Efficacy and selectivity of alternative herbicides to glyphosate on maize

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ABSTRACT

The aim was to evaluate the selectivity and weed control of herbicides atrazine, nicosulfuron, mesotrione and tembotrione, applied alone and associated, in post-emergence of maize. Were carried out two experiments, one in the field in a randomized complete block design with four replications and eleven treatments, the second in greenhouse in a completely randomized design, with four replications and ten treatments. The treatments were composed of isolated and associated herbicides. Treatments were applied V4 stage of plants. For first experiment, crop injury and control evaluations were performed, as well as variables related to agronomic performance (plant height, ear insertion height, prolificacy index, yield and mass of 1,000 grains) and mass of weeds. For second experiment, evaluations of crop injury, height, diameter and dry mass of plants were performed. The lower yield for experiment one was verified in the treatment where only mesotrione was applied, which was attributed to the lower control of monocotyledon weeds. Crop injury were observed at 21 DAA in both experiments, but not exceeding 7.5%. All treatments were considered selective to maize. The herbicides atrazine, nicosulfuron, mesotrione and tembotrione, at associations, were effective in the weed control, except the association atrazine + mesotrione.

Keywords: atrazine; nicosulfuron; mesotrione; tembotrione; Zea mays L.

INTRODUCTION

Maize (Zea mays L.) has high yield potential, which guarantees high yield in Brazil, mainly due to C4 metabolism and its physiological characteristics (Fancelli & Dourado Neto, 2000). In 2017/2018 season the total area sown with crop maize was 16,614.4 thousand hectares, with a yield of 4,857 kg per hectare and production of 80,709.5 thousand tons (Companhia Nacional de Abastecimento - Conab 2019).

Several factors interfere in the maize yield, among them weeds. In Brazil, several monocotyledons and eudicotyledons species are common in crops such as Amaranthus sp., Cardiospermum halicacabum, Bidens sp., Euphorbia heterophylla, Ipomoea sp., Raphanus sativus, Richardia brasiliensis, Commelina benghalensis, Sida sp., Urochloa sp., Cenchrus echinatus, Digitaria sp., Echinochloa sp., Eleusine indica and Panicum maximum (Borém et al., 2015). The chemical control is the main method used in the control of weeds and the herbicides are applied according to the time of application: pre-planting, pre-emergence and initial and late post-emergence (Oliveira Júnior, 2011).

With the advent of glyphosate-tolerant crops, the use of glyphosate herbicide was intensified. Correa & Alves (2009), Ramires et al. (2010), Oliveira Neto et al. (2013), among others, report their efficacy in weed control. However, with continued use of the herbicide glyphosate over the years, it has selected resistant weed biotypes.

In Brazil, there are 50 cases of weeds resistant to one or more herbicides belonging to one or more mechanisms of action. Of these, 8 species present resistance to glyphosate, 6 of them being verified in maize crop (Heap, 2019).
To minimize problems caused by weeds, tolerant or resistant, Green (2012) and Riar et al. (2013) emphasize the importance of integrated weed management, which includes crop rotation and rotation of herbicide mechanisms of action. Besides that, Gazziero (2015) emphasizes the importance of further studies on the herbicide tank mixture, demonstrated in its work that 97% of the farmers make mixtures of more than one product per spray tank.

As herbicides alternative to glyphosate, used in post-emergence of maize, are applied atrazine, nicosulfuron, mesotrione, tembotrione and others, alone or in mixtures (Rodrigues & Almeida, 2018). Studies highlight the efficacy and/or selectivity of these herbicides in maize, however most often in association with glyphosate (Soltani et al., 2010; Chahal et al., 2018; Giovanelli et al., 2018). There are few recent studies evaluating efficacy and/or selectivity of these herbicides, without association with glyphosate, in maize. This highlights the importance of studies of the efficacy and selectivity of the other herbicides, beyond glyphosate, used in the maize.

It is believed that atrazine, nicosulfuron, mesotrione and tembotrione, may be alternative herbicides to glyphosate for management of weeds in maize. The aim was to evaluate the selectivity and weed control of atrazine, nicosulfuron, mesotrione and tembotrione, applied alone and associated, in post-emergence of maize.

