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DEPOSITION OF DIQUAT WITH DIFFERENT SPRAY TIPS, EFFICIENCY ON COMMON WATER HYACINTH, AND EFFECT ON WATER QUALITY

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Abstract
Eichhornia crassipes, known as common water hyacinth, has a high growth rate and produces large amounts of biomass when there are imbalances in water bodies, making it one of the worst aquatic weeds in the world. A study was carried out under small water reservoir field conditions to evaluate the herbicide diquat (960 g ha^{-1}) in controlling this species, at the adult stage development. Four spray tips (AI 11002VS, XR 11002VS and, TXVK-8 with spray volume of 200 L ha^{-1} and XR 11003VS with 400 L ha^{-1}) were tested. Spraying was performed using a CO_2-pressurized sprayer under constant pressure attached to a boat. Plant control was visually evaluated at 1, 3, 7, 11, 14, 21, 29, 60, 87, and 98 days after herbicide application and dry matter accumulation was determined at the end of the experimental period, as well as the spray solution deposition in the application area and water physical and chemical quality. The herbicide diquat was efficient in controlling *E. crassipes* plants at the dose applied and in development stage of the studied plants, regardless of the type of spray tip at the end of the evaluations. At the beginning of evaluations, the spray tip XR 11002VS was the least effectivity in controlling water hyacinth plants. Spray solution losses were high in all tips tested for control of *E. crassipes* plants, and the spray tips AI 11002VS and XR 11003VS provided the lowest losses during spraying. No water physical or chemical characteristics were negatively affected by diquat application.

Keywords: *Eichhornia crassipes*. Herbicide. Reward. Spray Technology. Water plant.

1. Introduction

Aquatic weed management programs must address a wide range of scientific, operational, environmental, economic, and sociological factors to achieve desired results. Aquatic weed control can be performed using mechanical, chemical, biological, and physical methods. The method or set of methods to be adopted is determined by the type of plants, uses of water, available resources, and legislation (Hussner et al. 2017).

Herbicides are important components of aquatic weed control programs, as they represent a fast, inexpensive, and efficient method of controlling them. However, herbicides require knowledge to be used safely and effectively. One of the herbicides used in various countries to control aquatic plants is diquat, indicated for management of aquatic vegetation in tanks, lakes, reservoirs, rivers, and drainage and irrigation channels (Wersal and Madsen 2012; Gichuki et al. 2012; Mudge and Netherland 2014). This herbicide is effective for the control of several species such as *Pistia stratiotes* L., *Salvinia auriculata* Aubl., *Egeria densa* Planch., *Egeria najas* Planch., and *Eichhornia crassipes* (Mart.) Solms (Cardoso et al. 2003; Martins et al.

2005; Marchi et al. 2009; Costa et al. 2011; Souza et al. 2011; Martins et al. 2011; Mudge and Netherland 2015), many of this works carried out in water tank conditions.

However, some of these studies reported unsatisfactory controls, which may be related to plant development stage at the time of herbicide application and the applied dose. In addition, the ineffectiveness may also be due to the lack of proper contact between the spray solution and plants or the application technology, which is linked to environmental conditions at the time of spraying (Martins et al. 2002; Costa et al. 2011; Pitelli et al. 2011). In this sense, the type of spray tip used for spraying (flat fan or hollow cone spray tip) may influence the amount of sprayed spray solution deposits on plants and thus their control, as observed in *S. auriculata* plants in association with *E. crassipes* (Marchi et al. 2009) or *P. stratiotes* (Marchi et al. 2011).

Regarding the size of *E. crassipes* plants during spraying, Pitelli et al. (2011) worked with plants 10 to 15 cm high and obtained 99% control when using diquat at a dose of 400 g ha^{-1}. Costa et al. (2011) used plants between 25 and 30 cm in height and observed 94.8% control with the use of the same dose. However, Martins et al. (2002), also working with plants 10 to 15 cm high and diquat at a dose of 480 g ha^{-1}, obtained 100% control of plants. In another study with plants between 40 and 50 cm in height and using diquat at a dose of 960 g ha^{-1}, Martins et al. (2011) did not obtain total control of the plants but reported 97.7% control at 28 days after herbicide application.

