence herbicides. However, onion growers have been facing difficulties in finding efficient herbicides to weed control in production areas and selective for the crop. In Brazil, 14 active ingredients of herbicides for pre or post-emergence weed control in onion crops are registered (MAPA, 2024), but many of these are not used by onion producers due to high levels of phytotoxicity and low control spectrum.

The use of pre-emergence herbicides is essential

Received: 22 February 2024
Accepted: 22 April 2024

for early control of weeds, preventing competition with the crop and ensuring that the quality and yield of onion bulbs are not affected. A new alternative for pre-emergence weed control in onions is pyroxasulfone. This pre-emergence herbicide is already registerd for crops such as soybeans, wheat, corn and cotton, acting on the control of narrow-leaf weeds (grasses) and small-seeded broadleaf weeds (Nakatani et al., 2016; Tanetani et al., 2009). Pyroxasulfone can also be used in combination with other herbicides, such as flumioxazin. This formulated mixture had its initial registration for weed in pre-emergence for weed control in soybeans (Mcnaughton et al., 2014). Currently it is only used experimentally in this culture.

Santa Catarina is the largest onion producer in Brazil, with significant economic and social importance for producers, serving as a source of income mainly in small properties. In the 2023/24 crop season, 402 thousand tons were produced (Gugel, 2024). In the state, seeding followed by transplanting is the most commonly used method for implementing the crop (NEC, 2024).

Due to the importance of this culture for Santa Catarina State and given the limited number of molecules and the culture's sensitivity to weed interference, studies on the efficacy and selectivity of new molecules are necessary. Thus, this study aimed to evaluate the efficiency and selectivity of the active ingredients pyroxasulfone and the mixture of pyroxasulfone plus flumioxazin for onion cultivation.

Material and Methods

The experiments were conducted in onion commercial areas in the state of Santa Catarina, Brazil. The first experimental site, located in the municipality of Imbuia (27°29'19''S latitude, 49°23'12''W longitude, and 815 meters altitude), was conducted between August and December 2021. The second site, in Curitibanos (27°29'52''S latitude, 50°69'72''W longitude, and 955 meters altitude), was conducted between September and December 2022.

The soil in the experimental area of Imbuia was classified as Haplic Cambisol Typic Hapludox (Santos et al., 2018). Soil chemical analysis, sampled in the 0 to 0.2 meter layer, revealed a pH in water of 5.3; clay content of 47%; organic matter (OM) of 0.9%; phosphorus (P) of 13.1 mg dm^{-3}; potassium (K) of 213.8 mg dm^{-3}; aluminum (Al) of 0.5 cmolc dm^{-3}; cation exchange capacity (CTC) of 19.03 cmolc dm^{-3}, and base saturation (V%) of 72.70. In Curitibanos, the soil was classified as Humic Cambisol (Santos et al., 2018). Soil chemical analysis, performed in the 0 to 0.2 meter layer, revealed a pH in water of 6,1; clay content of 68%; OM of 3.5%; P of 34.7 mg dm^{-3}; K of 279.2 mg dm^{-3}; Al of 0.5 cmolc dm^{-3}; CTC of 17.4 cmolc dm^{-3}, and V% of 84.0.

According to Köppen, the municipality of Imbuia was classified as humid subtropical climate (Cfa), with an average annual temperature and precipitation of 19.1°C and 1,530 mm, respectively (Instituto Cepa/SC, 2003). Meanwhile, Curitibanos has a temperate, mesothermal, humid climate (Cfb), with mild summers, and an average annual precipitation of 1,600 mm and temperature of 16.5°C (Instituto Cepa/SC, 2003).

For the implementation of both experiments, the soil was prepared through plowing, harrowing, and ridging operations. In Imbuia, the experiment was conducted with the Crioula cultivar, transplanted on August 19, 2021. In Curitibanos, the Mulata Calibrada onion cultivar was used, with transplantation carried out on September 4, 2022. Transplanting for both areas occurred when the onion seedlings had three leaves.

The experimental plots were arranged in six planting rows with a spacing of 0.2 meters between rows and a planting density of 10 seedlings per meter. Each plot had an area of 3.6 m². In both experiments, fertilization, cultural practices, and irrigation were carried out following the management practices of the property, based on recommendations for onion cultivation in Santa Catarina.