**MATERIAL AND METHODS**

**Conditions and experimental design**

Two experiments were carried out in the 2016/17 season, in the Piracicaba, state of São Paulo (SP), Brazil. Experiment I was conducted in the field (22°42’51.4”S 47°37’43.1”W), and the experiment II was conducted under greenhouse conditions (22°42’32.0”S 47°37’43.1”W).

The climate is characterized as Cwa (humid subtropical with drought in the winter) by the climatic classification of Köppen. Figure 1 shows the rainfall and temperature distribution throughout the period of conduction of the experiment I in the field.

Table 1 shows the chemical and physical analysis of the soil of the experimental area and the soil used to fill the pots of the experiment II in the greenhouse. Conventional maize hybrid 30F53, which has an early cycle, was under natural infestation of several weed species: C. benghalensis, U. decumbens, Digitaria sp., E. heterophylla, Ageratum conyzoides, Bidens sp., Ipomoea sp., and Alternanthera tenella.

**Evaluations and data collection**

The crop injury and weed control were evaluated by means of visual evaluations, in which percentages ranged from 0 to 100% in each experimental unit (where 0 represents no symptoms of injury and 100% death of plants), considering in this case symptoms significantly visible in the plants, according to their development (Velini et al., 1995). These evaluations were performed for experiment I at 7, 14, 21, 28, 35 and 42 days after application (DAA). For the experiment II only the evaluation of crop injury at 7, 14, 21 and 28 DAA.

In the experiment I, at 42 DAA the shoot of remaining weeds of each plot was collected, with a square with an area of 0.25 m² (two replicates per plot). The material was dried in an oven with forced air ventilation for 72 h at 65°C and to measure the masses, an analytical balance was used with precision of three decimal places.

For experiment I, was performed evaluation of variables related to agronomic performance (plant height, ear insertion height, prolificacy index, yield and mass of 1,000 grains).

For the measurement of the variables: total plant height (from the soil surface to the insertion of the male inflorescence - tassel) and height of the ear insertion (from the soil surface to the ear insertion) were evaluated ten plants of the useful area per plot. A millimeter ruler was used, with the results expressed in meters.
For the determination of the prolificacy index, the number of ears per plants was counted, with the values obtained divided by 10, number of plants evaluated from the useful area of each parcel.

Yield estimation was carried out with the ear of the area of the plots manually harvested and threshed in a theshers for experiments, cleaned with the aid of sieves and placed in paper bags. The grains produced in each parcel had their weight measured and the moisture corrected to 13%, from these data the yield was calculated in t ha$^{-1}$. For the mass of one thousand grains the mass of two sub-samples per plot was measured and the moisture corrected to 13%.

For the experiment II, height evaluation was performed at 7, 14, 21 and 28 DAA. The two plants of each pot were measured, millimeter ruler was used, with results expressed in centimeters. At 28 DAA the shoot of each plant was collected to measure the dry matter mass. For drying oven with forced ventilation was used for 72 h at 65 °C and to measure the masses, an analytical balance was used with precision of three decimal places.

**Statistical analysis**

It was performed analysis of variance by the F-test ($p < 0.05$) and the means of the treatments were compared by Tukey’s (1949) test ($p < 0.05$) (Pimentel-Gomes & Garcia, 2002). For this purpose, the Sisvar 5.6 software was used (Ferreira, 2011). For crop injury, data were analyzed descriptively by percentage scale.

**RESULTS**

In the experiment I, at 7 DAA, injury was observed for nicosulfuron (6.8%), atrazine + nicosulfuron (5%) and mesotrione + nicosulfuron (6.3%) treatments. At 14 DAA

| Experiment I | Clay | Silt | Sand |
|--------------|------|------|------|
| pH (CaCl$_2$) | 5.3 | < 1.0 | 25.0 |
| Al | 10.0 | 2.8 | 26.0 |
| H + Al | 13 | 41.8 | 66.8 |
| K | 54.0 | 63 |
| Ca | 25.0 | 10.0 | 2.8 |
| Mg | 7.0 | 2.6 | 2.6 |
| SB | 39.0 | 16 | 57.6 |
| CEC | 82.8 | 70 |
| V | 40.0 | 54.0 |

