PLANTA DANINHA
SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS
<http://www.sbcpd.org>
ISSN 0100-8358 (print)
1806-9681 (online)

Article

Association of Mechanical and Chemical Methods for Cotton Stalk Destruction

Associação de Métodos Mecânicos e Químicos Visando a Destruição de Soqueiras de Algodoeiro

FRANCISCHINI, A.C.[1]
CONSTANTIN, J.[2]
MATTE, W.D.[2]*
OLIVEIRA JR., R.S.[2]
RIOS, F.A.[2]
MACHADO, F.G.[2]

ABSTRACT - The destruction of cotton stalks after harvesting is a prophylactic measure aimed at reducing the population of insects and disease inoculants that may remain in the crop residues and remaining cotton plants. The objective of this work was to evaluate integrated methods of management of the cotton stalks, combining mechanical and chemical control, to promote the eradication of cotton stalks. A 7x5 factorial experiment was installed where seven different methods of mechanical control of cotton stalk and five herbicide treatments were tested. The percentage of control (visual scale of 0 to 100%) and the number of plants regrowth per meter were evaluated at 14, 28 and 50 days after herbicide application treatment. At the end of the experiment, the size of the regrowth was evaluated at 50 days. The methods of management with mowing associated with an application on the stalk followed by another application to plant regrowth's and mowing with two sequential applications in the sprouts, for the herbicidal treatments 2,4-D + glyphosate in association with [imazapic + imazapyr]) or saflufenacil, promoted the highest control rates of cotton stalks. Aiming at the effectiveness and speed of control, the management with the application of the treatment with 2,4-D + glyphosate + saflufenacil on the stalk, after mowing, associated to another application in the regrowth, provided 100% control at 14 days after the last application and totally inhibited the regrowth of the stalks, and was considered the most effective in the destruction of cotton stalks.

Keywords: *Gossypium hirsutum*, herbicides, integrated management, host-free period.

RESUMO - A destruição de soqueiras do algodoeiro após a colheita é uma medida profilática que visa reduzir a população de insetos-praga e de inóculos de doenças que podem permanecer alojados nos restos culturais e plantas de algodoeiro remanescentes. O objetivo deste trabalho foi avaliar métodos integrados de manejo das soqueiras, conciliando controle mecânico e químico, que promovam a erradicação de soqueiras do algodoeiro. Dessa maneira, foi instalado experimento fatorial 7x5, em que foram testados sete diferentes métodos de manejo da soqueira do algodoeiro e cinco tratamentos herbicidas. Avaliou-se a porcentagem de controle e o número de plantas rebrotadas por metro aos 14, 28 e 50 dias após a aplicação dos herbicidas. Ainda, ao final do experimento foi avaliado o tamanho de rebrote, aos 50 dias. Os métodos de manejo com roçada associada a uma aplicação no toco seguida por outra aplicação no rebrote e roçada com duas aplicações sequenciais nos rebrotes, para os tratamentos herbicidas 2,4-D + glyphosate em associação com [imazapic + imazapyr]) ou saflufenacil, promoveram as maiores taxas de controle das soqueiras do algodoeiro. Visando a eficácia e a velocidade de controle, o manejo com aplicação do tratamento 2,4-D + glyphosate

*** Corresponding author:**
<willianmatte@hotmail.com>

Received: July 10, 2018
Approved: November 21, 2018

Planta Daninha 2019; v37:e019207486

[1] Sumitomo Chemical SCLA, São Paulo-SP, Brasil; [2] Universidade Estadual de Maringá, Maringá-PR, Brasil.

Doi: 10.1590/S0100-83582019370100141

+ saflufenacil no toco, logo após a roçada, associado à outra aplicação no rebrote, proporcionou 100% de controle aos 14 dias após a última aplicação e inibiu totalmente o rebrote das soqueiras, sendo considerado o mais eficaz na destruição das soqueiras do algodoeiro.

Palavras-chave: *Gossypium hirsutum*, herbicidas, manejo integrado, vazio sanitário.

INTRODUCTION

The cultivation of the herbaceous cotton (*Gossypium hirsutum* L. var. *latifolium Hutch*) is highlighted in the Brazilian agricultural scenario. Cotton growing is one of the activities of major economic interest worldwide, and its products are used in the textile, oil chemical, food, among others (Freire, 2015).

As it is a perennial species, the permanence of the plants in the field after cotton harvesting causes severe problems, since the sprouted plants and crop residues constitute sources of food for insects and host of important pathogens (Ribeiro et al., 2015). The elimination of cotton crop residues has become a mandatory practice in Brazil and is supported by federal law number 8,589, and it is an obligation of cotton producers to eliminate the stalks soon after the harvest, given the host-free period established for each state (Almeida et al., 2008).