The experiments were conducted in randomized complete blocks with four replications. The Imbuia experiment consisted of eight treatments, consisting of the application of the following herbicides and doses: T1: diuron (D) + pyroxasulfone (PYR) (500 + 50 g ha^{-1}), T2: D + PYR (500 + 75 g ha^{-1}), T3: D + PYR (500 + 100 g ha^{-1}), T4: D + PYR + flumioxazin (FLU) [500 + (60 + 40 g ha^{-1})], T5: D + PYR + FLU [500 + (75 + 50 g ha^{-1})], T6: D + PYR + FLU [500 + (90 + 60 g ha^{-1})], T7: Weed free check, and T8: Control. In Curitibanos, an additional treatment was added, consisting of the application of diuron alone (500 g ha^{-1}).

The herbicides were applied after transplanting the onion seedlings and before weed emergence. In Imbuia, the application occurred at 15 DAT, and in Curitibanos, it occurred at seven DAT of the onion seedlings. Herbicide application was carried out using a pressurized backpack sprayer with CO_2, at an application rate of 150 L ha^{-1} in Curitibanos and 200 L ha^{-1} in Imbuia. The weeded free check was maintained by manual weeding to promote onion growth without weed interference. In the control, no weed management was performed to demonstrate the damage caused by weed interference to the crop.

The evaluations were conducted on the central rows of the plots, excluding the outer rows. For the variables of phytotoxicity and weed control, evaluations were carried out at 15 and 30 days after application (DAA), using a visual rating scale ranging from 0 to 100%, where a score of 0 represents absence of symptoms or control and a score of 100 represents death of the evaluated plant (Kuva et al., 2016). To identify the weeds present in the study area at 15 DAA, the weeds in the control plot were identified and counted.

After the onion plants were damping-off, the plant stand was determined in two one-meter rows in the center of each plot. The bulbs present in these two rows were harvested and subjected to curing in a protected environment. When they reached the ideal curing point, the aerial part and the root system of all bulbs were removed for evaluation of diameter (using a digital caliper) and weight. The bulbs were classified as class three (> 55 mm – commercial bulbs) and smaller than class three (< 55 mm – industrial bulbs) (MAPA, 2022), extrapolating the weight values per plot to estimate the yield of commercial and total bulbs.

The data of the variables studied in the experiment were subjected to analysis of variance by the F test ($p < 0.05$). Subsequently, they were subjected to mean comparison using the Tukey test ($p < 0.05$). All statistical analyses were performed using the SISVAR program.

Results and Discussion

In the experimental area of Imbuia, during the 2021 crop season, the most prevalent weeds spotted, at 15 DAA, in the control plot, were ladysthumb (*Polygonum persicaria*) (16 plants m^{-2}), gallant soldier (*Galinsoga parviflora*) (40 plants m^{-2}), swine cress (*Coronopus didymus*) (16 plants m^{-2}), and wild radish (*Raphanus* spp.) (20 plants m^{-2}). Meanwhile, in Curitibanos, during the 2022 crop season, at 15 DAA, 12 weed species were identified, with wild radish standing out, representing 90% of the total, with a density of 46 plants m^{-2}.

In Imbuia, the evaluation of weed control percentage at 15 DAA demonstrated excellent control (> 99%) of all weed species regardless of herbicide treatment. This control was close to or equal to 100%, indicating its effectiveness in pre-emergence control of *Polygonum persicaria*, *Galinsoga parviflora*, *Coronopus didymus*, and *Raphanus* spp. (**Figure 1**). At 30 DAA, all herbicides provided complete control (100%) of weed species infesting the experimental area (data not shown).