A relevant aspect in the management of aquatic plants is water quality after the application of an herbicide regarding physical, chemical, and residue aspects of the applied product. The decomposition of controlled plants may influence the chemical oxygen demand and water turbidity and their nutrient content (Domingos et al. 2011). Possible herbicide residues in the water depend on several factors such as dose, application technology, water turbidity, clay type, organic matter content, and target shape. Under Brazilian conditions, Botucatu/SP, Negrisoli et al. (2002) found a half-life between 18 and 28 days for diquat when applied directly to water when working with *E. densa* and *E. najas* plants immersed in water tanks. It should be noted that diquat herbicide has as its mechanism of action the inhibition of photosystem I, where it functions as an electron acceptor, and when it gains an electron, it is reduced and quickly transfers the electron to molecular oxygen, forming the superoxide anion that is highly reactive and damaging to cells.

Although there are searches that evaluate herbicide efficiency, little information can be found regarding application technology in aquatic environments. Thus, this study aimed to evaluate the spray solution deposition and the efficiency of the herbicide diquat applied using different spray tips to control *E. crassipes* under field small water body conditions, as well as its effect on water quality.

2. Material and Methods

The experiment was carried out in a systematized floodplain located in Botucatu-SP that was initially intended for rice cultivation. The geographical coordinates of the area are 22k 0766927 and UTM 7474362. The total floodplain area had 6,151.71 m^2, with an average depth of 0.4 m, and consisted of a sequence of three earth dikes oriented following the terrain slope. The first earth dike (1,666.08 m^2) had *E. crassipes* plants (10 bands of 1.0 × 20 m) as a control for comparing the effects of diquat on plants. The second dike (2,323.56 m^2) had only water used as a control for procedures of water quality assessment. The third earth dike (2,162.07 m^2) also had *E. crassipes* plants (10 bands of 1.0 × 20 m) in which each band was divided into two 10-m plots (totaling 20 plots) and received the application of the herbicide diquat. All plots were bounded with ropes to keep common water hyacinth plants within the enclosed area. Common water hyacinth plants were acclimatized within their earth dikes for ten days before herbicide application. *E. crassipes* plants were at full vegetative development and occupied the entire area intended for growth, with plants varying from 30 to 35cm in height. All plots had a similar infestation level, with an average of 51 plants/m^2. Plants of *Azolla* sp. were in the water as it was an area of rice production. Visual details of the earth dikes before the application are shown in Figures 1A, B, C, and D.