The practice of post-harvesting destruction of cotton stalks aims to interrupt the biological pest cycle, reducing the insect population (*Anthonomus grandis*, *Helicoverpa armigera*) in quiescence, which have the ability to survive during the off-season (Ribeiro et al., 2015). The practice is also valid for inoculants of major diseases such as boll rot, angular leaf spot, Fusarium leaf spot, and for management of nematodes that compromise cotton yield and quality (Silva et al., 2006). In addition to indirect effects, improperly managed plants can cause interference on crops sown in succession, which gets worse when crops have the same herbicide resistance technology (Minozzi et al., 2017).

Chemical destruction through herbicides is one of the main options to control the cotton stalks, especially due to the improved operational efficiency. The conventional cotton stalks (non-GMO herbicide resistance) can be controlled with glyphosate and 2,4-D (Yang et al., 2006; Greenberg et al., 2007; Ribeiro et al., 2015). However, the chemical destruction of glyphosate-resistant cotton cultivars has been limited due to the ineffectiveness of this herbicide for these transgenic cultivars.

Some studies indicate that two sequential applications of 2,4-D, one after harvest and the second after regrowth, are an option in destroying cotton stalks (Yang et al., 2011). The exclusive use of the chemical method through the application of herbicides does not always result in effective control of the stalks, since after harvest the leaf area of cotton plants is minimal and plants are usually under water stress, situations that make herbicide absorption very limited. A single application of glyphosate or 2,4-D usually does not control the sprouts of cotton stalks, requiring sequential applications (Corrêa and Gomes, 2005; Silva et al., 2015; Ferreira et al., 2018).

Cotton plants at advanced stages of development may have higher epicuticular waxes, constituting a physicochemical barrier to herbicide penetration by leaves. After cotton harvesting, mechanical control with cotton stalk mowing aims to stimulate the regrowth of plants. The emitted leaves will have high photosynthetic activity and limited wax deposition on the cuticle, which facilitates the absorption and translocation of applied herbicides (Silva et al., 2007).

The association of mechanical control with herbicide use represents an important management option, as it may contribute to both speed and control effectiveness. The method of mechanical management with cotton stalk mowing associated with two sequential applications of 1,000 g a.e. ha^{-1} of 2,4-D on regrowth, according to Ferreira et al. (2018), is an effective option in the destruction of glyphosate-resistant cotton stalks. So far, these practices have not been sufficiently evaluated. Thus, the objective of this work was to evaluate the effectiveness of the integration between mechanical and chemical management methods aiming at the control of cotton stalks and to point out the management that promotes the best and fastest control.

MATERIAL AND METHODS

The experiment was conducted at Santo Antônio de Posse - SP (22°36'13.5" S, 46°59'05.7" W, at 658 m altitude) from August to December 2013. The climate of the region is classified as Cfa, characterized by uncommon hot summers and frosts, with a tendency of rainfall concentration in the summer months, but with no defined dry season. The average annual temperature is 19.3 °C. Rainfall data and average monthly temperatures during the experiment are shown in Figure 1.

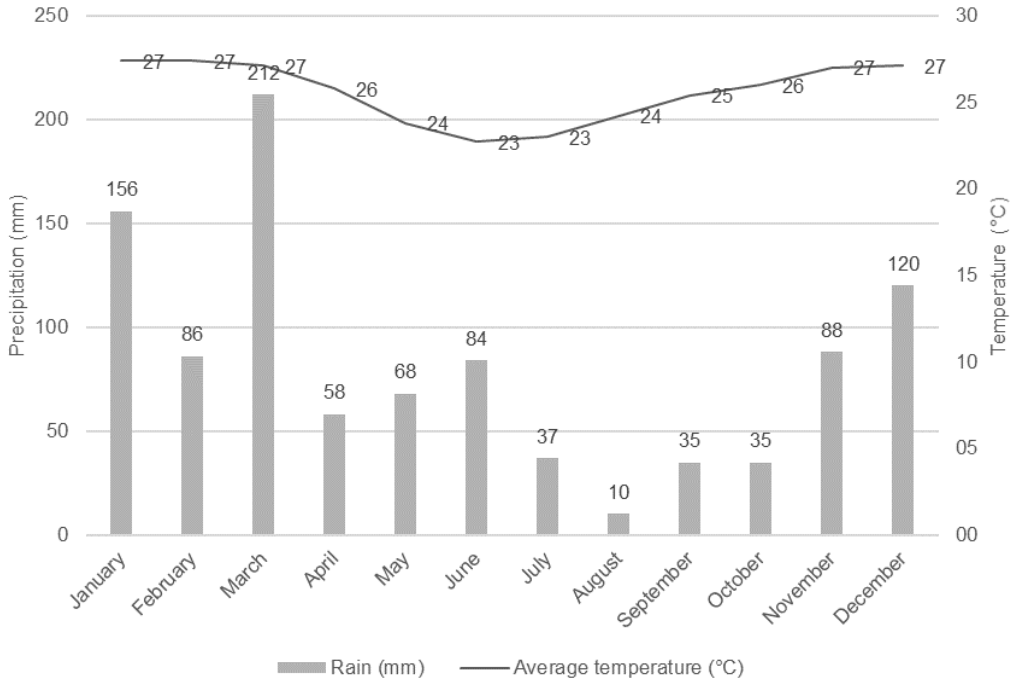

Figure 1 - Rainfall and average maximum temperature data during the experimental period. Santo Antônio de Posse(SP), 2013.

