SBCPD
<http://www.sbcpd.org>

Planta Daninha

Journal of The Brazilian Weed Science Society

ISSN 0100-8358 (print)
1806-9681 (online)

Research Article

Weed control and selectivity herbicides pre emerging in garlic cultivars

Naiara Guerra[a]*, Renan Haramoto[a], Jaqueline Schmitt[b], Gabriel D. Costa[a], Juliano J. Schiessel[a], Antonio M. Oliveira Neto[c]

[a] Universidade Federal de Santa Catarina, Curitibanos, SC, Brasil; [b] Universidade Federal de Pelotas, Pelotas, RS, Brasil; [c] Universidade do Estado de Santa Catarina, Lages, SC, Brasil.

INFORMATION ARTICLE

Received: September 20, 2019
Accepted: August 12, 2020

Keywords:
Allium sativum
residual activity
pendimethalin

***Corresponding author:**
<naiaraguerra.ng@gmail.com>

Cite this article:
Guerra N, Haramoto R, Schmitt J, Costa GD, Schiessel JJ, Oliveira Neto, AM. Weed control and selectivity herbicides pre emerging in garlic cultivars. Planta Daninha. 2020;38:e020228966. https://doi.org/10.1590/S0100-83582020380100074

Conflict of Interest:
The authors declare that there is no conflict of interest regarding the publication of this manuscript.

HIGHLIGHTS

- The infesting species of the experiments were *Stellaria media* and *Stachys arvensis*.
- The highest injuries in the garlic were caused by S-metolachlor.
- Pendimethalin provided excellent weed control and being selective for both garlic cultivars.

ABSTRACT

Background: Garlic cultivation is characterized by low capacity of competition with weed, mainly due to the characteristics of the canopy and it´s slow initial growth that make it difficult to cover the soil.
Objective: This work aimed to evaluate the efficiency and selectivity of herbicides applied in the pre-emergence of two garlic cultivars in the edaphoclimatic condition of Santa Catarina State.
Methods: Two experiments were carried out in the commercial garlic area with Ito and Chonan cultivars. Both experiments were conducted in randomized block design. The traits for Ito cultivar were without weed control, with weed control, with linuron (810 g ha^{-1}), diuron (1,000 g ha^{-1}), pendimethalin (1600 g ha^{-1}), S-metolachlor (1200 g ha^{-1}), oxyfluorfen (720 g ha^{-1}) or flumioxazin (40 g ha^{-1}). For the experiment with Chonan cultivar the treatment composed by oxadiazon (1000 g ha^{-1}) was included. The analyzed variables were based on weed community control and phytotoxicity, stand, diameter of bulbs and productivity of garlic.
Results: The infesting species of the experiment with the cultivar Ito were *Stellaria media* and *Stachys arvensis*, whereas for Chonan, only the first was found. The herbicides applied in pre-emergence were efficient in controlling these species until 45 days after application - DAA. The highest injuries at 45 DAA were caused by S-metolachlor, with 33% for Ito cultivar and 10% for Chonan. The best herbicides, taking into account weed control and productivity, were pendimethalin and S-metolachlor, for the Ito cultivar, and pendimethalin, oxyfluorfen, and flumioxazin for the Chonan cultivar.
Conclusions: The pendimethalin stood out for presenting excellent weed control and being selective for both garlic cultivars.

1 INTRODUCTION

In the 2018/19 harvest, Brazil produced 135,517 tons of garlic, on 11,216 hectares of land with an average yield of 12.08 t ha^{-1} (Anapa, 2018). In 2018, the states of Minas Gerais and Goiás stood out in national production with about 37% and 26% of the total produced, respectively, followed by Santa Catarina with a 14% share of national production (Conab, 2020). In Santa Catarina this culture is concentrated in a few municipalities, located mainly in the Plateau region, such as

Frei Rogério, Curitibanos and Fraiburgo (Conab, 2020).

The cultivation of garlic requires several management techniques to achieve high productivity and quality of bulbs, which makes the culture costly. Among the factors that need to be managed correctly are weeds. According to Lucini (2009), weeds compete with garlic for nutrients, water and light, can host pests and diseases and release allelochemicals that suppress the growth and development of the crop.

Most of the time, the weeds that infest the garlic crops prevail in the use of the environment's resources (Ferreira and Silva, 1978). This is because the garlic culture has a low initial growth rate and low leaf development, which results in a limited canopy and with a low capacity to shade the soil, making it uncompetitive compared to weeds (Lucini, 2009; Sahoo et al., 2018). In addition, the cultivation of garlic requires frequent irrigation and requires a high amount of fertilizers, which can favor weed infestation (Sahoo et al., 2018), since they are almost always more efficient in the extraction and use of resources if compared to cultivated plants.