In Curitibanos, applications of diuron, and its mixture with pyroxasulfone at doses of 50 and 75 g ha^{-1}, showed lower efficacy in controlling wild radish

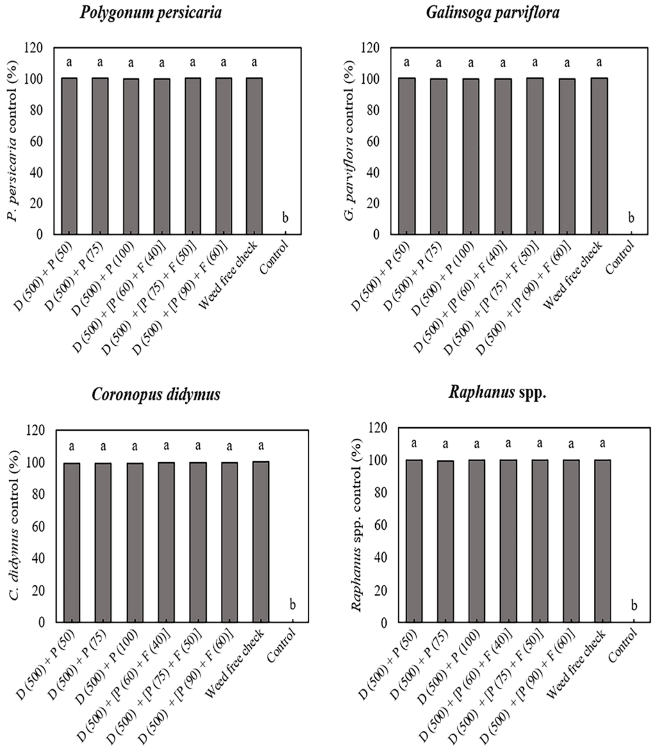

Figure 1. Percentage of control of *P. persicaria*, *G. parviflora*, *C. didymus*, and *Raphanus* spp. at 15 days after application (DAA) of pre-emergence herbicides in Imbuia, SC, Brazil, 2021. D (diuron); P (pyroxasulfone) and F (flumioxazin).

compared to other treatments (**Figure 2**). At 15 DAA, in the first evaluation, the lower dose of pyroxasulfone (50 g ha^{-1}) associated with diuron showed unsatisfactory control (<80%), while in the second evaluation, at 30 DAA, the combination of diuron with pyroxasulfone at a dose of 75 g ha^{-1} and diuron applied alone also demonstrate inefficiency, not being satisfactory in reducing the emergence of *Raphanus* spp.

The decrease in the effectiveness of these herbicides when applied in the experimental area of Curitibanos, during the 2022 crop season, may be directly linked to soil characteristics and the high infestation of wild radish.

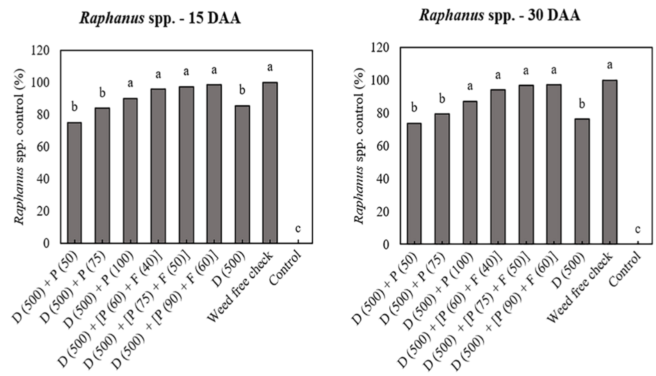

Figure 2. Percentage of control of *Raphanus* spp. as a function of pre-emergence herbicide application in Curitibanos, SC, Brazil, 2022. D (diuron); P (pyroxasulfone) and F (flumioxazin); DAA (days after application).

In the experimental area of Imbuia, the soil organic matter content was 0.90%, while in Curitibanos it was 3.50%. According to Westra et al. (2023), the sorption of pyroxasulfone to the soil is correlated with organic matter, increasing the molecule retention proportionally to the increase in organic matter content in the soil. The higher sorption of the herbicide results in lower weed control in the area, as it reduces the amount of herbicide available in the soil solution and consequently the possibility of absorption by weeds. The sorption process of diuron is also influenced by organic matter, but mainly by the clay content in the soil. Through the analysis of Latosol with different textural classes, Rocha et al. (2013) observed that for soils with higher clay content, such as that of the present study, the sorption and retention process of diuron is intensified, decreasing its availability in the soil solution.

As for wild radish, it is a species that presents rapid growth and high competitive capacity (Franceschetti et al., 2019), especially in crops with slow initial growth and leaf architecture that does not favor soil coverage, such as onions. Furthermore, the low temperatures during the onion cultivation period in Curitibanos allow for the emergence of new wild radish, as it is a winter annual plant. These various plant emergence flows and high population density can lead to a decrease in height, stem diameter, leaf area, bulb diameter, and dry mass of onions (Franceschetti et al., 2019).