Soil samples were collected at a depth of 0 to 20 cm and subjected to analysis to determine chemical and particle size characteristics. The analysis results showed the following characteristics: pH in $CaCl_2$ of 5.8; 22 $mmol_c$ dm^{-3} of H + Al^{+3}; 43.3 mg dm^{-3} of P; 54 $mmol_c$ dm^{-3} of Ca^{+2}; 26.5 $mmol_c$ Mg^{+2} dm^{-3}; 2 $mmol_c$ dm^{-3} of K^+; 24 g dm^{-3} O.M.; and clay texture (14% coarse sand, 38% fine sand, 6% silt and 42% clay).

The soil was prepared by a one-time plowing and two harrowing operations. Cotton sowing was performed with the cultivar Fiber Max 966 LL® (resistant to ammonium glufosinate herbicide) on 2/28/2013, by using six seeds per meter and spacing of 80 cm between seeding lines, aiming to obtain a population of 75 thousand plants ha^{-1}. During the cotton cycle, hand weeding was carried out to control weeds.

At the end of the crop development cycle, a 7x5 factorial design was installed in a randomized block design with four replications. The first factor evaluated consisted of the use of different management methods for the destruction of cotton stalks (Table 1), and the second was composed of herbicide treatments (Table 2). The experimental units had a total area of 16 m^2, being 5 m long and 3.2 m wide (four seeding lines). The useful area of the plots was composed of two central lines for 2 m each, totaling 3.2 m^2.

The herbicide application dates associated with the management methods are presented in Table 3. On July 17, 2013, ten days before the cotton harvest, 0.5 L c.p. ha^{-1} of the Dropp Ultra SC® defoliant (thiazuron 120 g L^{-1} + diuron 60 g L^{-1}) + 0.5% Dash® v v^{-1}) was applied in total area. Cotton was manually harvested on 7/27/2013.

All applications were made using a 1.5 bar constant pressure CO_2 pressurized backpack sprayer equipped with five XR 110.02 tips spaced 0.5 m apart and positioned 0.5 m from the target surface, providing a volume of 150 L ha^{-1}. All treatments were applied using lateral

Table 1 **-** Description of the management methods used in the destruction of the cotton stalks. Santo Antônio de Posse (SP), 2013

Method	Description
A	After harvesting, the cotton plants were mowed at 37 cm height and immediately after the herbicide treatment was applied to the stump. The plants were expected to have at least 12 leaves regrowth, which occurred after 45 days, and again the cotton plants were mowed at a height of 23 cm, immediately after the herbicide treatment was applied.
B	Pre-harvest herbicide treatment application 14 days before harvesting cotton. After harvesting, the cotton plants were mowed at a height of 29-32 cm and herbicide treatment was applied immediately after mowing.
C	Pre-harvest herbicide treatment application 14 days before harvesting cotton. After harvesting, the cotton plants were mowed at a height of 29-32 cm. When the plants had regrowth of at least 12 leaves, which occurred after 45 days, the herbicide treatment was applied again.
D	Pre-harvest herbicide treatment application 14 days before harvesting cotton. After harvest, when the plants had regrowth of at least 12 leaves, which occurred after 45 days, the herbicide treatment was applied again.
E	After harvesting, the cotton plants were mowed at a height of 29-32 cm and, when the plants had regrowth of at least 12 leaves, which occurred after 45 days, herbicide treatment was applied.
F	After harvesting, the cotton plants were mowed at a height of 29-32 cm and immediately after the herbicide treatment was applied to the stump. The plants were expected to have regrowth of at least 12 leaves, which occurred after 45 days, and again the herbicide treatment was applied.
G	After harvest, the cotton plants were mowed at a height of 29-32 cm and, after the plants had regrowth of at least 12 leaves, which occurred after 45 days, herbicide treatment was applied. The plants were again expected to have at least 12 leaves regrowth and a second application of the herbicide treatment was performed.

Table 2 **-** Treatments with herbicides applied aiming at the control of cotton stalks. Santo Antônio de Posse (SP), 2013

Active ingredient	Dose (g a.i.. or a.e. ha^{-1})
2,4-D + glyphosate	1,340 + 720
2,4-D + glyphosate + saflufenacil	1,340 + 720 + 105
2,4-D + glyphosate + [imazapic + imazapyr]	1,340 + 720 + [26.25 + 78.75]
Glyphosate + chlorimuron-ethyl	720 + 20
Check	-

All herbicide treatments had the addition of Dash adjuvant 0.5% v v^{-1}.

