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# Effectiveness of herbicides imazapic and amicarbazone sprayed on different amounts of sugarcane straw for the control of weeds[1]

## Eficácia dos herbicidas imazapic e amicarbazone aplicado em diferentes quantidades de palha de cana-de-açúcar para o controle de plantas daninhas

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**Abstract -** The straw left on the soil surface after the sugarcane mechanical harvest affects directly the weed infestation, due to, among others, the limitation of temperature variation on the seed bank, the formation of a physical barrier which enables weed emergence, and the possible allelopathic effect of the sugarcane straw. On the other hand, the straw also works as a barrier to the herbicide until it is leached into the soil. The objective of this study was to test the effect of herbicides amicarbazone and imazapic applied on different amounts of straw for the control of *Luffa aegyptiaca*, *Ipomoea hederifolia* and *Bidens pilosa*. Two herbicides - amicarbazone and imazapic were tested at three different rates: 1008 g a.i. $ha^{-1}$, 1260 g a.i. $ha^{-1}$ and 1512 g a.i. $ha^{-1}$ of amicarbazone, and 123.2 g a.i. $ha^{-1}$, 154 g a.i. $ha^{-1}$ and 184.8 g a.i. $ha^{-1}$ of imazapic, combined with the following amounts of straw: 6 t $ha^{-1}$, 8 t $ha^{-1}$, 10 t $ha^{-1}$ and 12 t $ha^{-1}$, for both herbicides. The effectiveness of the control was evaluated until 120 days after the date of application. For the species *Luffa aegyptiaca*, the herbicide imazapic provided an efficient control during the 120 days of evaluation. This species growth showed a positive correlation with the amount of straw on the soil surface. The herbicide amicarbazone effectively controlled *Luffa aegyptiaca* at all doses, even when associated with higher amounts of sugarcane straw, where this species had a greater development. For the species *Ipomoea hederifolia*, both herbicides amicarbazone and imazapic showed satisfying control at all doses during the first 120 days, showing no statistical differences between the factors studied. For the species *Bidens pilosa*, all three doses, associated with all four amounts of straw, for both herbicides, showed above 95% of control in all assessments, with no statistical differences between the treatments.

**Keywords:** *Saccharum* spp., mulch, *Bidens pilosa*, *Ipomoea hederifolia*, *Luffa aegyptiaca*

**Resumo:** A palha deixada pelos processos de colheita mecanizada da cana-de-açúcar afeta diretamente o estabelecimento de plantas daninhas, devido, dentre outros, à limitação da variação de temperatura sobre o banco de sementes, à formação de uma barreira física que dificulta a

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emergência das plantas daninhas e ao possível efeito alelopático da palha da cana-de-açúcar. Por outro lado, quando herbicidas são aplicados sobre a palha, esta se torna uma barreira até que o herbicida seja lixiviado até o solo atue nas plantas daninhas. O objetivo desse trabalho foi testar a ação dos herbicidas amicarbazone (Dinamic) e imazapic (Plateau) sobre diferentes quantidades de palha, para o controle de *Luffa aegyptiaca, Ipomoea Hederifolia e Bidens pilosa*. Os herbicidas foram aplicados nas seguintes doses: 1,8 kg $ha^{-1}$, 1,44 kg $ha^{-1}$ e 2,16 kg $ha^{-1}$ para amicarbazone e 0,220 kg $ha^{-1}$, 0,176 kg $ha^{-1}$ e 0,264 kg $ha^{-1}$ para imazapic, combinadas com as quantidades de palha equivalentes a 6 t $ha^{-1}$, 8 t $ha^{-1}$, 10 t $ha^{-1}$ e 12 t $ha^{-1}$, para ambos os herbicidas. A eficiência do controle foi avaliada por 120 dias, a partir do dia da aplicação. Para a espécie *Luffa aegyptiaca*, o herbicida imazapic controlou eficientemente essa espécie durante os 120 dias de condução do experimento. Esta espécie mostrou uma correlação positiva entre seu crescimento e desenvolvimento com a quantidade de palha que a cobriu. Entretanto, o herbicida amicarbazone controlou eficientemente esta espécie em todas as doses estudadas, mesmo as doses associadas com as quantias mais altas de palha, onde essa espécie teve maior desenvolvimento. Para a espécie *Ipomoea hederifolia,*ambos os herbicidas amicarbazone e imazapic mostraram controle satisfatório em todas as doses durante os 120 dias de condução do experimento, não mostrando diferença estatística entre os fatores estudados. Para a espécie *Bidens pilosa*, independente da quantidade de palha, todas as doses de ambos herbicidas mostraram controle satisfatório, acima de 95% em todas as avaliaões, não havendo diferenças estatísticas entre os tratamentos.