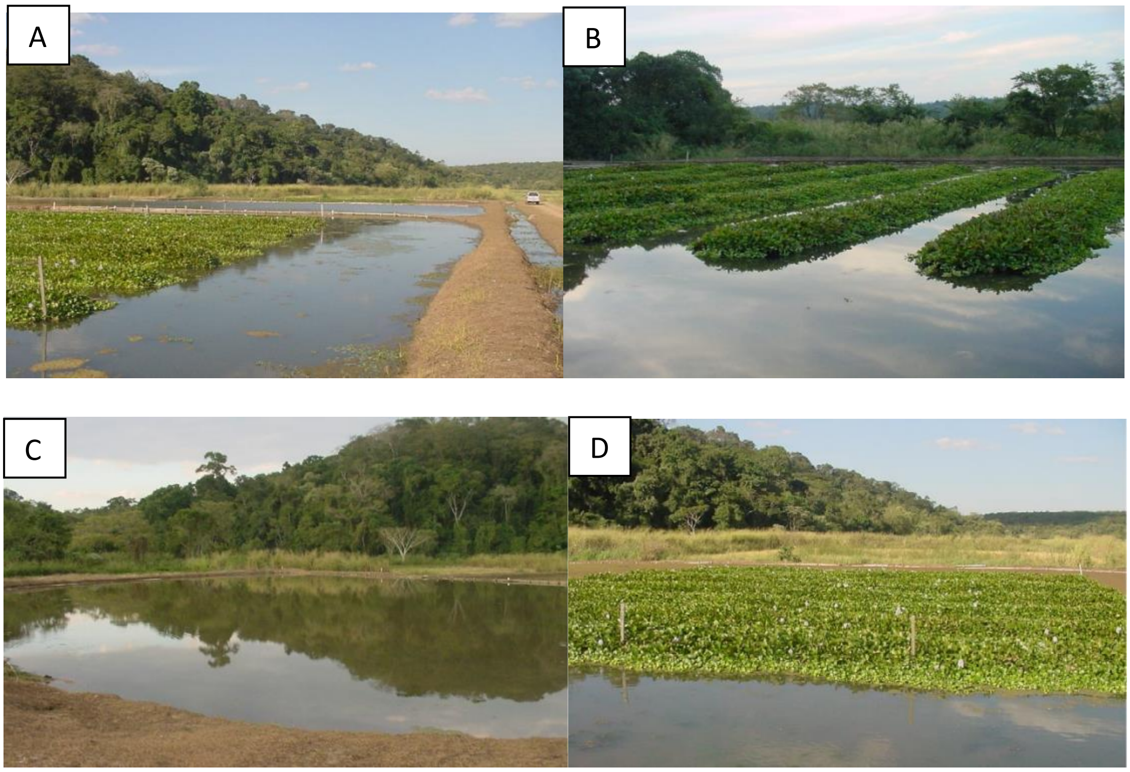

Figure 1. A – Overview of the earth dike used in the study; B – specific view of the earth dike used as a control; C – specific view of the earth dike used for water quality control; D – specific view of the earth dike used for diquat application.

The herbicide diquat was applied at a dose of 960 g a.i. ha^{-1} (Reward®) for the control of *E. crassipes* plants. Four spray tips were tested: three flat fan spray tips (XR 11002VS, XR 11003VS, and AI 11002VS) and one hollow cone spray tip (TXVK-8) and, the spacing between tips was 0.5m. The experiment had five replications. The environmental conditions of each application are shown in Table 1.

Table 1. Spray tips, spray solution volume, and environmental conditions in summer when applying the herbicide diquat.

Spray Tips[1]	Volume (L ha^{-1})	Temperature (°C)	Relative humidity (%)	Windy Speed km h^{-1}	Pressure KPa
1. XR 11002VS	200	27.9	52	2.4	359
2. XR 11003VS	400	30.5	40	2.6	359
3. TXVK-8	200	30.1	42	2.8	537
4. AI 11002VS	200	29.8	39	2.4	173

[1]Teejet®

We opted to test a treatment with a larger spray volume (400 L ha^{-1}), with the XR 11003VS tip, as this type of flat jet tip is among the most used for the application of herbicides and because it is the diquat a contact herbicide and thus a greater volume of spray could increase the control of plants. It cannot be the XR 11002VS tip, as it would have to increase the working pressure and as a negative consequence would be the formation of a larger number of small drops with consequent elevation of the drift, generating spray volumes losses.

An application system with spray boom, spray tips, CO_2 cylinder, and spray solution tank (Figure 2A and B) was coupled to an aluminum boat, which was pulled with ropes attached to the opposite bank of the earth dike, allowing adjusting its movement and speed manually, as needed. The spraying speed was 1m s^{-1}.

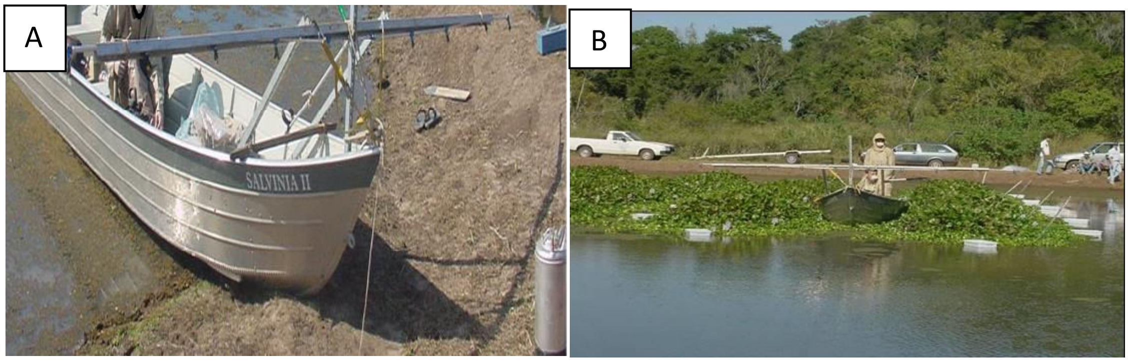

Figure 2. A – Application boat with the spray boom; B – Earth dike showing diquat application with spray solution collection trays positioned along the plot.