On the other hand, the application of the mixture of diuron with pyroxasulfone at a higher dose (100 g ha^{-1}) and with pyroxasulfone plus flumioxazin at all tested doses, in Curitibanos, also showed good performance. Although not completely controlling, it reduced the population of *Raphanus* spp. to a low competitive level, with satisfactory efficacy. This is because flumioxazin (Protox enzyme inhibitor) provides a wider spectrum of control for broadleaf weeds with large seeds. As a consequence, treatments with this association show better wild radish control. Unlike flumioxazin, pyroxasulfone is a grass herbicide, with action spectrum on broadleaf weeds with small seeds (Presoto et al., 2022) that acts on initial growth due to inhibition of the biosynthesis of very long-chain fatty acids (VLCFA) (Tanetani et al., 2009).

However, research on the control of pyroxasulfone on broadleaf weeds has already been conducted, as demonstrated in this study, in which the mixture of diuron with pyroxasulfone at 100 g ha^{-1} obtained good wild radish infestation control, being statistically equal to those that had the association with flumioxazin. The combination of these two molecules has shown synergism and efficacy in weed control. Its application has also been efficient in controlling weed infestations in crops such as soybeans (Ferrier et al., 2022) in pre-emergence, and in post-emergence of onion itself (Vieira Neto et al., 2023) and wheat (Johnson et al., 2018).

Regarding the evaluation of phytotoxicity of onion plants, it was observed no visual symptoms of phytotoxicity noticeable (data not shown) after herbicide application in both experiments, thus indicating the selectivity of these treatments to the onion materials cultivated in Imbuia and Curitibanos.

The stand of onion plants in treatments with herbicide application showed behavior similar to weed free check for both experiments. In Imbuia, the values ranged from 10 to 11 bulbs m^{-1}, and in Curitibanos from 7 to 9 bulbs m^{-1} (**Figure 3**). In Curitibanos, weed interference resulted in a reduction in onion stand, as the tratament without control showed only 4 bulbs m-$^{-1}$, while in Imbuia it showed 9 bulbs m^{-1} (Figure 3). This can be justified by the significant interference caused by wild radish plants, which were present at a high density in Curitibanos (46 plants m^{-2}). As they are tall and very aggressive plants, they caused the death of onion plants in the control.

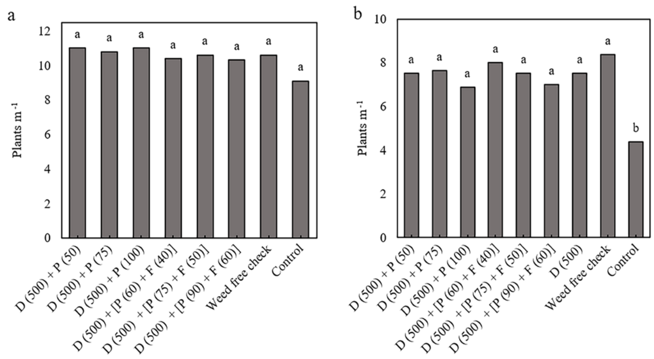

Figure 3. Stand (plants·m^{-1}) of onions in Imbuia, SC, Brazil, 2021 (a), and in Curitibanos, SC, Brazil, 2022 (b) as a function of pre-emergence herbicide application. D (diuron); P (pyroxasulfone) and F (flumioxazin).

The results obtained in Curitibanos are in line with the work of Khokhar et al. (2006), which found that area cleaning and weed control with herbicides promote a greater number of bulbs compared to control.

The degree of weed infestation in the area directly influenced the onion bulb diameter, as high infestations resulted in smaller bulbs. In the Imbuia experiment, all treatments with herbicide application and weed free check had statistically equal bulb diameters, resulting in bulbs with an average diameter ranging from 56 to 60 mm. Weed infestation throughout the crop cycle had a negative effect on onion bulb diameter, as in the control, the average diameter was 37 mm (**Figure 4**a), classified as class 1, which represents very low commercial value.