| Experiment II | Clay | Silt | Sand |
|--------------|------|------|------|
| pH (CaCl$_2$) | 5.3 | < 1.0 | 25.0 |
| Al | 7.0 | 2.6 | 2.6 |
| H + Al | 39.0 | 16 | 57.6 |
| K | 82.8 | 70 |
| Ca | 40.0 | 6.0 | 6.0 |
| Mg | 54.0 | 54.0 |
| SB | 54.0 | 54.0 |
| CEC | 54.0 | 54.0 |
| V | 54.0 | 54.0 |

Units: Al, H + Al, K, Ca, Mg, SB and CEC (mmol dm$^{-3}$); P (resin) (mg dm$^{-3}$); V, clay, silt and sand (%).
the scores were maintained for atrazine + nicosulfuron and mesotrione + nicosulfuron, whereas for nicosulfuron alone it increased to 7.5%; in this evaluation, 5% was also observed for atrazine + tembotrione treatment, which remained until 21 DAA. At 28, 35 and 42 DAA, no more symptoms of injury were observed in maize plants, for the application of all treatments (Table 3).

For experiment II, at 7 DAA, treatments that caused injury to maize plants were nicosulfuron (3.5%), tembotrione (3%) and atrazine + mesotrione + nicosulfuron (3.5%). At 14 DAA the score remained at 3% for tembotrione and reduced to 3% for the triple association. Whereas, at 21 DAA, the application that caused injury were atrazine + nicosulfuron (3%), mesotrione + nicosulfuron (4.5%), atrazine + tembotrione (3%), atrazine + nicosulfuron (3%) and mesotrione with a reduction to 3.5% (Table 4). Thus, the crop injury was found in experiment I and experiment II up to 21 DAA, after this evaluation no symptoms were observed in all treatments.

There were differences in the height in the experiment II at 7 DAA, for the treatment atrazine + mesotrione + nicosulfuron, with a lower value at 8.38 cm in relation to the control. At 28 DAA, the lowest values were for mesotrione, atrazine + nicosulfuron, mesotrione + nicosulfuron and for atrazine + mesotrione + nicosulfuron. However, to the shoot dry mass, there was no difference between the means in relation to the control (without application) (Table 5).

At 14, 21 and 28 DAA, atrazine + mesotrione + nicosulfuron, mesotrione + nicosulfuron, atrazine + tembotrione and atrazine + nicosulfuron provided the same weed control. At 7 DAA only the triple association was equal to the weed control, with control of 86.25%. On the other hand, treatments with isolated herbicides and the association atrazine + mesotrione resulted in lower control than weed control in all evaluations (Table 6).

The total dry mass of weeds was higher for atrazine (18.51 g), mesotrione (35.9 g) and atrazine + mesotrione (18.6 g) treatments, in which the highest dry mass was monocotyledons with 17.98, 26.61 and 17.17 g, respectively. However, for eudicotyledons weeds, the highest dry masses were observed in the treatments mesotrione (9.29 g), nicosulfuron (6.61 g) and tembotrione (3.76 g) (Table 7).

Maize yield was lower only when was applied mesotrione alone (Table 8), which can be explained by the low control of weeds, mainly monocotyledons.

**DISCUSSION**

Dan et al. (2011) also observed injury in maize hybrids submitted to nicosulfuron at rates of 50 and 60 g a.i. ha⁻¹.
and in association of nicosulfuron + atrazine (20 + 1,500 and 40 + 3,000 g a.i. ha⁻¹) at 14 DAA. The symptoms varied from 2.33 to 5% in the lowest rate of nicosulfuron, reaching 7% in the highest rate, agreeing with the verified in this work where the scores ranged from 6.75% at 7 DAA and 7.5% at 14 DAA. The authors attributed scores up to 2.33% in the lowest rates and up to 3% in the highest rates applied to the 14 DAA, for the associations. These scores are being close to those found in this study, in which the scores were up to 5%, but with the hybrid different from that studied.