Control of common water hyacinth plants provided by diquat was visually evaluated the phytotoxicity at 1, 3, 7, 11, 14, 21, 29, 60, 87, and 98 days after herbicide application (DAA) by assigning percentage scores, where zero consisted of no control and 100 plant death, according to the grade scale proposed by SBCPD (1995). The effects of the action of the herbicide diquat were compared to control plants located in the first earth dike. The dry matter of plants floating in the plots (1 m^2) and the control were determined at the last control evaluation at 98 days after application.

Spray solution deposition and, consequently, the drift generated by the technology used in the experimental area (different spray tips) was evaluated using the herbicide diquat itself. Eight collectors (plastic trays) containing water (100 mL) were placed on Styrofoam plates floating on the water surface, six on the sides and one on each end of the plot (Figure 2B). The liquid from trays was placed in collectors after spraying and taken to the laboratory for the determination of diquat concentrations and the percentage of spray drift.

The diquat concentration in the earth dike water was quantified at 1, 2, 6, and 12 hours and 1, 2, 3, 4, 7, 14, 21, 28, 60, and 90 days after herbicide application. The determination of diquat concentrations was performed using a Cintra 40 UV-visible spectrophotometer at 308 nm wavelength, 5 nm light bandpass, and 5 cm optical path. Reading was repeated four times for each sample, after which the mean was determined (Hodgeson et al. 1992). The concentration of the herbicide diquat followed the following curve: herbicide concentration (ppm) = 0.7418 + 50.95391 × A, where A is the absorbance reading with r^2 = 0.9595648.

Water physical characteristics like water temperature, dissolved oxygen content, pH, turbidity, electrical conductivity, soluble solids, suspended solids, total solids, and chemical oxygen demand (COD) were analyzed in the three earth dikes (control with common water hyacinth plants, only water, and diquat application on common water hyacinth plants) at 0 (application time), 3, 5, 7, 11, 21, 29, 60, and 90 days after herbicide application. Water entry into earth dikes was interrupted after herbicide application, and the system was closed during the study period. Total precipitation of 182.2 mm was observed during the 90 days of the study.

The data of the percentage of control and dry matter of common water hyacinth plants were subjected to analysis of variance by the F-test and means of treatments were compared by the t-test at 5% probability.

3. Results and Discussion

The herbicide diquat provided toxic effects on common water hyacinth plants with the use of four different spray tips at 1 DAA. The spray tip XR 11003VS was statistically superior to the others, but with an unsatisfactory control (38%). The tips TXVK-8 and XR 11003VS provided controls of 89 and 88.7% at 3 DAA, respectively, which was statistically superior to the controls provided by other spray tips. The spray tip XR 11002VS was the least effective at the same time to control of common water hyacinth plants, with 62% control (Table 2).

Table 2. Effect of the herbicide diquat (960 g ha^{-1}) applied with different spray tips on the percentage of control of *Eichhornia crassipes* plants.

Treat.	L ha^{-1}	Days After Application								
		1	3	7	11	14	29	60	87	98
1. XR 11002VS	200	31.2^{b}	62.0^{c}	60.2^{c}	66.6^{c}	81.6^{b}	82.9^{c}	96.5^{b}	98.7^{b}	100.0
2. XR 11003VS	400	38.0^{a}	88.7^{a}	88.7^{a}	89.6^{a}	93.6^{a}	94.5^{b}	99.9^{a}	100.0^{a}	100.0
3. TXVK-8	200	31.3^{b}	89.0^{a}	89.0^{a}	87.7^{a}	92.4^{a}	95.8^{b}	99.9^{a}	100.0^{a}	100.0
4. AI 11002VS	200	22.70^{c}	80.7^{b}	80.7^{b}	80.9^{b}	93.5^{a}	97.8^{a}	99.9^{a}	100.0^{a}	100.0
5. control	-	-	-	-	-	-	-		-	-
F treat.	-	96.6**	79.2**	42.6**	70.2**	82.9**	196.9**	17.3**	98.8**	-
CV (%)	-	11.4	3.6	1.6	3.2	1.4	1.0	0.8	0.1	-
LSD	-	5.5	3.8	1.99	3.96	1.96	1.47	1.26	0.15	-

Treat. = Treatment; **Significant at 1% probability. Means followed by the same letter in the column do not differ statistically from each other by the *t* test (P>0.05).