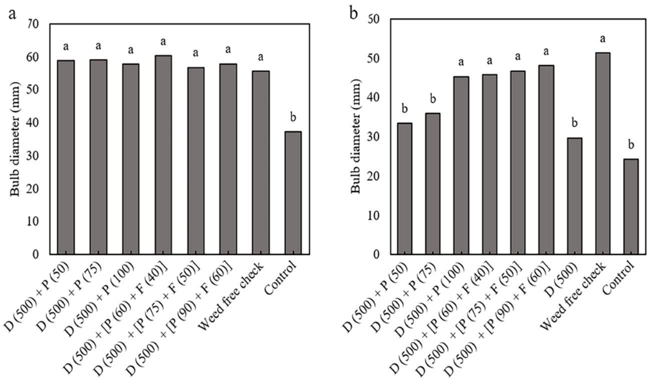

Figure 4. Bulb diameter (mm) of onions in Imbuia, SC, Brazil, 2021 (a), and in Curitibanos, SC, Brazil, 2022 (b), as a function of pre-emergence herbicide application. D (diuron); P (pyroxasulfone) and F (flumioxazin).

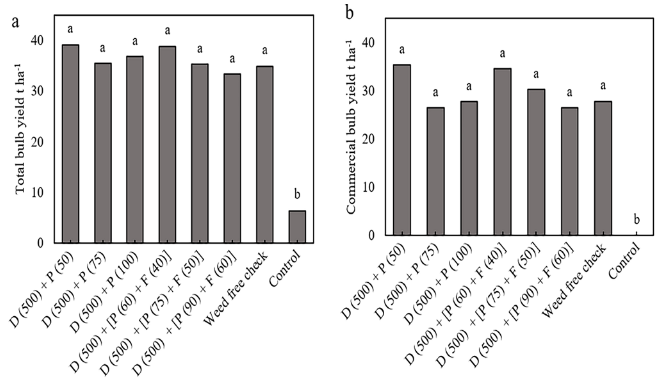

Figure 5. Total bulb yield (a) and commercial bulb yield (b) (t·ha^{-1}) of onions as a function of pre-emergence herbicide application in Imbuia, SC, Brazil, 2021. D (diuron); P (pyroxasulfone) and F (flumioxazin).

In Curitibanos, the smallest bulbs were obtained in the control, with an average diameter of 25 mm (class 1). Bulbs resulting from treatments with the combination of diuron and pyroxasulfone (50 and 75 g ha^{-1}), and diuron alone also showed a reduction compared to the weed free check, with an average diameter between 28 and 45 mm, classified as class 1 and 2 bulbs, respectively (Figure 4b). Kalhapure & Shete (2013) observed that onions in competition with weeds throughout their cycle had their bulb diameter affected, showing a decrease of 40 mm compared to the hand-weeded control.

The effectiveness of all herbicide mixtures in the Imbuia experimentation allowed for the full development of onions, resulting in larger diameter and, consequently, higher total and commercial bulb yields. Competition between transplanted onions and weeds throughout the cycle leads to a decrease in bulb diameter, and as a consequence, there is a reduction in total crop yield (Al-Khaz'Ali et al., 2023; Ibrahim et al., 2022).

The total bulb yield of the area in Imbuia obtained good results regardless of the herbicide treatment, with an average of 36.4 t ha^{-1}. Ferreira (1985) reveals that herbicide applications under favorable conditions, doses, and timing result in effective control and satisfactory onion yield (**Figure 5**a).

The results regarding the yield of commercial bulbs in Imbuia show the same response as total bulbs in all treatments (Figure 5b). The production of commercial bulbs reached 90.82% of its entirety in the treatment involving the application of diuron with pyroxasulfone at a dose of 50 g ha^{-1}, and 88.92% for the mixture of diuron with pyroxasulfone and flumioxazin at doses of 60 and 40 g ha^{-1}.

Onions transplanted in competition with weeds throughout the cycle have their number of leaves, leaf area, plant height, diameter, bulb weight, and stand drastically reduced, resulting in low total bulb productivity (Islam et al., 2020; Sahoo et al., 2017). The strong influence of weed interference on total bulb productivity of onions is evidenced in the control in both experiments, showing a total productivity of 6.4 t ha^{-1} in Imbuia (Figure 5a) and 2.9 t ha^{-1} in Curitibanos (**Figure 6**a).