Table 3 **-** Dates of herbicide applications associated to management methods. Santo Antônio de Posse (SP), 2013

Herbicide treatment		Application dates					
		Application pre-harvest	Application after mowing (stump)	Application 35 days after mowing	Application 48 days after mowing	Application 52 days after mowing	Application 94 days after mowing
		07/13/2013	08/03/2013	08/17/2013	09/20/2013	09/24/2013	11/05/2013
1	2,4-D + glyphosate	B, C e D	A, B e F	D	C, E, F e G	A	G
2	2,4-D + glyphosate + saflufenacil	B, C e D	A, B e F	D	C, E, F e G	A	G
3	2,4-D + glyphosate + [imazapic + imazapyr]	B, C e D	A, B e F	D	C, E, F e G	A	G
4	Glyphosate + chlorimuron-ethyl	B, C e D	A, B e F	D	C, E, F e G	A	G
5	Check	-	-	-	-	-	-

protection between plots to avoid drift effect. The mowing of the plants was performed with a tractor rotary mower, according to what was indicated in each treatment.

Evaluations regarding the percentage of control (0 to 100% visual scale) were performed at 14, 28 and 50 days after the last application of each treatment (DAT), where 0% represents no control and 100% total control of cotton plants (SBCPD, 1995). On the same evaluation dates, the sprouted plants were counted per meter, using the average of two 1 m lines within the useful area. The regrowth size (average regrowth length of four plants per plot) was evaluated at 50 DAT.

In the present work, the term “management” was used to define the combination of one herbicide treatment with mechanical control. Thus, to be considered as effective, one

management strategy should meet three requirements: percentage of control of cotton stalks ≥95%; number of sprouted plants per useful plot equal to or less than one plant in the plot useful area and the regrowth size of less than 3 cm the end of the experiment.

The data from the response variables were subjected to analysis of variance, and the means compared by Student's t-test at 5% probability.

RESULTS AND DISCUSSION

There was a significant interaction between herbicide application and mechanical methods for all response variables. The results of the percentage of visual control of cotton plants at 14, 28 and 50 DAT are presented in Table 4.

The treatments with herbicide application in combination with the mechanical control that stood out in the control of cotton stalks and promoted satisfactory control (≥95%) up to 50 DAT were those that had in their composition the herbicide 2,4-D. This can be explained by the high sensitivity of cotton to 2,4-D, which is affected even by very low doses of this herbicide (Constantin et al., 2007).

The initial action of 2,4-D involves nucleic acid metabolism and cell wall plasticity. Synthetic auxin influences plant development, causing changes at the cellular level that affect turgor and elongation as well as cell division and differentiation (Kelley and Riechers, 2007). In lower doses of this hormonal herbicide, there is an abnormal increase in these metabolic processes, leading to the synthesis of auxins and gibberellins, which will promote accelerated and disordered cell division and elongation in younger parts of the plant, activating its metabolism and leading to exhaustion (Oliveira Jr., 2011).

As auxin rates in plants increase, they cause growth abnormalities in sensitive dicotyledons. The effects begin by inhibiting cell division and growth, usually in the meristematic regions, leading to symptoms ranging from epinasty and stem twisting, stem and root thickening, and finally chlorosis and necrosis (Kelley and Riechers, 2007). This process can be potentiated as

Table 4 **-** Visual control (%) of cotton stalks at 14, 28 e 50 days after treatment (DAT). Santo Antônio de Posse (SP), 2013