As a result of the low competitive capacity of garlic, it is common to have a reduced crop productivity due to weed interference, reaching up to 80% (Garcia et al., 1994), in addition to resulting in a long critical interference prevention period (CIPP), which generally ranges from 25 to 120 days after emergence for the cultivars used in Santa Catarina (Lucini, 2009). Studies by Contieiro et al. (2008) found that for the garlic crop to express maximum productivity, the crop must be free of weeds from 20 to 100 days after planting the bulbils. However, at the end of the critical period, even if there is no further damage to production, the presence of weeds significantly affects the harvest, making lamination difficult, causing the loss of bulbs at the start and requiring greater use of labor, which ends up justifying the maintenance of weed-free crops until harvest (Lucini, 2009).

Among the techniques used to control weeds in garlic, we can highlight the use of herbicides in pre-emergence (Ferreira and Silva, 1978; Mehmood et al., 2007; Mohite et al., 2015). The duration of the herbicide residual applied in pre-emergence is of paramount importance, since the residual control for a long period allows the development of the crop and reduces the number of applications in post-emergence, favoring the planning of operations and reducing the cost with weed management.

However, a drawback of herbicide application is due to the fact that garlic is very sensitive to these products, which, depending on the conditions in which they are applied, can cause the crop to be phytotoxic, including reducing productivity (Lucini, 2009; Walperes et al., 2015). This sensitivity varies according to the cultivar (Carvalho et al., 2009) and edaphoclimatic factors, and there are few published works with the cultivars currently used.

Thus, the hypothesis was formulated that pre-emergent herbicides can be tools for the control of weeds in the culture of garlic grown in the Plateau region of the State of Santa Catarina. Based on the information presented, this work aimed to evaluate the efficiency and selectivity of herbicides applied in the pre-emergence in two garlic cultivars for the edaphoclimatic condition of the Plateau region of the State of Santa Catarina.

2 Materials and Methods

Two experiments were conducted in areas of commercial garlic production, located in the municipality of Curitibanos-SC, in 2017. The climate of the region is of the Subtropical Mesothermal Humid type and mild summer (Cfb) (Köppen, 1948). The average annual temperature varies between 16 and 17 ºC, with an average rainfall of 1,500 to 1,700 mm. The soil was classified as Latossolo Bruno Álico (Embrapa, 2018) in both locations, presenting 59% and 48% clay in the area with the cultivar Ito and Chonan, respectively. In the chemical analysis, the soil of experiment 1 (cv. Ito) presented pH in H_2O of 6.20; $H^- + Al^{+3}$ of 3.42 $cmol_c\ dm^{-3}$; Ca^{+2} of 10.73 $cmol_c\ dm^{-3}$; Mg^{+3} of 4.03 $cmol_c\ dm^{-3}$; K^+ of 0.76 $cmol_c\ dm^{-3}$; P of 68.70 mg dm^{-3} and Carbon of 27.25 g dm^{-3}. While in the area of experiment 2 (cv. Chonan) the pH in H_20 was 5.30; $H^- + Al^{+3}$ of 7.76 $cmol_c\ dm^{-3}$; Ca^{+2} of 7.40 $cmol_c\ dm^{-3}$; Mg^{+3} of 2.18 $cmol_c\ dm^{-3}$; K^+ of 0.52 $cmol_c\ dm^{-3}$; P of 42.00 mg dm^{-3} and Carbon 28.88 g dm^{-3}

Experiment 1 was implemented on July 3 with the cultivar Ito, and experiment 2 on July 24 with the cultivar Chonan. These represent the main garlic cultivars grown in the Curitibanos-SC region.

The experiments were conducted in a randomized block design. Experiment 1 (cv. Ito) consisted of eight treatments, with three replicates, while experiment 2 (cv. Chonan) had nine treatments and four replicates. The treatments in experiment 1 were: control with weed removal, control without weed removal, linuron (810 g ha^{-1}), diuron (1,000 g ha^{-1}), pendimethalin (1,600 g ha^{-1}), S-metolachlor (1,200 g ha^{-1}), oxyfluorfen

(720 g ha^{-1}) and flumioxazin (40 g ha^{-1}). For experiment 2, oxadiazon treatment (1,000 g ha^{-1}) was added.