In the Imbuia experiment, there was a decrease in total productivity of 81.66%, and in Curitibanos, of 90.28%, when compared to their weed free check. These data corroborate with works by Ferreira (1985), Soares et al. (2003), Qasem (2006), and Vieira Neto et al. (2023), in which weed competition led to a decrease in onion productivity by, respectively, 89%, 92%, 95%, and even 100%.

For Curitibanos, low total yields were also observed in the treatment with diuron applied alone and in its association with pyroxasulfone at a lower dose (50 g ha^{-1}), with productivities of 6.2 t ha^{-1} and 9.2 t ha^{-1}, respectively. On the other hand, mixtures of diuron, pyroxasulfone, and flumioxazin at doses of 75 + 50 and 90 + 60 g ha^{-1} were able to achieve a yield of approximately 23.5 t ha-

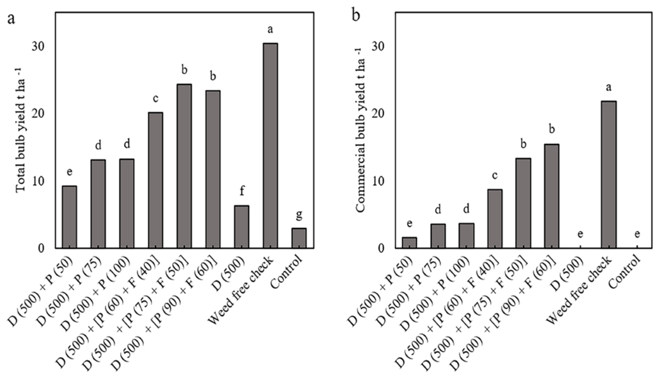

Figure 6. Total bulb yield (a) and commercial bulb yield (b) (t·ha^{-1}) of onions as a function of pre-emergence herbicide application in Curitibanos, SC, Brazil, 2022. D (diuron); P (pyroxasulfone) and F (flumioxazin).

[1], reinforcing the fact that to achieve good productivity in onion crops, it is essential to control infesting weeds in the field (Figure 6a). This analysis demonstrates that total productivity is directly linked to the control of *Raphanus* spp., as treatments with lower infestation control obtain lower productivity.

Weed interference, in addition to drastic losses in total onion bulb productivity, results in a decrease in the yield of marketable bulbs, which can be reduced by up to 100% (Soares et al., 2003), especially in the presence of weeds such as shepherd's purse and velvetleaf (Souza, 2016). In other words, the higher the aggressiveness and density of the weed species, the greater the proportion of bulbs with smaller diameters, and consequently, the lower the yield of commercial bulbs (Qasem, 2006), as well as the value received at the time of commercialization of these bulbs.

The increase in the yield of bulbs classified as industrial (class 1 and class 2 – diameter < 55mm) in treatments with higher weed infestation can be attributed to competition with onions for environmental resources such as water, nutrients, and light, resulting in reduced bulb size, while the use of herbicides controls infestation and provides a more favorable environment for bulb development (Khokhar, 2006).

Unlike Imbuia, Curitibanos showed the best result of marketable bulbs in the weed free check, with 21.8 t ha^{-1}, representing 71.7% of its total productivity. Among the herbicide application treatments, once again, the combination of pyroxasulfone plus flumioxazin (90 + 60 g ha^{-1}) with diuron was the best, with a commercial bulb yield of 15.4 t ha^{-1}, representing 66.2% of its total productivity (Figure 6b).

The effectiveness of this mixture aplied in pre-emergence of weed and after the transplanting of onion seedlings, in both experiments, was crucial for the high production of commercial bulbs, as weed control must be initiated early in the season to avoid significant losses in onion production and maintained until harvest (Islam, 2020).

In summary, the study of these variables further highlights the importance of using pre-emergence herbicides and demonstrates that pyroxasulfone and pyroxasulfone plus flumioxazin are a new option for controlling weed infestations in onion cultivation. Thus, it is essential to study these molecules to enable their future registration for the crop.

Conclusion

The herbicides pyroxasulfone and pyroxasulfone plus flumioxazin, combined with diuron, were effective in pre-emergence control of *Polygonum persicaria*, *Galinsoga parviflora*, and *Coronopus didymus*. *Raphanus* spp. control was effective with aplication of diuron with pyroxasulfone at a higher dose (100 g ha^{-1}) and with pyroxasulfone plus flumioxazin (60 + 40, 75 + 50, and 90 + 60 g ha^{-1}).