Herbicide treatment		Control % at 14 DAT						
		Method A	Method B	Method C	Method D	Method E	Method F	Method G
1	2,4-D + glyphosate	57.75 Ae	90.25 Bbc	95.75 Ba	91.25 Bb	88.25 Bc	73.00 Bd	94.50 Aa
2	2,4-D + glyphosate + saflufenacil	48.25 Bd	95.75 Abc	98.75 Aa	97.75 Aab	94.25 Ac	100.00 Aa	94.50 Ac
3	2,4-D + glyphosate + [imazapic + imazapyr]	58.00 Ae	92.50 Bb	96.50 ABa	90.25 Bbc	89.50 Bc	63.50 Cd	91.50 Bbc
4	Glyphosate + chlorimuron-ethyl	6.25 Ce	41.25 Cb	21.00 Cd	33.00 Cc	48.00 Ca	33.25 Dc	39.50 Cb
5	Check	0.00 Da	0.00 Da	0.00 Da	0.00 Da	0.00 Da	0.00 Ea	0.00 Da
CV (%) = 3.08								
		Control % at 28 DAT						
1	2,4-D + glyphosate	84.75 Bd	95.00 ABb	91.00 Bc	98.00 Aa	72.75 Be	93.25 Cbc	98.50 Aa
2	2,4-D + glyphosate + saflufenacil	84.75 Bd	93.50 Bc	96.00 Abc	98.25 Aab	77.50 Ae	100.0 Aa	97.00 Ab
3	2,4-D + glyphosate + [imazapic + imazapyr]	89.00 Ab	97.25 Aa	97.50 Aa	96.25 Aa	80.00 Ac	96.50 Ba	96.00 Aa
4	Glyphosate + chlorimuron-ethyl	48.50 Cb	41.25 Cc	27.50 Ce	31.75 Bd	29.25 Cde	47.25 Db	54.75 Ba
5	Check	0.00 Da	0.00 Da	0.00 Da	0.00 Ca	0.00 Da	0.00 Ea	0.00 Ca
CV (%) = 2.90								
		Control % at 50 DAT						
1	2,4-D + glyphosate	82.75 Bd	79.75 Ae	93.25 Bc	93.75 Bbc	39.50 Cf	96.25 Bab	98.75 Aa
2	2,4-D + glyphosate + saflufenacil	85.00 Bc	69.25 Bd	98.50 Aa	94.00 Bb	48.75 Ae	100.00 Aa	98.75 Aa
3	2,4-D + glyphosate + [imazapic + imazapyr]	93.00 Ab	80.25 Ac	96.25 Aa	96.75 Aa	44.00 Bd	97.50 ABa	97.50 Aa
4	Glyphosate + chlorimuron-ethyl	27.00 Ccd	33.00 Cb	25.25 Cde	38.00 Ca	24.25 De	38.25 Ca	29.00 Bc
5	Check	0.00 Da	0.00 Da	0.00 Da	0.00 Da	0.00 Ea	0.00 Da	0.00 Ca
CV (%) = 3.31								

Average in the same column followed by the same capital letter and in the line followed by lower case don't differ from each other at 5% by the Student test.

the application is performed in plants that sprouted after mowing, which have few reserves, paralyzing its growth and causing the death of meristematic regions and, consequently, of plants.

The mixture 2,4-D + glyphosate + saflufenacil (T2) provided the highest percentages of control of cotton stalks under methods C, E, F and G (98.5, 48.75, 100 and 98.75%, respectively) at 50 DAT. For the methods A, B and D the herbicide treatment that presented the highest percentage of control of the cotton stalks was the triple mixture of 2,4-D + glyphosate + [imazapic + imazapyr] (T3), with 93%, 80.25% and 96.75% control, respectively, at 50 TED. Until the last evaluation date, the combination of glyphosate + chlorimuron-ethyl showed inferior control when compared to the other treatments, being superior only to the control without herbicide application.

Herbicide treatments containing 2,4-D mixed with glyphosate provided superior control when compared to treatment without 2,4-D. This may be related to the fact that glyphosate in combination with 2,4-D has a synergistic effect, which has already been observed in the control of several weeds (Takano et al., 2013; Osipe et al., 2017). Ferreira et al. (2018) found that two sequential applications of 2,4-D, each with 1,000 g e.a. ha^{-1}, resulted in improved control of glyphosate-resistant cotton stalks, reaching 95%. The control of 100% of cotton stalks is generally very difficult to obtain with herbicides alone (Silva et al., 2015).

Among the treatments with herbicide application was the 2,4-D+glyphosate+ saflufenacil associated to the method F (with a mowing followed by the first application on the stump and the second after regrowth), promoted 100% control of cotton stalks from 14 to 50 DAT. Saflufenacil is a protoporphyrinogen oxidase (PROTOX) inhibitor that can be absorbed by the roots, stems and leaves of the plant; after application, the tissues exposed to light die quickly (Oliveira Jr., 2011). As this herbicide has limited translocation in plants, its contact effect may have aided the control of lateral buds present in the stem, reducing the regrowth rate. Thus, when associated with systemic herbicides (2,4-D and glyphosate), fast and prolonged control of the cotton stalks was observed.

Another herbicide that, when added to the 2,4-D + glyphosate mixture, increased the control levels of cotton plants, but in a slower way, was the formulated mixture [imazapic + imazapyr], except for the mechanical control E. This can be explained by the systemic effect of herbicides. Imazapic and imazapyr are absorbed via both leaf and soil, slowly translocating via apoplast and symplast (Oliveira Jr., 2011). Thus, it is believed that the residual effect on the soil of these products in the aforementioned treatment has collaborated in order to promote a prolonged control, being beneficial for systems of destruction of cotton stalks, especially if there is moisture in the soil.

One single herbicide application after mowing was not sufficient to promote satisfactory control of cotton stalks (mechanical control E). The methods that received two applications promoted control rates up to two times higher than the method that received only one application. Corrêa and Gomes (2005) observed that low doses of glyphosate (480 g a.e. ha^{-1}) or 2,4-D (806 g a.e. ha^{-1}) do not control the sprouts of the herbaceous cotton stalks, requiring sequential applications.