Only the spray tip XR 11002VS presented a control considered by Kuva et al. (2016) as insufficient (60.2%) at 7 DAA. Also, the spray tips XR 11003VS (88.7%), TXVK-8 (89%) and AI 110.02VS (80.7%) provided control levels above 80% still at 7 DAA, similarly to the evaluation performed at 11 DAA (Table 2). These results corroborate those of Martins et al. (2011), who worked with the same dose of diquat, plant size, and spray tip AI 11002VS under reservoir conditions and found 83.7% control of common water hyacinth at 7 DAA. Costa et al. (2011) worked with plants with a height between 10–15cm and diquat at a dose of 400 g ha^{-1} and found 97% control at 10 DAA using the spray tip XR 11002VS. However, Souza et al. (2011) reported 100% control of common water hyacinth plants at 12 DAA using the spray tip XR 11002VS and a diquat dose of 600 g ha^{-1}. The best control found in these studies may be related to the fact that smaller plants provide fewer problem with 'umbrella' effect from spraying than lager plants, making droplet deposition more uniform on the leaves of smaller plants.

The control level provided by the different spray tips was increased at 14 DAA. In this case, the spray tip XR 11002VS reached a good control only in this period (81.6%), but still statistically lower than those found with the other spray tips, which varied from 92.4 to 93.6% (Table 2). In this same period, Cardoso et al. (2002) used spray tips Teejet XR 11002VS, a dose of 480 g ha^{-1}, and spray solution consumption of 193 L ha^{-1} and found 100% control of common water hyacinth plants. Pitelli et al. (2011) worked with the same spray tip, a volume of 200 L ha^{-1}, and diquat dose of 400 g ha^{-1} and obtained 96.5% control of common water hyacinth when the herbicide was applied at the stage of 10 to 15 cm plant height. This better control recorded in these studies may be related to the stage of plant development at the time of diquat application, which was between 10 and 15 cm high when compared to the stage of 30–35 cm of the studied plants. Thus, the stage of development of common water hyacinth is as important as the diquat dose.

The evaluation performed at 29 DAA showed little evolution in the control of common water hyacinth plants for all spray tips. In this sense, the spray tip AI 11002VS stood out, being superior to the others, with 97.8% control, while XR 11002VS provided the lowest control, with a control value of 82.9% during the same period (Table 2). Martins et al. (2002) also worked with the spray tip XR 11002VS at the same diquat dose and application volume of 180 L ha^{-1} and found 100% control of common water hyacinth plants, but the application stage was 10–15 cm, showing the importance of the stage to control this species.

The evaluation carried out at 60 DAA showed a marked increase in control level provided by all spray tips, with the spray tip XR 11002VS (96.5%) still inferior to the others, which reached controls of the order of 99%. All spray tips showed increases in the control, reaching 100% at 87 DAA, except the spray tip XR 11002VS, which reached 98.7% control, and only reached 100% control as the others at the end of the study, i.e., at 98 DAA (Table 2).

Initial control differences observed between XR 11002VS and XR 11003VS may be due to the application volume, as both spray tips produce fine droplets (Costa et al. 2008). It is probably due to the high size of common water hyacinth plants (30–35cm) since a larger spray solution volume probably led to a better distribution of droplets on plants and maybe less effect 'umbrella'.

The effect of the herbicide diquat applied with different spray tips on dry matter accumulation in *E. crassipes* plants are shown in Table 3. Significant reductions in dry matter accumulation occurred with all spray tips in relation to the control, standing out the spray tip AI 110.02VS, which determined the biggest reduction followed by the spray tips XR 11002VS, XR 11003VS, and TXVK-8, confirming the good results found in the visual evaluation of control (Table 2). Other studies also have found a considerable reduction in dry matter accumulation of common water hyacinth plants with diquat application. In this sense, Wersal and Masen (2012) used diquat at a dose of 560 g ha^{-1} and obtained a reduction of 88 % in plant dry matter accumulation, while Mudge and Netherland (2014) found a 91% decrease with the use of 1,121 g ha^{-1} of diquat. The visual percentages of control found in these studies were 95 and 100%, respectively, which is like results found here.