Weed control with atrazine (2,400 g a.i. ha⁻¹) and mesotrione (192 g a.i. ha⁻¹) isolated were studied by Philippi et al. (2016), that observed control of 58.75% and 32.5% for atrazine and mesotrione, respectively. The control may have been compromised due to the climatic conditions of high temperatures and low relative air humidity, reducing the effectiveness of the herbicides and raising the seed bank in the later crop, in which, they verified controls of 89.2% for atrazine and 85.6% for mesotrione.

In a study by Brown et al. (2016), the use of atrazine (1,500 g a.i. ha⁻¹) for Conyza canadensis (eudicotyledon weed) resulted in a control of 48% in the evaluation of 8 weeks after application, when in association with the mesotrione the control reached 97%. As in this study, that the control with atrazine alone was 46.25% and 10% for mesotrione at 42 DAA. However, in this study, the weed control with atrazine + mesotrione resulted in efficacy of only 45%, which is explained by the high presence of monocotyledons weeds, with dry mass of 26.61 g.

Table 4: Evaluation of crop injury at 7, 14, 21 and 28 days after application (DAA) of maize plants under isolated or associated application of herbicides (experiment II). Piracicaba - SP, 2016/17 season

| Treatments                          | Crop injury (%) |
|-------------------------------------|-----------------|
|                                     | 7   | 14  | 21  | 28   |
| control                             | 0.0 | 0.0 | 0.0 | 0.0  |
| atrazine                            | 0.0 | 0.0 | 0.0 | 0.0  |
| nicosulfuron                        | 3.5 | 0.8 | 0.0 | 0.0  |
| tembotrione                         | 3.0 | 3.0 | 0.0 | 0.0  |
| atrazine + nicosulfuron             | 0.0 | 3.0 | 0.0 | 0.0  |
| mesotrione + nicosulfuron           | 0.0 | 4.5 | 3.5 | 0.0  |
| atrazine + mesotrione + nicosulfuron| 3.5 | 3.0 | 0.0 | 0.0  |
| Mean                                | 1.3 | 2.0 | 0.4 |      |

Table 5: Height and dry mass of shoot of maize plants under isolated or associated application of herbicides (experiment II). Piracicaba - SP, 2016/17 season

| Treatments                          | Height (cm) | Shoot dry mass (g) |
|-------------------------------------|-------------|-------------------|
|                                     | 7 | 14  | 21  | 28   |    |
| control                             | 29.63 a     | 41.63             | 55.25 | 84.50  | 39.45 |
| atrazine                            | 24.88 ab    | 46.13             | 61.63 | 86.13  | 42.24 |
| mesotrione                          | 25.50 ab    | 40.38             | 43.50 | 73.75  | 38.04 |
| nicosulfuron                        | 22.88 ab    | 41.63             | 55.88 | 89.38  | 41.08 |
| tembotrione                         | 27.50 ab    | 44.88             | 55.25 | 84.50  | 42.15 |
| atrazine + mesotrione               | 23.25 ab    | 38.38             | 51.50 | 73.75  | 43.24 |
| atrazine + nicosulfuron             | 25.50 ab    | 41.75             | 56.25 | 81.00  | 35.98 |
| atrazine + tembotrione              | 23.13 ab    | 38.50             | 49.88 | 75.50  | 36.38 |
| mesotrione + nicosulfuron           | 24.63 ab    | 43.88             | 59.63 | 91.00  | 43.61 |
| atrazine + mesotrione + nicosulfuron| 21.25 b     | 39.25             | 44.25 | 74.50  | 32.83 |
| Mean                                | 24.51       | 41.45             | 53.75 | 82.86  | 39.34 |
| CV (%)                              | 12.44       | 11.04             | 18.04 | 3.49   | 13.58 |
| F                                   | 2.70*       | 0.95**            | 1.01* | 0.59*  | 0.42**|

* Means followed by the same letter in the column do not differ statistically from each other by the Tukey’s (1949) test (\(p < 0.05\)). ns - not significant, means do not differ statistically from each other by the F-test (\(p < 0.05\)).
The weed control in conventional maize with nicosulfuron (35 g a.i. ha\(^{-1}\)) in V4 stage, sequential application of nicosulfuron (35 g a.i. ha\(^{-1}\)) in V4 and V6 and nicosulfuron (35 g a.i. ha\(^{-1}\)) + metolachlor (1,120 g a.i. ha\(^{-1}\)) in V4, resulted in 61, 66 and 68% control, respectively. The use of residual herbicides is necessary to obtain better results (Burke et al., 2008). In the present study, although nicosulfuron did not cause symptoms of injury after 21 DAA, the control percentage reached a maximum of 80% (21 DAA).