Mechanical control B, in which the second application was performed immediately after mowing, was the only mechanical method where there were at least two applications of herbicides mixed with 2,4-D and that did not present, at 50 DAT, control of cotton stalks greater than 95%; in this method there was no application after regrowth. This result demonstrates that the application of the herbicide after regrowth is fundamental in the success of the control of cotton stalks. Also, the presence of leaves at the time of application is essential for the absorption and translocation of the herbicide in the plant.

The management methods also presented a significant difference in the treatments that received herbicide application. The adoption of methods C, D, F and G in association with the herbicide treatments that contained 2,4-D in their composition presented visual control superior to the minimum level established as satisfactory in this study (≥95%).

The practice of isolated mowing was not determinant for the increase of control of the cotton stalks in the present experiment, being the mechanical and chemical management methods employed considered the determining factors for the success in the destruction of the cotton stalks. The method without mowing (D) associated with the herbicide treatment 2,4-D + glyphosate

+ saflufenacil provided a higher rate of desiccation of the cotton stalks, however, the control levels decrease over the evaluation period. If mowing is not done, the plant does not waste its reserves for regrowth and can recover more quickly from the effect caused by herbicides, and the plant has more growth points than a mowed plant.

Applying herbicides right after mowing can amplify absorption, promoting greater and faster penetration of herbicides into the vascular system of plants. However, it may show a loss of effectiveness over time, especially when there is no application after regrowth, as observed in method B, in which the association between 2,4-D + glyphosate + saflufenacil showed control of cotton stalks above 95% already at 14 DAT; however, it lost efficiency in subsequent evaluations (28 and 50 DAT). Comparing method E with A, F and G, it is noted that two applications after a single mowing (29-32 cm height) were fundamental for the effective control of cotton stalks.

The management methods that had the mowed plants (A, B, C, E, F and G) presented control percentages similar to the method in which there was no mowing (D). However, over time, there is a reduction in control due to the number of sprouted cotton plants in mechanical method D. Another important factor in the desiccation of cotton stalks may have been the leaf area available on the plant. In the case of mechanical control G, it is possible to note that when the herbicide is applied after regrowth, with sufficient leaf area to promote absorption, the probability of success is higher, ensuring control levels above 95% at 28 TED for most treatments.

Over time after herbicide application, it can be seen that due to inefficient translocation, specific characteristics of certain herbicides or the cotton morphophysiology itself, herbicide absorption, penetration and translocation can be enhanced or impaired. Thus, herbicides should be applied when the regrowth has sufficient leaf area to absorb the applied herbicide. In management methods C, F and G, for example, the application of herbicide treatment after regrowth with at least 12 leaves was crucial to obtain satisfactory levels of control.

The treatments that provided the lowest numbers of sprouted cotton plants up to 50 DAT were those in which 2,4-D was added, except for method E, and their maximum efficiency was expressed in management methods F and G (Table 5). The application of 2,4-D + glyphosate +

Table 5 - Number of cotton plants sprouted at 14, 28 and 50 days after treatment (DAT). Santo Antônio de Posse (SP), 2013

Herbicide Treatment		Number of sprouted plants at 14 DAT						
		Method A	Method B	Method C	Method D	Method E	Method F	Method G
1	2,4-D + glyphosate	8.00 Aa	2.25 Be	2.00 Be	3.25 Bd	4.25 Bc	6.50 Bb	2.00 Ce
2	2,4-D + glyphosate + saflufenacil	8.00 Aa	2.25 Bb	0.75 Cc	1.00 Cc	2.25 Db	0.00 Cd	2.25 BCb
3	2,4-D + glyphosate + [imazapic + imazapyr]	8.00 Aa	2.75 Bc	1.50 Bd	3.25 Bc	3.00 Cc	8.00 Aa	2.75 Bc
4	Glyphosate + chlorimuron-ethyl	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa
5	Check	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa
CV (%) = 9.85								
		Number of sprouted plants at 28 DAT						
1	2,4-D + glyphosate	3.50 Bb	2.50 Bc	3.00 Bbc	1.00 Bd	7.75 Aa	2.50 Bc	1.25 Cd
2	2,4-D + glyphosate + saflufenacil	3.50 Bb	2.25 CBcd	3.00 Bbc	1.00 Be	6.25 Ba	0.00 Cf	1.75 BCde
3	2,4-D + glyphosate + [imazapic + imazapyr]	3.75 Bb	1.50 Cc	1.50 Cc	1.75 Bc	5.75 Ba	1.75 Bc	2.25 Bc
4	Glyphosate + chlorimuron-ethyl	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	7.50 Aa
5	Check	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa
CV (%) = 11.25								
		Number of sprouted plants at 50 DAT						
1	2,4-D + glyphosate	3.75 Bc	4.75 Cb	2.50 Bd	2.50 Bd	8.00 Aa	1.50 Be	1.00 Be
2	2,4-D + glyphosate + saflufenacil	2.50 Cc	5.75 Bb	1.00 Cd	2.25 Bc	8.00 Aa	0.00 Ce	1.00 Bd
3	2,4-D + glyphosate + [imazapic + imazapyr]	2.75 Cc	4.25 Cb	2.25 Bcd	1.75 Bde	8.00 Aa	1.00 Be	1.50 Bde
4	Glyphosate + chlorimuron-ethyl	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa
5	Check	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa	8.00 Aa
CV (%) = 10.88								