Table 3. Effect of the herbicide diquat applied with different spray tips on the dry matter accumulation of *Eichhornia crassipes* plants.

Spray Tips	Volume L ha^{-1}	Dose g a.i ha^{-1}	Dry Matter g m^{-2}	% Reduction Dry Matter
1. XR 11002VS	200	960	570.7^{b}	83.7
2. XR 11003VS	400	960	433.5^{bc}	87.7
3. TXVK-8	200	960	226.3^{cd}	93.6
4. AI 11002VS	200	960	181.1^{d}	94.9
5. Control	-	-	3522.5^{a}	-
F treatment	-	-	280.56**	
CV (%)	-	-	15.14	
LSD	-	-	269.5	

**Significant at 1% probability. Means followed by the same letter in the column do not differ statistically from each other by the *t* test (P>0.05).

The dead plant dry matter was still floating on the water depth even at 98 DAA. Martins et al. (2011) also reported it at the Salto Grande reservoir in Americana-SP at the end of the evaluation of the herbicide diquat on common water hyacinth plants. Herbicides considered effective in controlling common water hyacinth plants, such as glyphosate and 2,4-D, which cause the plants to sink at the control site soon after their death (Cardoso et al. 2002). It would probably increase COD at the application site itself, and if dry plants spread through the water body due to wind action, this problem could be mitigated with diquat application.

The highest percentage of deposition of the herbicide spray solution in the study area was 35.76%, which was provided by spray tip AI 11002VS (coarse droplets), followed by XR 11003VS (fine droplets), TXVK-8 (very fine droplets), and XR 11002VS (fine droplets), with values of 34.24, 31.60, and 30.78%, respectively (Figure 3), but statistically superior only the XR 11002VS. Losses due to drift or non-deposition during the time interval between the exit of droplets from spray tips and their arrival on the target were of the order of 69.96, 65.76, 69.22, and 64.24% for the spray tips XR 11002VS, XR 11003VS, TXVK-8, and AI 11002VS, respectively. High values of spray solution losses as reported here have also been found in other studies on droplet deposition (Nogueira et al. 2001). It is emphasized that in the literature there are no field studies that compare different spray tips in water hyacinth plant.

Costa et al. (2008) studied the deposition of glyphosate spray solution provided by spray tips XR 11002VS (flat fan spray tip), TXVK-8 (hollow cone spray tip), and AI 11002VS (flat fan spray tip) tips on *Brachiaria brizantha* (Hochst.) Stapf plants at the same volumes studied in the present study. The authors verified a higher deposition of spray solution when the spray tip AI 11002VS was used, corroborating the results now recorded, followed by XR 11002VS and TXVK-8, which also presented the lowest droplet deposition on common water hyacinth plants. Costa et al. (2008) carried out this study under weather conditions with temperatures from 26.8 to 29.6 °C and relative air humidity from 57 to 73%, considered technically more appropriate to the good droplet deposition when compared to those observed in the present study (Table 1).

In addition, in water tank conditions, Marchi et al. (2009) studied the droplet deposition on *E. crassipes* plants using a food coloring used as spray solution tracer and spray tips TXVK-8 and DG 11002VS (flat fan spray tips) and observed that TXVK-8 provided depositions higher than that observed for DG 11002VS, as found here for the spray tip XR 11002VS. Similarly, Marchi et al. (2009) also worked under weather conditions technically suitable to a good spray solution deposition because temperature was lower (21.2 to 21.4 °C) and relative air humidity was higher (63 to 66%) when compared to the study presented here (Table 1), allowing a better target wetting. Marchi et al. (2011), also working under the same weather and method conditions, reported that the spray tip TXVK-8 provided higher depositions on the aquatic plant *S. auriculata* when compared to DG 11002VS. Thus, classifying a spray tip as good or bad depends on which ones are being compared, target species, and environmental conditions that influence spraying.