To define the doses of each herbicide, the respective registration dose for the cultivation of garlic was used as a criterion, or culture with similar characteristics in the case of herbicides that do not have a registration for garlic, according to Rodrigues and Almeida (2018). The commercial products with their respective concentrations and formulations used in the experiments were: linuron - Afalon® 450 g L^{-1}, SC; diuron - Diuron Nortox® 500 g L^{-1}, SC;pendimethalin - Herbadox® 400 g L^{-1}, EC; S-metolachlor - Dual Gold® 960 g L^{-1}, EC; oxyfluorfen - Galigan® 960 g L^{-1}, EC; flumioxazin - Flumyzin® 500 g kg^{-1}, WP and oxadiazon - Ronstar® 250 g L^{-1}, SC.

The blocks were represented by beds with 1.25 m in length and 0.15 m in height. The experimental units consisted of three double rows with spacing of 0.10 m and 0.35 m between lines, 3 m in length and spacing between plants of 0.10 m. Each plot had a total area of 3.75 m². The bulbils were planted manually with a depth of 1 to 2 cm.

The basic fertilization was carried out with 750 kg ha^{-1} of supersimples 00-20-00 and 1,000 kg ha^{-1} of the formulated fertilizer NPK 04-24-12. In coverage, in haul, 350 kg ha^{-1} of urea (45% N) were applied in three equal applications, at 30, 50 and 70 days after planting.

The herbicides were applied in the pre-emergence of garlic cultivation, one day after planting, with the aid of a pressurized backpack sprayer of CO_2 equipped with flat jet tips model AVI 110.02, spaced 0.50 m apart. The working pressure used was 276 kPa and displacement speed of 1.0 ms^{-1}, which provided an application rate of 200 L ha^{-1}.

The environmental conditions at the time of application were monitored by means of a thermohygroanemometer, showing for experiment 1: average air temperature of 13.3 ºC, relative humidity of 73.1%, gusts of 2.4 km h^{-1} and moist soil. For experiment 2 the average air temperature was 23 ºC, 55% relative humidity, wind gusts up to 1.2 km h^{-1} and moist soil.

Although pre-emergence herbicides are tested, they are not enough to ensure that the critical interference prevention period is free of weeds. Thus, the control was complemented with two post-emergence applications of the herbicide ioxynil (167.5 g ha^{-1}) (Totril®, 335 g L^{-1}, EC) in all treatments, including witnesses. This herbicide is an inhibitor of Photosystem II recommended for post-emergence applications in garlic culture (Rodrigues and Almeida, 2018). The application of ioxynil was carried out at 45 and 75 days after the application of pre-emergent treatments, when the phytointotoxicity and control evaluations had already ended.

Disease management was carried out by the producer, following the recommendations for the cultivation of garlic grown in the region. The area of both experiments had a sprinkler irrigation system and were irrigated one day after the application of the pre-emergent herbicides, and later when necessary.

The variables analyzed were based on the weed community in the experimental area and on the culture. Regarding the weed community, the percentage of control was evaluated at 17, 30 and 45 days after application (DAA) using a visual scale of 0 and 100%, where 0 (zero) represented the absence of control (equal to the control) and 100 (one hundred) plant deaths (Kuva et al., 2016). The same methodology was used for a final evaluation of weed control, performed in the pre-harvest of garlic.

In the garlic culture, the percentage of phytotoxicity at 17, 30 and 45 DAA was evaluated, through the visual evaluation of 0 to 100%, where 0 (zero) represents the absence of injuries and 100 (one hundred) the death of plants (Kuva et al., 2016). In the pre-harvest, the stand was evaluated by counting the number of garlic plants present in 1 m of the central double line of each plot. The harvest was carried out on 11/17/2017 (experiment 1 - cv. Ito) and 11/24/2017 (experiment 2 - cv. Chonan). After harvesting, the garlic plants remained for about 20 days in a ventilated warehouse for the curing process. After this period, the diameter of the bulbs (mm) was determined in ten bulbs chosen at random from the material harvested with the aid of a digital caliper and the bulb productivity (kg ha^{-1}).

The data obtained were subjected to analysis of variance, and the significant variables by the F test ($p<0.05$) had the means grouped by the Scott Knott Test at the level of 5% probability of error. All analyzes were performed using the Sisvar statistical program.

3 Results and Discussion

3.1 Experiment 1 - Cultivate Ito

The weed species that infested the experiment with the Ito cultivar were chickweed (*Stellaria media*, Caryophyllaceae) and staggerweed

(*Stachys arvensis,* Lamiaceae), with the first representing 50 to 80% of the control infestation without weeding. The number of plants of *S. media* in the control without weeding throughout the evaluations varied from 15 to 88 plants m^{-2}, whereas for *S. arvensis* the infestation was between 12 and 54 plants per m^2.