Pyroxasulfone and pyroxasulfone plus flumioxazin was selective for transplanted onion and are importante tools for weed management in this crop.

Acknowledgements

The authors wish to extend their gratitude to the producers Marcus Varela from Curitibanos/SC, and Adenir Cleiton Rengel from Imbuia/SC, for providing the areas for experimentation.

References

Al-Khanz'Ali, A.J., Salman K.A., Ahmed, A.S. 2023. Evaluation of the Efficiency Of Some Herbicides For Controlling the Weeds Outgrowth in Onion Field (*Allium Cepa* L.). *Syrian Journal of Agricultural Research* 10: 362-370.

Ferreira, J.C. 1985. Avaliação de herbicidas aplicados em pré e pós-emergência na cultura da cebola (*Allium cepa* L.). *Planta Daninha* 9: 97-105.

Ferrier, J., Soltani, N., Hooker, D.C., Robinson, D.E., Sikkema, P.H. 2022. The interaction of pyroxasulfone and flumioxazin applied preemergence for the control of multiple-herbicide-resistant waterhemp (*Amaranthus tuberculatus*) in soybean. *Weed Technology* 36: 318-323.

Franceschetti, M.B., Galon, L.; Menegat, A.D., Brunetto, L., Silva, A.M.L., Toso, J.O., Perin, G.F, Gallina, A., Forte C.T. 2019. Competitive Interaction between Weeds and Onion Crop. *International Journal of Advanced Engineering Research and Science* 6: 99-104.

GUGEL, J.T. 2024. Cebola. In: EPAGRI. Boletim Agropecuário nº131. Epagri/Cepa, Florianópolis, Brazil, p. 29-32.

Ibrahim, H.H., Abdalla, A.A., Salem W.S. 2022. Efficacy of irrigation intervals and chemical weed control on optimizing bulb yield and quality of onion (*Allium cepa* L.). *Bragantia* 82: e1722.

Instituto CEPA/SC. 2003. *Curitibanos: Caracterização regional*. Instituto CEPA/SC, Florianópolis, Brazil. 33 p.

Islam, M.R., Moniruzzaman, M., Obaidullah, A.J.M., Fahim, A.H.F. 2020. Impact of integrated weed management on bulb yield of onion. *Bangladesh Agronony Journal* 23: 83-89.

Jangre N., Omesh T., Gupta, C.R., Pandey P. 2018. Review on pre and post emergence herbicides against weeds, yield attributes and yield of onion. *Internacional Journal of Current Microbiology and Applied Science* 7: 1222-1230.

Johnson, E.N., Wang, Z., Geddes, G.M., Coles, K., Hamman B., Beres B.L. 2018. Pyroxasulfone Is Effective for Management of *Bromus* spp. in Winter Wheat in Western Canada. *Weed Technology* 32: 739-748.

Kalhapure, A.H., Shete, B.T. 2013. Effect of Weed Management Practices on Weed Dynamics, Weed Control Efficiency, Bulb Yield and Economics in Onion. *Journal of Agriculture Research and Technology* 38: 238-240.

Khokhar, K.M., Mahmood, T., Shakeel, M., Chaudhry, M.F. 2006. Evaluation of integrated weed management practices for onion in Pakistan. *Crop Protection* 25: 968-972.

Kuva, M.A., Salgado, T.P., Revoredo, T.T.O. 2016. Experimentos de eficiência e praticabilidade agronômica com herbicidas. In: Monquero, P. A, *Experimentação com herbicidas.* RiMa, São Carlos, Brazil. p. 75-98.

MAPA - Ministério da Agricultura, Pecuária e Abastecimento. 2024. AGROFIT: consulta de ingrediente ativo. https://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons<Acess on 20 Jan. 2024>

MAPA - Ministério da Agricultura, Pecuária e Abastecimento. 2022. Portaria MAPA nº 427, de 27 de abril de 2022. https://www.in.gov.br/web/dou/-/portaria-mapa-n-427-de-27-de-abril-de-2022-395718201<Acess on 08 Feb. 2024>

Menezes Júnior, F.O.G., Marcuzzo, L.L. (Orgs.). 2016. *Manual de boas práticas agrícolas: guia para a sustentabilidade das lavouras de cebola do estado de Santa Catarina*. Epagri, Florianópolis, Brazil. 143 p.