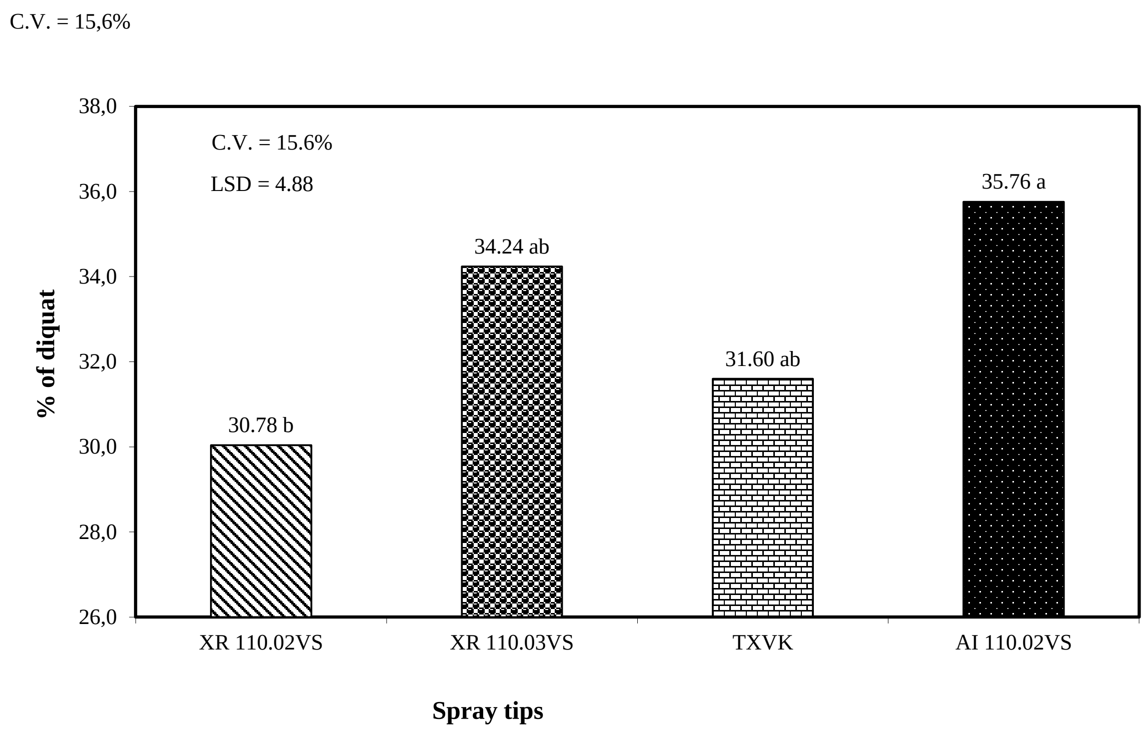

Figure 3. Percentage of deposition of the herbicide diquat in the earth dike with *Eichhornia crassipes* plants as a function of different spray tips. Means followed by the same letter do not differ statistically from each other by the t test (P>0.05).

The amount of diquat found in the water after its application on *E. crassipes* plants in the third earth dike was null for all evaluation periods since the herbicide was not found in the water according to the used methodology. In addition, from the total area of the third earth dike (2,162.07 m^2) and water volume (864.8 m^3), only 200 m^2 received diquat application, which corresponds to 9.2% of the earth dike. Also, herbicide application was performed on common water hyacinth plants and not directly on the water, which influenced its deposition on water and its dilution in the earth dike. Another fact to be highlighted is the short half-life of the herbicide diquat in the environment, which is between 18 and 28 days under Brazilian southwest conditions (Negrisoli et al. 2002).

Another aspect that should be considered regarding the non-detection of diquat in the water, in addition to those mentioned, is the turbidity found in the different earth dikes (Table 4). This turbidity, caused partially by the movement of clay from the bottom of the earth dike due to wind action, may have contributed to the adsorption and consequently to the product availability, which influenced its quantification.

Water physical and chemical characteristics of the different earth dikes (Table 4) showed no variations in all evaluated parameters that could be attributed to herbicide application. The three different earth dikes (control with plants, control without plants and with water, and diquat application) had similar quality parameters. Turbidity is the characteristic that needs more attention, as it presented high variations between earth dikes. It should be highlighted that the entry of water into the earth dikes was interrupted after herbicide application and the system was closed during the study period.

Table 4. Water physical and chemical parameters of different earth dikes (control with and without plants and applied area) at different water collection times.