Janak & Grichar (2016) studied the use of herbicides, at pre-emergence, to control monocotyledons and eudicotyledons weeds in maize. The authors found at 42 DAA that control for Brachiaria ruziens was 40% when using atrazine, 93% for s-metolachlor and 82% when both herbicides were associated. They also verified 90% control for this species when they associated s-metolachlor + atrazine + mesotrione. In addition, all treatments used resulted in injury symptoms of less than 3% and did not affect crop yield.

The control of E. crus-galli, Urochloa ramosa and I. hederacea with tembotrione (92 g a.i. ha\(^{-1}\)) was 86, 84 and 87%, respectively, at 28 DAA. In the treatments with atrazine (2,240 g a.i. ha\(^{-1}\)) were 80, 78 and 95% to the same

### Table 6: Weed control at 7, 14, 21, 28, 35 and 42 days after application (DAA) of maize plants under isolated or associated application of herbicides (experiment I), Piracicaba - SP, 2016/17 season

| Treatments                                    | Control (%) |
|-----------------------------------------------|-------------|
|                                              | 7           | 14          | 21          | 28           | 35           | 42           |
| control (with weeding)                        | 100.00 a    | 100.00 a    | 100.00 a    | 100.00 a     | 100.00 a     | 100.00 a     |
| control (without weeding)                     | 0.00 h      | 0.00 f      | 0.00 e      | 0.00 e       | 0.00 d       | 0.00 e       |
| atrazine                                      | 66.25 def   | 63.75 cd    | 58.75 c     | 55.00 d      | 50.00 c      | 46.25 d      |
| mesotrione                                    | 41.25 g     | 40.00 e     | 35.00 d     | 20.00 e      | 10.00 d      | 10.00 e      |
| nicosulfuron                                  | 68.75 cde   | 71.25 bc    | 80.00 b     | 78.75 bc     | 78.75 b      | 70.00 bc     |
| tembotrione                                   | 53.75 efg   | 51.25 de    | 53.75 cd    | 58.75 cd     | 61.25 c      | 61.25 cd     |
| atrazine + mesotrione                          | 51.25 fg    | 53.75 cde   | 53.75 cd    | 46.25 d      | 45.00 c      | 45.00 d      |
| atrazine + nicosulfuron                       | 77.50 bcd   | 85.00 ab    | 88.75 ab    | 90.00 ab     | 92.50 ab     | 89.25 ab     |
| atrazine + tembotrione                         | 83.75 bc    | 89.25 ab    | 91.75 ab    | 92.25 ab     | 92.25 ab     | 90.75 ab     |
| mesotrione + nicosulfuron                      | 77.50 bcd   | 85.00 ab    | 90.00 ab    | 90.00 ab     | 87.50 ab     | 86.25 ab     |
| atrazine + mesotrione + nicosulfuron           | 86.25 ab    | 95.00 a     | 95.50 ab    | 96.00 ab     | 96.00 ab     | 96.00 ab     |
| Mean                                          | 64.20       | 66.75       | 67.93       | 66.10        | 64.88        | 63.16        |
| CV (%)                                        | 10.04       | 11.55       | 11.87       | 12.65        | 10.56        | 12.87        |
| F                                             | 53.55*      | 51.36*      | 50.05*      | 49.22*       | 68.13*       | 49.06*       |

* Means followed by the same letter in the column do not differ statistically from each other by the Tukey’s (1949) test (p < 0.05).