**Palavras-chave:** *Saccharum* spp., palhada, *Bidens pilosa, Ipomoea hederifolia*, *Luffa aegyptiaca*

## Introduction

The sugarcane harvest without burning its leaves is a common practice in most areas nowadays. In the sugarcane harvest, 5 to 20 tons of mulch per hectare is left on the soil surface. The amount of mulch left on the soil after harvest depends directly on the characteristics of the sugarcane variety, such as: ease of stem defoliation, growth habit, uniformity in height and size, productivity and development of the sugarcane (Manechini, 1997). The adoption of this harvest system has modified crop cultivation techniques. In the raw sugarcane harvest, larger spacing is used and the straw is deposited on the soil at the moment of the harvest. This technique influences the weed management(Velini & Negrissoli, 2000).

The layer of straw left above the soil works as a physical barrier to seedling emergence, changes the water balance, changes the amount and quality of light that reaches the soil, interferes decisively in the range of thermal variation of the soil, provides the release of allelopathic compounds and also increases the amount of organic matter in the soil, improving its biological activity.

When the herbicide is sprayed over the mulch, it is intercepted and becomes vulnerable to degradation caused by volatilization and photodecomposition until it is transposed to the soil (Locke & Bryson, 1997). At the moment the herbicide reaches the ground, the product becomes more persistent and better distributed in the soil, because of the channels formed by residues and soil organisms, and, mainly, because the degradation processes slow down (Jones et al., 1990; Sorenson et al., 1991). Some species of weeds like *Ipomoea grandifolia, Ipomoea quamoclit, Ipomoea nil, Merremia cissoides, Euphorbia heterophylla and Bidens pilosa* have become dominant in sugarcane crops because their germination are not inhibited by the quantities of sugarcane straw that are normally found in the field (Velini & Negrissoli, 2000; Correa & Durigan, 2004).

Ipomoea is the genre that most stands out in the Convolvulaceae family, with 600 to 700 species spread worldwide. Among the species of the genre, there are many weeds that are important in annual and perennial crops, especially *Ipomoea hederifolia, Ipomoea quamoclit, Ipomoea purpurea, Ipomoea nil* and *Ipomoea triloba* (Kissman & Groth, 1999). According to Kissmann & Groth (1999), *I. hederifolia* has a vast and significant occurrence in Brazil, standing as the most frequent species in agricultural production areas. Currently, this species has been critical in some plantations like sugarcane, corn, soybeans and other crops, becoming a major concern for Brazilian growers. The species *Luffa aegyptiaca*, which belongs to the Cucurbitaceae family, is an annual herbaceous plant, provided with axillary tendrils, with climbing growth habit. According to Siqueira (2009), each plant can reach 9.96 kg of dry weight and, considering that the crop is established by up to 625 plants per hectare, it is a species with high dry weight and seed production.