According to Lucini (2009), these species are often found in areas cultivated with garlic in Santa Catarina. *S. media* is a species that grows in winter and tolerates intense frosts. It presents fast growth, taking advantage of the high fertility of the soils prepared for the cultivation of garlic. It spreads through seeds and spreads due to the rooting of the branches, being very difficult to be controlled with the application of herbicides in advanced stages of development (Lucini, 2009). *S. arvensis* is also a winter species that develops mainly in fertile and low acidity soils, which is why it is commonly found in garlic crops. It propagates exclusively through seeds (Kissmann and Groth, 1995; Lorenzi, 2014).

In the visual assessments of weed control carried out at 17, 30 and 45 DAA, satisfactory levels of control (≥ 80.00%) were observed, regardless of the herbicide used in the pre-emergence. Pendimethalin, S-metolachlor and oxyfluorfen stood out with a control ≥ 93.33%, with prolonged residual activity and excellent control up to 45 DAA. However, in the pre-harvest of garlic, only the pendimethalin maintained satisfactory levels of control (≥ 80.0%), not differing from the control with weeding (Table 1).

The good efficiency of these herbicides has already been described in the literature for other weed species in garlic crops. Rahman et al. (2012) observed excellent control of *Convolvulus arvensis, Chenopodium album, Chenopodium murale, Melilotus indica, Rumex dentatus* and *Euphorbia helioscopy* in the culture of garlic with pendimethalin (825 g ha^{-1}) and S-metolachlor (2,400 ha^{-1}). Ali et al. (2017), when evaluating the efficiency of herbicides applied in the pre and post-emergence of garlic, found that S-metolachlor in pre-emergence (1,920 g ha^{-1}) promoted excellent control of *Chenopodium album*, *Trianthema portulacastrum*, *Convolvulus arvensis*, *Dactyloctenum aegyptium* and *Echinochloa colona* at 30 DAA, standing out among the tested herbicides. The results obtained by these authors are in agreement with those observed in the present study for pendimethalin and S-metolachlor in the control of *S. arvensis* and *S. media*, until the evaluation at 45 DAA.

All herbicides provided symptoms of phytotoxicity in garlic plants compared to controls. The highest intensity of symptoms was observed for S-metolachlor, regardless of the evaluation. Even at 45 DAA, the plants still had a percentage of phytotoxicity of 33.33% (Table 2). The visual symptoms observed in garlic plants that received the application of S-metolachlor were lower growth and less leaf development. Ali et al. (2017) observed that garlic plants treated with S-metolachlor (1,920 g ha^{-1}) had a smaller stem diameter and lower fresh, dry mass of the plant compared to the control without herbicide, being considered a very phytotoxic herbicide for the crop, including reducing garlic growth, development and production. The lower growth in garlic plants treated with S-metolachlor may have occurred because it is an inhibitor of synthesis of very long chain fatty acids, or also called growth inhibition of the aerial part. This herbicide inhibits the action of elongase enzymes, responsible for elongating short chains of lipids, produced in previous stages by ACCase. These lipids are essential for the formation of membranes and cell

Table 1 - Weed control (%) in garlic, cv. Ito, after pre-emergence herbicide application. Curitibanos-SC, 2017

Treatment	Control			
	17 DAA*	30 DAA	45 DAA	PREC
Witness with weeding	100.00 a	100.00 a	100.00 a	100.00 a
Witness without weeding	0.00 b	0.00 b	0.00 c	0.00 c
Linuron	89.00 a	93.33 a	83.00 b	22.67 c
Diuron	81.00 a	87.33 a	84.33 b	55.00 b
Pendimethalin	81.67 a	94.33 a	98.00 a	94.33 a
S-metolachlor	91.00 a	98.33 a	93.33 a	33.33 c
Oxyfluorfen	85.00 a	80.00 a	96.33 a	68.00 b
Flumioxazin	82.33 a	93.33 a	79.33 b	15.00 c
CV (%)	12.90	8.38	4.13	4014
$F_{calculated}$	30.66	72.35	303.04	10.78

* Averages followed by the same letter in the column do not differ according to Scott Knott's test at 5% probability ($p<0.05$). * Days after application; PREC: early harvesting to thin crop.