### Table 7: Shoot dry mass of weeds monocotyledons, eudicotyledons and total under isolated or associated application of herbicides (experiment I), Piracicaba - SP, 2016/17 season

| Treatments                                    | MONO¹ | EUDI¹ | Total |
|-----------------------------------------------|-------|-------|-------|
| control (with weeding)                        | 0.00 a | 0.00 a | 0.00 a |
| control (without weeding)                     | 25.33 bc | 18.30 f | 43.63 c |
| atrazine                                      | 17.98 b | 0.53 ab | 18.51 b |
| mesotrione                                    | 26.61 c | 9.29 e  | 35.90 c |
| nicosulfuron                                  | 2.09 a | 6.61 d  | 8.70 a |
| tembotrione                                   | 1.64 a | 3.76 b  | 5.40 a |
| atrazine + mesotrione                          | 17.17 b | 1.43 ab | 18.60 b |
| atrazine + nicosulfuron                       | 2.06 a | 1.04 ab | 2.24 a |
| atrazine + tembotrione                         | 0.77 a | 1.42 ab | 2.19 a |
| mesotrione + nicosulfuron                      | 0.17 a | 2.07 bc | 2.24 a |
| atrazine + mesotrione + nicosulfuron           | 0.86 a | 0.61 ab | 1.47 a |
| Mean                                          | 8.60   | 4.09   | 12.62  |
| CV (%)                                        | 14.39  | 7.71   | 11.88  |
| F                                             | 13.38* | 8.12*  | 11.02* |

¹ MONO – monocotyledons. EUDI – eudicotyledons.

* Means followed by the same letter in the column do not differ statistically from each other by the Tukey’s (1949) test (p < 0.05).
Efficacy and selectivity of alternative herbicides to glyphosate on maize

Table 8: Agronomic performance variables of maize plants under isolated or associated application of herbicides (experiment I). Piracicaba - SP, 2016/17 season

| Treatments                                    | PH  | EH  | PI   | YIELD¹ | GM  |
|-----------------------------------------------|-----|-----|------|--------|-----|
| control (with weeding)                        | 2.38| 1.35| 1.20 | 10.89 a| 271.03|
| control (without weeding)                     | 2.35| 1.35| 1.40 | 7.91 b | 279.86|
| atrazine                                      | 2.42| 1.40| 1.10 | 9.14 ab| 279.86|
| mesotrione                                    | 2.33| 1.35| 1.25 | 7.85 b | 266.87|
| nicosulfuron                                  | 2.33| 1.37| 1.28 | 9.16 ab| 273.44|
| tembotrione                                   | 2.38| 1.35| 1.28 | 8.40 ab| 276.06|
| atrazine + mesotrione                          | 2.39| 1.38| 1.25 | 9.60 ab| 265.10|
| atrazine + nicosulfuron                       | 2.33| 1.37| 1.50 | 10.53 a| 290.31|
| atrazine + tembotrione                         | 2.40| 1.37| 1.20 | 10.79 a| 282.57|
| mesotrione + nicosulfuron                     | 2.32| 1.34| 1.28 | 10.11 ab| 296.89|
| atrazine + mesotrione + nicosulfuron          | 2.41| 1.37| 1.23 | 10.80 a| 281.21|
| Mean                                          | 2.37| 1.36| 1.27 | 9.56   | 277.34|
| CV (%)                                        | 3.60| 3.33| 14.90| 11.15  | 6.27  |

PH - plant height (m), EA - ear insertion height (m), PI - prolificacy index (plant ears⁻¹), YIELD (t ha⁻¹), GM - 1,000 grains mass (g).

* Means followed by the same letter in the column do not differ statistically from each other by the Tukey’s (1949) (p < 0.05). ns - not significant, means do not differ statistically from each other by the F-test (p < 0.05).

species. When the two herbicides were associated, the control obtained was 94, 92 and 96%. It was verified control of 43% for *Sorghum halepense* when only tembotrione was used and 39% for the application of atrazine isolated, but in the combination of herbicides this control was 73%. For *A. palmeri*, the two isolated or associated herbicides obtained controls above 92% (Stephenson IV et al., 2015). As in this work, the use of tembotrione and its association with atrazine did not reduce maize yield.