The species *Bidens pilosa*, has great adaptation to agricultural environments, in part due to its abundant seed production, added to its dormancy mechanism. According to Lorenzi (2008), a single plant can produce 3000 to 6000 seeds, most of which germinate readily after maturation, thus ensuring three to four generations per year. Dormancy mechanisms allow seeds that are buried deep in the soil for three, even five years, to present around 80% of germination (Lorenzi, 2008). This study aimed to evaluate the effectiveness of the herbicides amicarbazone and imazapic, applied on different amounts of straw for the control of *Bidens pilosa, Ipomoea hederifolia* and *Luffa aegyptiaca*.

## Material and Methods

The experiment was conducted in a greenhouse at the Department of Crop Science of "Escola Superior de Agricultura 'Luiz de Queiroz'", Piracicaba-SP, from September 2011 to January 2012.

The *Ipomoea hederifolia*, *Bidens pilosa* and *Luffa aegyptiaca seeds* were sown in 4 liters pots filled with clay soil. After that, amounts of straw equivalent to 0, 6, 8, 10 and 12 t $ha^{-1}$ were added to the pots, simulating a real situation in the field. The straw was acquired at field soon after the harvest of the sugarcane, variety SP81-3250.

Two herbicides - amicarbazone and imazapic - were tested at three different rates: 1008 g a.i. $ha^{-1}$, 1260 g a.i. $ha^{-1}$ and 1512 g a.i. $ha^{-1}$ of amicarbazone, and 123.2 g a.i. $ha^{-1}$, 154 g a.i. $ha^{-1}$ and 184.8 g a.i. $ha^{-1}$ of imazapic. These three different rates for each product represent, respectively, 20% less the standard dose, the standard dose (recommended by the manufacturer), and 20% higher the standard dose. The products were applied in pre-emergence, immediately after sowing the weeds and covering the pots with straw. The experimental design was completely randomized blocks with five replications, with treatments in a factorial arrangement. The factors consisted of herbicides and sugarcane straw amounts, and the levels were three herbicides and five amounts of straw to control two weeds using two herbicides, as well as an additional treatment control (without straw and without herbicide).

For all applications, a $CO_2$ pressured sprayer equipped with two nozzles of the fan type XR110.02, spaced 0.50m apart, under constant pressure of 2.0 kgf $cm^{-2}$ was used. These conditions of application provided the equivalent of a 200 L $ha^{-1}$ spray. The percentage of control was evaluated at 15, 30, 60, 90 and 120 days after application (DAA), using a scale where 0% corresponds to no injury, and 100% corresponds to the death of all the plants, according to the Brazilian Society of Weed Science (SBCPD, 1995) recommendations. Soon after the last evaluation (120 DAA),

the remaining plants were collected to be dried in a forced circulation oven at 60 °C for 72 hours, in order to measure the dry matter. All data were initially submitted to the F test (analysis of variance) and then were compared by applying the Tukey test at 5% of significance level.

## Results and Discussion

Table 1 shows the dry mass of *Luffa aegyptiaca* evaluated at 120 DAA of amicarbazone. These data presented a positive correlation with the amount of straw and the dry weight when no herbicide was applied. Therefore, the higher the amount of straw left on the soil, the greater is the dry mass of this species, emphasizing the need to effectively control *Luffa aegyptiaca* from the beginning of its development in a field covered with sugarcane straw. Table 1 also shows that this species have presented high susceptibility to the herbicide amicarbazone, since that all doses of the herbicide effectively controlled this weed when there was no straw on the soil. Table 2 shows that there was a significant interaction of the factors "dose x amount of straw", “dose” and “straw amount”. The doses of 1008 was more efficient combined with the amount of 6, 8 and 12 t $ha^{-1}$ and the rate 1512 g a.i. $ha^{-1}$ of amicarbazone was more effective at controlling the weed when combined with 10 and 12 t $ha^{-1}$ of straw, whereas 1260 g a.i. $ha^{-1}$ of amicarbazone presented the same efficiency of control independently of the amount of straw on the soil (Table 1).