Average in the same column followed by the same capital letter and in the line followed by lower case don't differ from each other at 5% by the Student test.

saflufenacil differed from the other treatments within the mechanical control F and did not present, until 50 TED, any plant regrowth, demonstrating efficiency in the control of cotton stalks. The application of glyphosate + chlorimuron-ethyl did not reduce the number of sprouted plants, regardless of mechanical control or evaluation date, being equal to the control without herbicide application.

The treatments with herbicide application, when mixed with 2,4-D, presented the smallest regrowth sizes, except for the method with only one herbicide application (E), evidencing that the single application of herbicide treatment, even over enough area to promote absorption, was ineffective in controlling cotton regrowth (Table 6). The method with a mowing followed by the first application on the stump and the second after regrowth (F) provided the smallest regrowth sizes; however, it only differed from method E, which was composed of only one herbicidal application 45 days after mowing. The largest regrowth sizes were observed in the treatment without herbicide application and glyphosate + chlorimuron-ethyl application, regardless of the mechanical control adopted.

Thus, considering all the evaluated variables, the managements that stood out in the control of the cotton stalks and that promoted satisfactory control (≥95%), number of plants regrowth in the useful plot equal to or less than one plant and regrowth size smaller than 3 cm were 2,4-D + glyphosate associated with method G, 2,4-D + glyphosate + [imazapic + imazapyr] associated with method F and 2,4-D + glyphosate + saflufenacil associated with management methods C, F and G, which are considered the most efficient in the destruction of the cotton stalks. Table 7 shows the color scale of herbicide treatments and management methods for their effectiveness in destroying cotton stalks according to the pre-established criteria.

Table 6 - Size of the cotton stalks sprouts at 50 days after treatment (DAT). Santo Antônio de Posse (SP), 2013

Herbicide treatment		Size of the cotton stalks sprouts (cm) at 50 DAT						
		Method A	Method B	Method C	Method D	Method E	Method F	Method G
1	2,4-D + glyphosate	3.00 Aa	5.22 Aa	3.52 Aa	2.60 Aa	44.25 Bb	1.87 Aa	1.05 Aa
2	2,4-D + glyphosate + saflufenacil	4.07 Aa	5.77 Ab	2.10 Aa	3.92 Aa	39.75 Bc	0.00 Aa	1.25 Aa
3	2,4-D + glyphosate + [imazapic + imazapyr]	1.82 Aa	4.92 Aa	2.70 Aa	3.05 Aa	30.00 Ab	1.65 Aa	1.75 Aa
4	Glyphosate + chlorimuron-ethyl	49.25 Ba	59.00 Bbc	62.25 Bcd	52.50 Ba	65.50 Cd	53.00 Bab	59.50 Bcd
5	Check	54.00 Ba	111.00 Cb	111.00 Cb	208.50 Cc	111.00 Db	111.00 Cb	111.00 Cb
CV (%) = 11.48								

Average in the same column followed by the same capital letter and in the line followed by lower case don't differ from each other at 5% by the Student test.

Table 7 - Efficiency of the management methods used in the destruction of cotton stalks. Santo Antônio de Posse (SP), 2013

Herbicide treatment		Method A	Method B	Method C	Method D	Method E	Method F	Method G
1	2,4-D + glyphosate	(3)	(3)	(2)	(2)	(3)	(2)	(1)
2	2,4-D + glyphosate + saflufenacil	(3)	(3)	(1)	(2)	(3)	(1)	(1)
3	2,4-D + glyphosate + [imazapic + imazapyr]	(2)	(3)	(2)	(2)	(3)	(1)	(2)
4	Glyphosate + chlorimuron-ethyl	(3)	(3)	(3)	(3)	(3)	(3)	(3)
5	Check	(3)	(3)	(3)	(3)	(3)	(3)	(3)

(1) Green: effective control; (2) Yellow: intermediate control; (3) Red: Inefficient control. Criteria for considering effective control: control ≥95%, number of regrowth plants in useful plot equal to or less than one plant, and regrowth size less than 3 cm.