Several studies highlight the efficacy of glyphosate, in different associations, for weed control in maize, with control of different weeds around 90% (Patches et al., 2017; Chahal et al., 2018; Chahal & Jhala, 2018; Kaur & Jhala, 2018). This same control level was observed in this study for the application of atrazine + nicosulfuron, atrazine + tembotrione, mesotrione and nicosulfuron + atrazine + nicosulfuron + mesotrione without the use of glyphosate.

These results indicate that in certain situations effective weed management in maize is possible even without glyphosate. This herbicide is very important in different crops for weed control, but the characterization of alternative treatments is very important in the management and prevention of selection of glyphosate-resistant biotypes. As highlighted by several studies, management with alternative herbicides to glyphosate is necessary to assist in the management of herbicide resistance to weed resistance (Heap & Duke, 2018; Neve et al., 2018; Rosario-Lebron et al., 2019).

In addition, the associations help in effective control, mainly of monocotyledons, helping to maintain the maize yield, as observed in this study. Other studies also highlight the importance of using glyphosate alternative herbicides in maize, highlighting atrazine and/or nicosulfuron (Ganie et al., 2017; Chahal & Jhala, 2018; Galon et al., 2018).

CONCLUSIONS

The post-emergence (V4) application of atrazine, nicosulfuron, mesotrione and tembotrione, applied alone and associated was selective to the conventional maize hybrid 30F53.

The herbicides atrazine, nicosulfuron, mesotrione and tembotrione, at associations, were effective in the weed control, except the association atrazine + mesotrione.

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REFERENCES

Borém A, Galvão JCC & Pimentel MA (2015) Milho: do plantio à colheita. 1ª ed. Viçosa, Editora UFV. 351p.

Brown LR, Shropshire C & Sikkema PH (2016) Control of glyphosate-resistant Canada fleabane in corn with preplant herbicides. Canadian Journal of Plant Science, 96:932-934.

Burke IC, Thomas WE, Allen JR, Collins J & Wilcut JW (2008) A comparison of weed control in herbicide-resistant, herbicide-tolerant, and conventional corn. Weed Technology, 22:571-579.
Chahal PS & Jhala AJ (2018) Economics of management of photosystem II- and HPPD-inhibitor-resistant Palmer amaranth in corn. Agronomy Journal, 110:1905-1914.

Chahal PS, Ganie ZA & Jhala AJ (2018) Overlapping residual herbicides for control of photosystem (PS) II-and 4-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibitor-resistant Palmer amaranth (Amaranthus palmeri S. Watson) in glyphosate-resistant maize. Frontiers in Plant Science, 8:2231.

CONAB - Companhia Nacional de Abastecimento (2019) Acompanhamento da safra brasileira: Grãos: Safra 2018/19, quinto levantamento, fevereiro de 2019. Brasília, CONAB. 122p.

Correa MP & Alves PLCA (2009) Efficacy of herbicides applied in post emergence on conventional and transgenic soybean. Planta Daninha, 27:1035-1046.

Dan HA, Lemos Barroso AL, Braz GBP, Moraes Dan LG, Ferreira Filho WC, Menezes CCE & Azambuja US (2011) Seletividade do nicosulfuron e da mistura com atrazine na cultura do milho. Agrarian, 3:243-252.

Fancelli AL & Dourado Neto D (2000) Produção de Milho. Guaíba, Editora Agropecuária. 360p.

Ferreira DF (2011) Sisvar: a computer statistical analysis system. Ciência e Agrotecnologia, 35:1039-1042.

Galon L, David FA, Forte CT, Júnior FWR, Radunz AL, Kujawinski Heap I & Duke SO (2018) Overview of glyphosate resistant weeds. Pest Management Science, 74:1323-1331.

Heap I (2019) International survey of herbicide resistant weeds. Pest Management Science, 74:1040-1049.

Heap I (2019) International survey of herbicide resistant weeds. Available at: <http://www.weedscience.org>. Accessed on: August 12th, 2019.

Janak TW & Grichar WJ (2016) Weed control in corn (Zea mays L.) as influenced by preemergence herbicides. International Journal of Agronomy, 2016:01-09.