**Table 1:** Dry mass (g) of *Luffa aegyptiaca* in different concentrations of amicarbazone and in different amounts of straw, 120 days after application. ESALQ-USP. 2011/2012.

| **Dry mass (g) - *Luffa aegyptiaca* - 120 DAA*** | | | | | |
|---|---|---|---|---|---|
| **Straw Amount (t $ha^{-1}$)** | **Amicarbazone (g a.i $ha^{-1}$)** | | | | |
| | **0** | **1008** | **1260** | **1512** | **MSD** |
| **0** | 2.95 cA | 0 cB | 0 bB | 0 cB | 2.38 |
| **6** | 5.31 bcA | 0.87 abcB | 0.56 abB | 0.83 bB | 3.63 |
| **8** | 19.46 abcA | 1.90 aB | 1.11 aB | 1.64 aB | 14.35 |
| **10** | 20.34 abA | 0.63 bcB | 1.38 aB | 0.77 bB | 5.6 |
| **12** | 30.88 aA | 1.38 abB | 0.81 abB | 1.10 abB | 10.82 |
| **MSD**** | 17.18 | 1.05 | 0.87 | 0.75 | - |

*Averages followed by the same lower case on column or same capital letter on the row, are not statiscally different by the Tukey’s test, at 5% of significance. **Minimum Significant Difference.

**Table 2:** Analysis of variance of amicarbazone sprayed on *Luffa aegyptiaca*.

| **Source** | **DF** | **Mean Square** | **Pr>F** |
|---|---|---|---|
| Dose | 3 | 1391.55 | <0.0001* |
| Straw Amount | 4 | 206.10 | <0.0001* |
| Dose*Straw Amount | 12 | 156.77 | <0.0001* |
| Block | 4 | 29.18 | $0.0246^{ns}$ |

"*" and "ns" indicate, respectively, significant and non-significant statistical difference, at p=0,05.

Likewise the herbicide amicarbazone, imazapic showed to be very effective in controlling the species *Luffa aegyptiaca*, which can be observed in the weed dry mass evaluation at 120 DAA (Table 3). For imazapic, a significant interaction was observed between the factors and a significant difference was observed for the factor “amount of straw” and “dose”. Moreover, results obtained by Santos et al (2009) showed that the sugarcane straw did not interfere in the transposition of imazapic, even in amount of 20 t $ha^{-1}$ of sugarcane straw. These results are similar with the present experiment, since all of rates worked

efficiently, regardless the amount of straw left on the soil.

**Table 3:** Dry weight (g) of *Luffa aegyptiaca* in different concentrations of imazapic and in different amounts of straw, 120 days after application. ESALQ-USP. 2011/2012.

| Dry mass (g) - *Luffa aegyptiaca* - 120 DAA* | | | | | |
|---|---|---|---|---|---|
| **Straw Amount (t ha$^{-1}$)** | **Imazapic (g a.i ha$^{-1}$)** | | | | |
| | **0** | **123.2** | **154** | **184.8** | **MSD** |
| **0** | 2.95 cA | 0.00 aB | 0.00 aB | 0.00 bB | 2.38 |
| **6** | 5.31 bcA | 0.07 aB | 0.00 aB | 0.10 abB | 3.58 |
| **8** | 19.46 abcA | 1.18 aB | 0.23 aB | 0.13 abB | 14.51 |
| **10** | 20.34 abA | 2.76 aB | 0.41 aB | 0.86 aB | 7.83 |
| **12** | 30.88 aA | 0.34 aB | 0.42 aB | 0.28 abB | 10.73 |
| **MSD**** | 17.18 | 5.05 | 0.65 | 0.85 | - |

*Averages followed by the same lower case on column or same capital letter on the row, are not statiscally different by the Tukey's test, at 5% of significance. **Minimum Significant Difference.