Mcnaughton, K.E., Shropshire, C., Robinsin, D.E., Sikkema, P.H. 2014. Soybean (*Glycine max*) Tolerance to timing applications of pyroxasulfone, flumioxazin, and pyroxasulfone + flumioxazin. *Weed Technology* 28: 494-500.

Nakatani, M., Yamaji, Y., Honda, H., Uchida, Y. 2016. Development of the novel pre-emergence herbicide pyroxasulfone. *Journal of Pesticide Science* 41: 107-112.

Núcleo de Estudos em Cebolicultura – NEC. CebolaNET. https://ciram.epagri.sc.gov.br/cebolanet/ <Access on 22 Set. 2024>

Presoto, J.C., Andrade, J.F., Netto, A.G., Malardo, M.R., Nicolai M., Christoffoleti, P.J. 2022. Effectiveness and interaction of the association of flumioxazin and pyroxasulfone in the control of guinea grass *(Panicum maximum*). *Revista de Ciências Agroveterinárias* 21: 435-440.

Qasem, J.R. 2006. Response of onion *(Allium cepa* L.) plants to fertilizers, weed competition duration, and planting times in the central Jordan Valley. *Weed Biology and Management* 6: 212–220.

Resende, G.M., Costa, N.D. 2007. Plantas daninhas. In: Resende, G.M., Costa, N.D. (eds.), *Cultivo de cebola no Nordeste*. EMBRAPA, Petrolina, Brazil. p. 39-42.

Rocha, P.R.R., Faria, A.T., Borges, L.G.F.C., Silva, L.O.C., Silva, A.A., Ferreira, E.A. 2013. Sorção e dessorção do diuron em quatro latossolos brasileiros. *Planta Daninha* 31: 231-238.

Sahoo, S.K., Chakravorty, S., Soren, L., Mishra, C., Sahoo, B.B. 2017. Effect of weed management on growth and yield of onion (*Allium cepa* L.). *Journal of Crop and Weed* 13: 208-211.

Santos, H.G., Jacomine, P.K.T., Anjos, L.H.C., Oliveira, V.A., Lumbreras, J.F., Coelho, M.R., Almeida, J.A., Araújo Filho, J.C., Oliveira, J.B., Cunha, T.B.F. 2018. *Sistema brasileiro de classificação de solos*. Embrapa, Brasília, Brasil. 356 p.

Soares, D.J., Pitelli, R.A., Braz, L.T., Gravena, R., Toledo, R.E.B. 2003. Períodos de interferência das plantas daninhas na cultura de cebola (*Allium cepa*) transplantada. *Planta Daninha* 21: 387-396.

Souza, J.I., Maciel, C.D.G., Jadoski, S.O., Silva, A.A.P., Matias, J.P. 2015. Resposta a aplicação sequencial tardia de herbicidas na cultura da cebola transplantada em diferentes arranjos de plantas. *Brazilian Jounal of Applied technology for Agricultural Science* 8: 25-33.

Souza, J.I., Silva, A.A.P., Chagas, R.R., Oliveira Neta, A.M., Maciel, C.D.G., Resende, J.T.V., Ono, E.O. 2016. Weed interference periods and transplanting densities of onion crop in the brasilian region of Guarapuava/PR. *Planta Daninha* 34: 299-308.

Tanetani, Y., Kaku, K., Kawai, K., Fujioka, T., Shimizu, T. 2009. Action mechanism of a novel herbicide, pyroxasulfone. Pesticide Biochemistry and Physiology 95: 47-55.

Vieira Neto, J., Gomes, C.A., Reis, M.R. 2023. Prospecção de herbicidas em pós-emergência e técnicas de aplicação em cebola transplantada. *Rev. Agronomia Brasileira* 7: e-ISSN 2594-6781.

Westra, E.P., Shaner, D.L., Barbarick, K.A., Khosla, R. 2015. Evaluation of sorption coefficients for pyroxasulfone, s-metolachlor, and dimethenamid-p. *Air, Soil and Water Research* 8: 9-15.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.