Janak TW & Grichar WJ (2016) Weed control in corn (Zea mays L.) as influenced by preemergence herbicides. International Journal of Agronomy, 2016:01-09.

Kaur S & Jhala AJ (2018) Control of glyphosate-resistant giant ragweed (Ambrosia trifida L.) with premix of iodosulfuron/ thiencarbazone applied alone or in tank mixtures in no-till corn (Zea mays L.). Canadian Journal of Plant Science, 98:908-917.

Neve P, Barney JN, Buckley Y, Cousens RD, Graham S, Jordan NR, Shaw J, Lawton Rauh A, Liebman M, Megaran MB, Schut M, Shaw J, Storkey J, Baraibar B, Baucom RS, Chalak M, Childs DZ, Christensen S, Eizenberg H, Fernández Quintanilla C, French K, Harsch M, Heijting S, Harrison L, Loddo D, Macel M, Maczey N, Mortensen D, Necajeva J, Peltzer DA, Recasens J, Renton M, Riemen M, Sønderskov M & Williams M (2018) Reviewing research priorities in weed ecology, evolution and management: a horizon scan. Weed Research, 58:250-258.

Oliveira Júnior RS (2011) Mecanismos de Ação dos Herbicidas. In: Oliveira Júnior RS, Constant J & Inoue MH (Ed.) Biologia e Manejo de Plantas Daninhas. Curitiba, Omnipax. p.141-192.

Oliveira Neto AM, Constantin J, Júnior RSO, Guerra N, Braz GBP, Vilela LMS, Botelho LVP & Ávila LA (2013) Sistemas de dessecação em áreas de trigo no inverno e atividade residual de herbicidas na soja. Revista Brasileira de Herbicidas, 12:14-22.

Patchen KM, Curran WS & Lingenfelter DD (2017) Effectiveness of herbicides for control of common pokeweed (Phytolacca americana) in corn and soybean. Weed Technology, 31:193-201.

Philippi E, Ternus RM, Cavalcante JÁ & Fraga AM (2016) Desempenho de herbicidas no controle de plantas daninhas em milho silagem. Revista Verde de Agroecologia e Desenvolvimento Sustentável, 11:01-06.

Pimentel-Gomes F & Garcia CH (2002) Estatística aplicada a experimentos agronômicos e florestais: exposição com exemplos e orientações para uso de aplicativos. Piracicaba, FEALQ. 309p.

Ramos AC, Constantin J, Oliveira Júnior RS, Guerra N, Alonso DG & Biffé DF (2010) Control of Euphorbia heterophylla and Ipomoea grandifolia using glyphosate isolated or in association with broadleaf herbicides. Planta Daninha, 28:621-629.

Riar DS, Norsworthy JK, Steckel LE, Stephenson DO, Eubank TW, Bond J & Scott RC (2013) Adoption of best management practices for herbicide-resistant weeds in midwestern United States cotton, rice, and soybean. Weed Technology, 27:788-797.

Rodrigues BN & Almeida FS (2018) Guia de herbicidas. 7th ed. Londrina, Editing authors. 764p.

Rosario-Lebron A, Leslie AW, Yurchak VL, Chen G & Hooks CR (2019) Can winter cover crop termination practices impact weed suppression, soil moisture, and yield in no-till soybean [Glycine max (L.) Merr.]? Crop Protection, 116:132-141.

Stephenson IV DO, Bond JA, Landry RL & Edwards HM (2015) Weed management in corn with postemergence applications of metribuzine or thiacarbzone: metribuzine. Weed Technology, 29:350-358.

Soltani N, Van Eerd LL, Vyn RJ, Shrophshire C & Sikkema PH (2010) Weed control, environmental impact and profitability with glyphosate tank mixes in glyphosate-tolerant corn. Canadian Journal of Plant Science, 90:125-129.

Tukey JW (1949) Comparing individual means in the analysis of variance. Biometrics, 5:99-114.

Velini ED, Osipe R & Gazziero DLP (1995) Procedimento para instalação, avaliação e análise de experimentos com herbicidas. Londrina, SBCPD. 42p.