**Table 4:** Analysis of variance of imazapic sprayed on *Luffa aegyptiaca*.

| Source | DF | Mean Square | Pr>F |
|---|---|---|---|
| Dose | 3 | 1472.06 | <0.0001* |
| Straw Amount | 4 | 194.57 | <0.0001* |
| Dose*Straw Amount | 12 | 161.16 | <0.0001* |
| Block | 4 | 33.69 | 0.2104$^{ns}$ |

"*" and "ns" indicate, respectively, significant and non-significant statistical difference, at p=0,05.

The weed *Ipomoea hederifolia* was effectively controlled by all doses of amicarbazone, as shown in Table 5, which presents the species dry mass at 120 DAA. Table 6 shows that a significant difference was observed for the factor "dose" isolated. Statistically, all doses of the herbicide were equally efficient, except the dose 0 g a.i ha$^{-1}$ (Table 5). Cavenaghi et al. (2006) evaluated the dynamics of the herbicide amicarbazone applied over different quantities of sugarcane straw, in different time intervals and precipitation intensity after herbicide application. The results showed that the amount of amicarbazone leached by water varied according to the amount of straw (5, 10, 15 and 20 t ha$^{-1}$). In the 5 t ha$^{-1}$ of straw treatment, 2.5 mm of water carried down 40% of the amicarbazone applied, while in the 10, 15 and 20 tons of straw treatments, the same water amount leached 33, 25 and 25% of the amicarbazone applied, respectively. In other words, quantities of straw above or equal to 5 t ha$^{-1}$ showed significant herbicide interception.

**Table 5:** Dry weight (g) of *Ipomoea hederifolia* in different concentrations of amicarbazone and in different amounts of straw, 120 days after the application. ESALQ-USP. 2011/2012.

| Dry mass (g) - *Ipomoea hederifolia* - 120 DAA* | |
|---|---|
| **Amicarbazone (g a.i ha$^{-1}$)** | |
| **0** | 0.75 A |
| **1008** | 0.05 B |
| **1260** | 0.09 B |
| **1512** | 0.03 B |
| **MSD**** | 0.36 |

*Averages followed by the same letter on column are not statiscally different by the Tukey's test, at 5% of significance. ** Minimum Significant Difference.

Bringing Cavenaghi's results to this experiment, the amount of sugarcane straw did not interfere in the control of *Ipomoea hederifolia*, so it is possible to conclude that even only 33% of the herbicide leached through the straw amount of 10 t $ha^{-1}$ was enough to control totally this species. Therefore, this species showed to be very susceptible to this herbicide in any amount of sugarcane straw, in the way that this experiment was carried out.

**Table 6:** Analysis of variance of amicarbazone sprayed on *Ipomoea hederifolia*.

| Source | DF | Mean Square | Pr>F |
|---|---|---|---|
| Dose | 3 | 3.00 | <0.0001* |
| Straw Amount | 4 | 0.11 | $0.74^{ns}$ |
| Dose*Straw Amount | 12 | 0.12 | $0.90^{ns}$ |
| Block | 4 | 0.22 | $0.44^{ns}$ |

"*" and "ns" indicate, respectively, significant and non-significant statistical difference, at p=0,05.

Comparing *Ipomoea hederifolia* dry mass at 120 DAA of imazapic, all doses of the herbicide effectively controlled the weed, as shown in Table 7, indicating its high susceptibility to imazapic, even when exposed to doses lower than the recommended one. In the same way to amicarbazone, the herbicide imazapic showed no significant difference between the three different doses evaluated to control the weed, except the dose 0 g a.i $ha^{-1}$. No significant difference was observed on the factor "straw amount", neither between the two factors (Table 8). A significant difference was observed only for the factor "dose" (Table 8).