Aiming at the control speed of cotton stalks, mainly due to the mandatory host-free period determined by law, the management with one mowing followed by the first application on the stump and the second after regrowth (F) provided 100% control of the cotton stalks at 14 TED when in association with the herbicide treatment 2,4-D + glyphosate + saflufenacil, being this combination of mechanical control and chemical control the most suitable for the destruction of the cotton stalks under the conditions in which the experiment was conducted.

REFERENCES

Almeida RP, Silva CAD, Ramalho FS. Manejo integrado de pragas do algodão. In: Beltrão NEM, Azevedo DMP, editores. O agronegócio do algodão no Brasil. 2ª.ed. Brasília, DF: Embrapa Informação Tecnológica; Campina Grande: Embrapa Algodão; 2008. p.1034-98.

Constantin J, Oliveira Júnior RS, Fagliari JR, Pagliari PH, Arantes JGZ, Cavalieri SD, et al. Efeito de subdoses de 2,4-D na produtividade do algodão e suscetibilidade da cultura em função de seu estádio de desenvolvimento. Eng Agríc. 2007;27:24-9.

Corrêa JC, Gomes AC. Manejo das soqueiras do algodoeiro herbáceo em plantio direto com rotação de culturas nos Cerrados. Rev Ceres. 2005;52:739-49.

Ferreira ACDB, Bogiani JC, Sofiatti V, Silva Filho JLl. Chemical control of stalk regrowth in glyphosate-resistant transgenic cotton. Rev Bras Eng Agríc Amb. 2018;22(8):530-4.

Freire EC. Algodão no cerrado do Brasil. Brasília, DF: Gráfica e Editora Positiva; 2015. 956p.

Greenberg SM, Sparks AN Jr, Norman JW Jr, Coleman R, Bradford JM, Yang C, et al. Chemical cotton stalk destruction for maintenance of host-free periods for the control of overwintering boll weevil in tropical and subtropical climates. Pest Manage Sci. 2007;63(4):372-80.

Kelley KB, Riechers DE. Recent developments in auxin biology and new opportunities for auxinic herbicide research. Pest Biochem Physiol. 2007;89(1):1-11.

Minozzi GB, Christoffoleti PJ, Monquero PA, Zobiole LHS, Pereira GR, et al. Controle em pré semeadura da cultura de soja de algodão voluntário tolerante ao glyphosate e amônio glufosinate e de *Eleusine indica*. Rev Bras Herb. 2017;16(3):183-91.

Oliveira Jr RS. Mecanismos de ação de herbicidas. In: Oliveira Jr RS, Constantin J, Inoue MH. Biologia e manejo de plantas daninhas. Curitiba: Omnipax; 2011. p.141-92.

Osipe JB, Oliveira Jr RS, Constantin J, Takano HK, Biffe DF. Spectrum of weed control with 2,4-D and dicamba herbicides associated to glyphosate or not. Planta Daninha. 2017;35:1-12.

Ribeiro EB, Castellani MA, Silva CAD, Melo TL, Silva GS, Vale WS, Santos AS. Methods de destruição de restos de cultura do algodoeiro e sobrevivência do bicudo. Pesq Agropec Bras. 2015;50(11):993-8.

Sociedade Brasileira da Ciência das Plantas Daninhas – SBCPD. Procedimentos para instalação, avaliação e análise de experimentos com herbicidas. Londrina: 1995. 42p.

Silva AA, Ferreira FA, Ferreira LR. Herbicidas: classificação e mecanismo de ação. In: Silva AA, Silva JF, editores. Tópicos em manejo de plantas daninhas. Viçosa, MG: Universidade Federal de Viçosa: 2007. p.83-148.

Silva AV, Chiavegato EJ, Carvalho LH, Kubiak DM. Crescimento e desenvolvimento do algodoeiro em diferentes configurações de semeadura. Bragantia. 2006;65(3):407-11.

Silva ORRF, Lamas FM, Ferreira ACB, Sofiatti V, Mederios JCM. Destruição dos restos culturais do algodoeiro. In: Freire EC, editor. Algodão no cerrado do Brasil. 3ª.ed. Brasília, DF: Gráfica e Editora Positiva; 2015. p.135-50.

Takano HK, Oliveira Jr RS, Constantin J, Biffe DF, Franchini LHM, Braz GBP et al. Efeito da adição do 2,4-D ao glyphosate para o controle de espécies de plantas daninhas de difícil controle. Rev Bras Herb. 2013;12(1):1-13.

Yang C, Greenberg SM, Everitt JH, Fernandez CJ. Assessing cotton defoliation, regrowth control and root rot infection using remote sensing technology. Int J Agric Biol Eng. 2011;4(4):1-11.

Yang C, Greenberg SM, Everitt JH, Norman Jr JW. Assessing cotton stalk destruction with herbicides using remote sensing technology. J Cotton Sci. 2006;10:136-45.