Table 2 - Phytotoxicity (%) of garlic plants, cv. Ito, after pre-emergence herbicide application. Curitibanos-SC, 2017

Treatment	Phytotoxicity (%)		
	17 DAA*	30 DAA	45 DAA
Witness with weeding	0.00 d	0.00 c	0.00 c
Witness without weeding	0.00 d	0.00 c	0.00 c
Linuron	16.00 b	7.66 b	5.00 b
Diuron	6.66 c	5.66 b	12.66 b
Pendimethalin	12.33 b	6.66 b	3.66 b
S-metolachlor	38.33 a	36.66 a	33.33 a
Oxyfluorfen	8.33 c	8.00 b	4.33 b
Flumioxazin	11.66 b	10.00 b	9.00 b
CV (%)	26.44	34.19	37.65
$F_{calculated}$	46.77	39.85	34.80

* Averages followed by the same letter in the column do not differ according to Scott Knott's test at 5% probability ($p<0.05$). * Days after application.

Table 3 - Stand (plants m^{-1}), bulb diameter (mm) and yield (kg ha^{-1}) of the garlic crop, cv. Ito, after pre-emergence herbicide application. Curitibanos-SC, 2017

Treatment	Stand (plants m^{-1})	Diameter (mm)	Productivity (kg ha^{-1})
Witness with weeding	8.16 ^{ns}	44.25 ^{ns}	12,966.69 a
Witness without weeding	8.50	43.96	10,616.59 c
Linuron	8.33	47.76	10,611.67 c
Diuron	8.83	46.34	11,719.70 b
Pendimethalin	8.83	46.00	12,539.97 a
S-metolachlor	8.66	43.23	12,802.60 a
Oxyfluorfen	7.66	46.27	11,021.53 c
Flumioxazin	7.00	43.15	10,075.14 c
Average	8.24	45.12	-
CV (%)	10.21	5.44	4.61
$F_{calculated}$	1.71	1.44	13.03

^{ns} not significant at 5% probability according to Scott Knott's test at 5% probability ($p<0.05$). * averages followed by the same letter in the column do not differ according to Scott Knott's test at 5% probability ($p<0.05$).

walls. Thus, its absence can result in lesser plant growth (Matthes et al., 1998; Schmalfub et al., 1998).

The herbicides evaluated did not interfere in the garlic stand, did not compromise the emergence of bulbils and did not cause the death of plants, with an average of 8.24 plants per linear meter (Table 3). The diameter of the bulbs was also not affected by the herbicides, varying between 43.15 and 47.76 mm (Table 3). This parameter is extremely important, not only because it is one of the yield components, but also because it determines the value of garlic marketing. According to the classification of the Mapa (1999), garlic bulbs with a diameter between 42 and 47 mm are classified as class 5 (on a scale of 3 to 7) and have high commercial value.

The yield of garlic cultivar Ito was affected by most of the treatments tested (Table 3). The highest yields were obtained using pendimethalin and S-metolachlor, with 12,539.97 and 12,802.60 kg ha^{-1}, respectively, not differing from the weeded control (12,966.69 kg ha^{-1}). Although severe phytotoxicity was observed at 45 DAA by S-metolachlor, this injury did not reflect a reduction in the productivity of the Ito cultivar, not corroborating the results obtained by Ali et al. (2017). This may have occurred due to the recovery of symptoms of phytotoxicity by garlic plants, or due to the excellent control provided by this herbicide treatment, resulting in less competition.

Diuron was grouped as an intermediary in terms of productivity, being inferior to the weeded control, pendimethalin and S-metolachlor, however it produced more than the group without weed control. This may have occurred due to the lower residual effect (lower control percentage) of diuron when compared to pendimethalin and S-metolachlor (Table 1), with the reduction in productivity being attributed to the greater weed interference. Linuron, oxyfluorfen and flumioxazin were equal to the control without weeding (Table 3). Sahoo et al. (2018) also found lower garlic bulb productivity compared to the weeded control when applying oxyfluorfen (2,400 g ha^{-1}).

3.2 Experiment 2 - Cultivar Chonan

In general, weed infestation in the experimental area with the cultivar Chonan was less than that observed in the experiment with cultivar Ito. This was because it was the first year of garlic cultivation in the area with Chonan, where grains (soy, corn and beans) were previously cultivated and with a history of good weed management in these crops. On the other hand, in the area with the cultivar Ito, garlic was already cultivated for three consecutive years. The predominant weed in the experimental area with the cultivar Chonan was *Stellaria media* (Caryophyllaceae), with infestation in the control without weeding ranging from 14 to 45 plants per m^2 throughout the evaluations. According to Garcia et al. (1984) this species is commonly found in garlic and onion crops in southern Brazil.

Regarding the percentage of weed control (Table 4), it was noted that at 17 DAA all herbicides promoted satisfactory control (≥80.00%). The controls provided by the herbicides linuron, diuron, oxyfluorfen and flumioxazin stand out, with percentages ≥92.25%, which characterizes excellent levels of control. In general, the herbicides linuron, pendimethalin, oxyfluorfen, diuron and flumioxazin showed high efficiency in the control of *S. media* until 45 DAA. However, in the pre-harvest, only pendimethalin and diuron stood out in the control of this species, showing satisfactory control (≥ 80%) even after 120 DAA.