As reported by Monqueiro (2010), comparing imazapic with sulfentrazone, it was observed that they both showed similar residual activity until 45 DAA, however, from 60 to 150 DAA, imazapic had lesser soil residual. On the other hand, Rodrigues et al. (2000) observed that the herbicide imazaquin, an imidazolinone such as imazapic, was leached through the straw by a 20 mm precipitation, whereas, prior to the irrigation, more than 90% of the product applied remained on the straw surface. They also observed that the carriage of the products could be explained by their high solubility in water.

**Table 7:** Dry mass (g) of *Ipomoea hederifolia* in different concentrations of imazapic in different amounts of straw, 120 days after the application. ESALQ-USP. 2011/2012.

| Dry mass (g) - *Ipomoea hederifolia* - 120 DAA* | |
|---|---|
| **Imazapic (g a.i $ha^{-1}$)** | |
| **0** | 0.75 A |
| **123.2** | 0.07 B |
| **154** | 0.21 B |
| **184.8** | 0.11 B |
| **MSD**** | 0.39 |

*Averages followed by the same letter on column are not statiscally different by the Tukey's test, at 5% of significance. ** Minimum Significant Difference.

Azania et al. (2002) stated that, with the soil covered with up to 15 t $ha^{-1}$ of straw, the emergence of *I. grandifolia*, *I. hederifolia* and *I. nil* was not significantly altered. A reduction in the populations of these weeds occurred only in the presence of 20 t $ha^{-1}$ of straw, showing that, for *I. hederifolia*, the straw did not directly affect the herbicides control, but worked as a physical/chemical barrier to be transposed by herbicide. In this context, these studies corroborate to the results obtained in this experiment. Probably, the herbicide was leached to the soil in all the four quantities of straw, since that the trial was carried out in a greenhouse, daily irrigated. In contradiction with these results,

Hernandez (2001) concluded that a layer of sugarcane (SP79 -1011) straw in an amount equivalent to 12 t $ha^{-1}$ reduced the action of imazapic to control the species *Ipomoea grandifolia*, but does not interfere with the action of this herbicide, neither isolated nor mixed with pendimethalin, in the control of *Panicum maximum, Brachiaria plantaginea, Digitaria horizontalis, Cyperus rotundus* and *Amaranthus viridis.*

**Table 8:** Analysis of variance of imazapic sprayed on *Ipomoea hederifolia*.

| Source | DF | Mean Square | Pr>F |
|---|---|---|---|
| Dose | 3 | 2.49 | <0.0001* |
| Straw Amount | 4 | 0.19 | 0.5983$^{ns}$ |
| Dose*Straw Amount | 12 | 0.11 | 0.9572$^{ns}$ |
| Block | 4 | 0.46 | 0.1766$^{ns}$ |

"*" and "ns" indicate, respectively, significant and non-significant statistical difference, at p=0,05.

The species *Bidens pilosa* was highly susceptible to both herbicides, in all combinations of the amounts of straw, performing over 95% of control in all treatments and experimental units. In a study conducted by Carbonari et al (2010) it was observed that, between the species *Bidens pilosa, Ipomoea quamoclit, Merremia cissoides, Euphorbia heterophylla, Ipomoea nil, Ipomoea grandifolia, Brachiaria decumbens and Panicum maximum*, the species *Bidens pilosa* was the most susceptible to amicarbazone.

## Conclusions

The species *Luffa aegyptiaca* is sensitive to both herbicides imazapic and amicarbazone, even 120 days after treatment.

The species *Luffa aegyptiaca* had its growth stimulated by the sugarcane straw, in the way that this experiment was carried out.

The sugarcane straw does not decrease the efficacy of both imazapic and amicarbazone to control *Luffa aegyptiaca, Ipomoea hederifolia* and *Bidens pilosa*.

The species *Ipomoea hederifolia* was highly sensitive to both herbicides amicarbazone and imazapic, with long residual activity up to 120 days after application, even in a daily irrigated greenhouse.

The species *Bidens pilosa* was highly sensitive to both herbicides combined with all the amounts of sugarcane straw, in the conditions that this experiment was carried out.

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