	Period (days)	T water (°C)	O_2 (mg L^{-1})		COD (ppm O_2)	Turbidity (NTU)	Conduct. (µS cm^{-1})	Solids (g m^{-3})		
Area				Ph				Suspended	Dissolved	Total
earth dike 1 – control with plants	0	18.5	5.12	7.08	32.4864	85	96.4	19.0	103.0	122.0
earth dike 2 – control without plants	0	18.8	5.54	7.96	30.4560	111	91.3	9.5	66.5	76.0
earth dike 3 – applied area with diquat	0	18.8	6.65	7.47	90.0144	151	88.4	13.5	66.5	80.0
earth dike 1 - control without plants	3	22.1	4.91	8.52	28.4256	159	77.6	22.0	69.5	91.5
earth dike 2 - control without plants	3	22.4	4.99	9.40	28.4256	549	76.1	22.5	40.5	63.0
earth dike 3 - applied area with diquat	3	21.0	4.44	7.30	87.3072	328	83.4	14.0	10.0	24.0
earth dike 1 - control with plants	5	23.8	5.66	8.08	22.3344	56	70.8	16.0	69.5	85.5
earth dike 2 - control without plants	5	23.0	6.05	9.08	41.9616	312	56.2	437.0	154.0	591.0
earth dike 3 - applied area with diquat	5	21.7	5.35	7.74	50.0832	520	64.8	159.0	68.5	227.5
earth dike 1 - control with plants	7	23.4	5.19	7.94	21.6576	109	111.6	6.5	42.5	49.0
earth dike 2 - control without plants	7	24.8	4.86	7.73	30.4560	382	55.8	13.5	40.0	53.5

earth dike 3 - applied area with diquat	7	21.3	4.39	7.05	18.2736	48	68.4	54.5	45.0	99.5
earth dike 1 - control with plants	11	22.3	7.04	7.53	14.2128	87	81.5	9.0	78.5	87.5
earth dike 2 - control without plants	11	20.4	6.14	8.76	27.0720	413	74.1	20.0	80.0	100.0
earth dike 3 - applied area with diquat	11	18.5	6.21	7.13	28.4256	76	108.4	3.0	101.0	104.0
earth dike 1 - control with plants	21	15.7	4.01	7.90	39.2544	638	64.9	72.0	49.5	121.5
earth dike 2 - control without plants	21	15.0	5.10	6.73	58.8816	295	63.1	20.5	26.5	47.0
earth dike 3 - applied area with diquat	21	14.4	4.58	6.80	39.9312	107	104.5	32.5	33.5	66.0
earth dike 1 - control with plants	29	19.6	4.13	6.89	32.4864	580	93.1	40.0	60.5	100.5
earth dike 2 - control without plants	29	19.7	4.93	8.05	28.4256	362	67.5	45.0	42.0	87.0
earth dike 3 - applied area with diquat	29	19.1	4.97	7.16	30.4560	734	96.5	28.5	43.5	72.0
earth dike 1 - control with plants	60	21.7	4.12	6.84	19.6272	294	89.0	13.5	75.5	89.0
earth dike 2 - control without plants	60	21.7	5.18	6.88	32.4864	483	61.6	18.5	50.0	68.5
earth dike 3 - applied	60	21.7	4.63	6.82	44.6688	325	71.6	81.0	8.5	89.5

area with diquat										
earth dike 1 - control with plants	90	23.4	5.38	6.50	68.3568	233	104.0	15.2	82.5	97.7
earth dike 2 - control without plants	90	23.1	5.76	6.85	25.0416	36	87.0	12.5	69.5	82.0
earth dike 3 - applied area with diquat	90	23.2	5.35	6.73	33.8400	39	80.0	18.6	75.3	93.9

T = temperature; COD = chemical oxygen demand; Conduct. = conductivity.

4. Conclusions

The herbicide diquat was efficient in controlling *E. crassipes* plants at the dose applied and in development stage of the studied plants, regardless of the type of spray tip at the end of the evaluations.

At the beginning of evaluations, the spray tip XR 11002VS was the least effectivity in controlling water hyacinth plants.

Spray solution losses were high in all tips tested for the control of *E. crassipes* plants, and the spray tips AI 11002VS and XR 11003VS provided the lowest losses during spraying.

No water physical or chemical characteristics were negatively affected by diquat application.

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