Table 4 - Weed control (%) in garlic, cv. Chonan, after herbicide application in pre-emergence. Curitibanos-SC, 2017

Treatment	Control			
	17 DAA*	30 DAA	45 DAA	PREC
Witness with weeding	100.00 a	100.00 a	100.00 a	100.00 a
Witness without weeding	0.00 c	0.00 c	0.00 c	0.00 c
Linuron	92.50 a	86.50 a	89.75 a	66.25 a
Diuron	91.25 a	79.50 a	82.00 b	82.50 a
Pendimethalin	88.75 b	97.75 a	93.50 a	90.25 a
S-metolachlor	83.75 b	62.50 b	81.50 b	46.25 b
Oxyfluorfen	93.00 a	95.00 a	86.50 a	47.50 b
Flumioxazin	94.25 a	98.50 a	87.00 a	77.50 a
Oxadiazon	85.00 b	60.00 b	72.50 b	53.00 b
CV (%)	5.56	16.52	10.49	26.57
$F_{calculated}$	186.77	26.49	54.83	13.21

* Averages followed by the same letter in the column do not differ according to Scott Knott's test at 5% probability (p<0.05). * Days after application; PREC: early harvesting to thin crop.

These results corroborate those of Kumar et al. (2013) who observed a significant reduction in plant density of *S. media* until 90 days after the application of pendimethalin (1,500 g ha^{-1}). Siddhu et al. (2018) also found that pendimethalin (750 and 1,000 g ha^{-1}) applied in the pre-emergence of garlic culture promoted a significant reduction in weed infestation for a period greater than 120 days.

In the phytotoxicity evaluations (Table 5), symptoms were observed in the garlic plants cultivar Chonan in all herbicide treatments, reaching levels of 13.75% for S-metolachlor at 17 DAA. The injuries were characterized by reduced plant size, folded leaves and mild chlorosis. However, over the course of the evaluations, the damage initially observed was recovered. However, at 45 DAA, the plants that received the application of s-metolachor still remained with a percentage of phytotoxicity of 10%, higher than the other herbicides and the controls.

Table 6 presents the components of yield (stand and diameter of bulbs) and the bulb productivity of the cultivar Chonan. For the stand there was no significant difference between treatments, with an average value of 9.30 plants per linear meter. Likewise, the diameter of the bulbs was not changed by the different treatments, with an average of 44.64 mm. It is important to highlight that according to the diameter, this garlic would also be classified as class 5 (between 42 and 47 mm) (Mapa, 1999), which represents the valorization at the moment of commercialization.

The herbicides pendimethalin, oxyfluorfen, flumioxazin and oxadiazon did not affect the yield of garlic cultivar Chonan and were similar to the control with weeding, with yields close to 12,000 kg ha^{-1} (Table 6). The other herbicides were grouped with the control without weeding, with yield reductions reaching 18.2% (Table 6). Qasem (1996), studying the effect of different herbicides applied in pre and post-emergence of garlic, found that oxadiazon in pre-emergence showed less efficiency in weed

Table 5 - Phytotoxicity (%) of garlic plants, cv. Chonan, after herbicide application in pre-emergence. Curitibanos-SC, 2017

Treatment	Phytotoxicity (%)		
	17 DAA*	30 DAA	45 DAA
Witness with weeding	0.00 c	0.00 d	0.00 c
Witness without weeding	0.00 c	0.00 d	0.00 c
Linuron	7.75 b	5.00 b	3.50 b
Diuron	5.50 b	7.25 a	6.00 b
Pendimethalin	9.75 b	2.25 c	5.00 b
S-metolachlor	13.75 a	8.50 a	10.00 a
Oxyfluorfen	6.75 b	4.75 b	4.00 b
Flumioxazin	8.75 b	7.75 a	4.50 b
Oxadiazon	7.50 b	3.50 c	4.50 b
CV (%)	37.73	38.30	34.64
$F_{calculated}$	12.45	14.66	17.64

* Averages followed by the same letter in the column do not differ according to Scott Knott's test at 5% probability (p<0.05). * Days after application.

Table 6 - Stand (plants m^{-1}), bulb diameter (mm) and yield (kg ha^{-1}) of the garlic crop, cv. Chonan, after herbicide application in pre-emergence. Curitibanos-SC, 2017

Treatment	Stand (plants m^{-1})	Diameter (mm)	Productivity (kg ha^{-1})
Witness with weeding	9.75 ^{ns}	44.20 ^{ns}	12,527.46 a
Witness without weeding	9.50	42.52	10,251.13 b
Linuron	9.00	42.87	11,042.18 b
Diuron	9.25	44.87	10,504.93 b
Pendimethalin	9.37	45.70	12,350.44 a
S-metolachlor	8.87	45.60	11,699.90 b
Oxyfluorfen	9.62	44.60	12,548.48 a
Flumioxazin	9.12	45.27	11,956.84 a
Average	9.25	46.13	12,722.71 a
CV (%)	9.30	43.61	-
$F_{calculated}$	6.53	5.86	8.70

^{ns} not significant at 5% probability according to Scott Knott's test at 5% probability (p<0.05). * averages followed by the same letter in the column do not differ according to Scott Knott's test at 5% probability (p<0.05).

control than when in post-emergence. However, the productivity achieved with the application in pre-emergence was not affected. Tunku et al. (2007) also verified the selectivity of oxadiazon (1,500 g ha^{-1}) in the pre-emergence of garlic culture. The selectivity of oxyfluorfen and pendimethalin was also reported by Oliveira Jr. et al (1994) and Ali et al. (2017).

Comparing the results of the experiments with the different cultivars, it is observed that the herbicide S-metolachlor was the one that promoted the highest levels of phytotoxicity for both cultivars. However, for the cultivar Ito the productivity was not affected, while for the cultivar Chonan, even with less intensity of the symptoms of phytotoxicity, there was a significant reduction in productivity, of 6.6% compared to the test with weeded control. In this way, more research is needed to determine the real impact of this herbicide on different garlic cultivars, in addition to determining which edaphoclimatic conditions can affect the dynamics of this herbicide, as well as other molecules.

Despite the satisfactory initial control provided by most of the tested pre-emergent herbicides, it is reiterated that complementary applications of the herbicide ioxynil were carried out in post-emergence in all treatments (including the controls). This was necessary because the residual activity of the herbicides is not sufficient to prevent new emergent weed flows during the spring, during the crop's CIPP.

The residual activity of herbicides applied in pre-emergence, such as that obtained with pendimethalin, is an important characteristic, as it allows later applications of herbicides in post-emergence. Also, in some cases, the number of applications in post-emergence can be reduced, reducing the cost of handling weeds and other impacts caused by herbicides. In addition, the application of pre-emergent herbicides, while not always causing total weed mortality, reduces their vigor, which reduces the competitive capacity of weeds and makes them more sensitive to the application of post-emergent herbicides. It is noteworthy that even with the application of ioxynil in post-emergence, differences in control were observed in pre-harvest, highlighting the importance of the combination of pre and post-emergent herbicides in the management of weeds.

In short, for the cultivar Ito the best herbicides, taking into account the control of *Stellaria media* and *Stachys arvensis* and bulb productivity, were pendimethalin and S-metolachlor. For the cultivar Chonan, which had an infestation of *Stellaria media*, the best herbicides were pendimethalin, oxyfluorfen and flumioxazin. Thus, among the tested herbicides, what stood out regarding weed control and productivity, when applied in the pre-emergence of weeds and culture, presenting consistent results for both cultivars and evaluated environments, was the pendimethalin.

4 Conclusion

Thus conclused that among the tested herbicides, what stood out regarding weed control and productivity, when applied in the pre-emergence of weeds and culture, presenting consistent results for both cultivars and evaluated environments, was the pendimethalin.

5 Contributions

All authors conceived and designed the research. RH, JS, GDC and JJS: conducted the experiments. NG and AMON: analyzed the data, prepared tables and wrote the article. All authors reviewed and approved the article.

6 Acknowledgments

The authors would like to thank the company Rika Alimentos for providing the areas and supplies necessary for the execution of the experiments.

7 References

Ali N, Ashiq M, Ameer H. Efficacy of herbicides for weed control in garlic (*Allium sativum* L.). J Environ Agric Sci. 2017;12:19-24.

Associação Nacional dos Produtores de Alho – ANAPA. Análise conjuntural. Nosso Alho. 2018;28:39-40.

Carvalho SJP, Nicolai M, Ferreira RR, Figueira AVO, Christoffoleti PJ. Herbicide selectivity by differential metabolism: considerations for reducing crop damages. Sci Agríc. 2009;66(1):136-42.

Companhia Nacional de Abastecimento – CONAB. Indicadores da Agropecuária Alho. Técnica de Planejamento -TNS IV. Brasília-DF: 2020. [acesso em: 16 jun. 2020]. Disponível em: https://www.ibge.gov.br/estatisticas/economicas/agricultura-e-pecuaria/9117-producao-agricola-municipal-culturastemporarias-e-permanentes.html?=&t=resultados

Contieiro RL, Lopes MC, Sirtoli LF. Diferentes períodos de competição de plantas daninhas na cultura do alho em Marechal Candido Rondon-PR. In: Anais do 26. Congresso Brasileiro da Ciência das Plantas Daninhas e 18. Congreso de la Asociación Latinoamericana de Malezas; 2008; Ouro Preto. Sete Lagoas: Sociedade Brasileira da Ciência das Plantas Daninhas; 2008. v.1, p.1-5.

Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA. Centro Nacional de Pesquisas de Solos. Sistema Brasileiro de Classificação de Solos. Brasília: Embrapa; 2018. p.590.

Ferreira FA, Silva JF. Herbicidas na cultura do alho. Inf Agropec. 1978;4(48):55-8.

Garcia DC, Barni V, Dettmann LA, Lopes SJ. Controle de plantas daninhas e seletividade de herbicidas em alho. Ci Rural. 1994;24(3):453-7.

Kissmann KG, Groth D. Plantas infestantes e nocivas. São Paulo: BASF; 1995.

Köppen W. Climatologia: com um estudo de los climas de la tierra. Mexico: Fundo de Cultura Economica; 1948. p.478.

Kumar S, Rana SS, Chander N, Sharma N. Integrated weed management in garlic. Indian J Weed Sci. 2013;45(2):126-30.

Kuva MA, Salgado TP, Revoredo TTO. Experimentos de eficiência e praticabilidade agronômica com herbicidas. In: Monquero PA, organizadora. Experimentação com herbicidas. São Carlos: RiMa; 2016. p.75-97.

Lorenzi H. Manual de identificação e controle de plantas daninhas. 7. ed. Nova Odessa-SP: Instituto Plantarum; 2014. p.204-205.

Lucini MA. Principais plantas daninhas na cultura do alho de Santa Catarina. Curitibanos, 2009. 6p.

Matthes B, Schmalfub J, Boger P. Chloroacetamide mode of action. II: Inhibiting of very long chain fatty acid synthesis in higher plants. Z. Naturforsch, 1998;53:1004-11.

Ministério da Agricultura Pecuária e Abastecimento – MAPA. Classificação de hortaliças. Brasília: Embrapa hortaliças; 1999. p.7-13.

Mehmood T, Khokhar KM, Shakeel M. Integrated weed management practices in garlic crop Pakistan. Crop Protection. 2007;26:1031-5.

Mohite KK, Alekar NA, Murade MN, Deshmukh GN. Influence of pre and post emergence herbicides on yield and quality of garlic. J Hortic. 2015;2(2):1-3.

Oliveira Jr. RS, Ferreira LR, Silva JF. Tolerância do alho (*Allium sativum* cv. Gigante roxão) ao oxyfluorfen. R Ceres. 1994;41(233):81-7.

Qasem JR. Chemical weed control in garlic (*Allium sativum*) in Jordan. Crop Protection. 1996;15(1):21-6.

Rahman HU, Khattak AM, Sadiq M, Ullah K, Javaria S, Ullah I. Influence of different weed management practices on yield of garlic crop. Sarhad J Agric. 2012;28(2):213-8.

Rodrigues BN, Almeida FLS. Guia de herbicidas. 7. ed. Londrina - PR: Edição dos autores; 2018. 764p.

Sahoo S, Patel TU, Baldaniya MJ, Chavan A, Murmu S. Effect of herbicide on crop growth and yield of garlic (*Allium sativum* L.). Int J Chem Sci. 2018;6(3):3248-50.

Schmalfub J, Matthes B, Mayer P, Boger P. Chloroacetamide mode of action. I: Inhibiting of very long chain fatty acid synthesis in Scenedesmus acutus. Z. Naturforsch, 1998;53:995-1003.

Siddhu GM, Patil BT, Bachkar CB, Handal SBB. Weed management in garlic (*Allium sativum* L.) J Pharmac Phytochem. 2018;7(1):1440-4.

Tunku P, Lagoke STO, Ishaya DB. Evaluation of herbicides for weed control in irrigated garlic (*Allium sativum* L.) at Samuru, Nigeria. Crop Protection. 2007;26:642-6.

Walperes KC, Reis MR, Carneiro GDOP, Rovha BH, Dias RC, Melo CAD, et al. Residual effect of metribuzin on the soil on the garlic, onion and beans. Rev Bras Herb. 2015;14(1):64-72.