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# Effect of Spray Tips and Mix Deposition on Common Water Hyacinth Growing with Varied Population Arrangements of Salvinia and Water Lettuce

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## ABSTRACT

Water hyacinth (*Eichhornia crassipes)* and other free floating plants continue to cause significant management problems in Brazilian reservoirs constructed for power generation. Herbicide management for control of these free-floating plants is currently under evaluation. In this study we evaluated two types of spray tips (ConeJet TXVK-8 and TeeJet DG 11002 VS) and the amount of spray mix deposited onto water hyacinth (*Eichhornia crassipes)* plants organized in different population arrangements with eared watermoss (*Salvinia auriculata*) and water lettuce (*Pistia stratiotes*) plants. In addition to a 100% water hyacinth arrangement, we tested arrangements with either eared watermoss or water lettuce at 75:25%, 50:50%, and 25:75%, plus a triple density with the three species placed equally at a 33% proportion. Dye solutions of FDC Yellow No. 5 at 3500 ppm and FDC Blue No. 1 at 1000 ppm were used as spraying tracers for TXVK-8 and DG 11002 VS nozzles, respectively. Both solutions were sprayed on the same plot at 30-min intervals through a $CO_2$ pressured backpack knapsack calibrated to deliver a spray volume around 200 L/ha. The TXVK-8 tip provided greater spray mix deposition when compared to the DG 11002VS tip, regardless of the plant proportions. For both spray tips, higher proportions of eared watermoss and the triple association among the plants provided the highest spray mix deposition on water hyacinth plants. The increase of spray mix deposition is likely related to the increase of eared watermoss or water lettuce as well as the decrease of water hyacinth plants in the association and consequent decreases of self covering among water hyacinth leaves. Lake managers should consider that improved herbicide uptake is possible through the choice of nozzle as well as applying herbicides to hyacinth before it forms dense monocultures or dense mixtures with other free-floating plants.

*Key words: Eichhornia crassipes*, nozzle, *Pistia stratiotes*, *Salvinia auriculata*, spray technology

## INTRODUCTION

A great diversity of aquatic plants can be found inhabiting the margins of rivers and reservoirs in Brazil. Among the most troublesome aquatic weeds in Brazil are *Eichhornia crassipes* (Mart.) Solms, *Pistia stratiotes* L., *Echinochloa polystachya* (H.B.K.) Hitchc.; aquatic species of the genera *Polygonum* and *Salvinia*; *Brachiaria subquadripara* (Trin.) Hitchc; *Typha dominguensis* Pers.; *Egeria densa* Planck; *Egeria najas* Planck; and aquatic species of the genus *Cyperus* (Martins et al. 2002). Free-floating aquatic weeds cause the most serious and generalized problems worldwide (Tanaka et al. 2002) because they normally have a fast vegetative multiplication capacity and do not depend on sexual reproductive structures.

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Additionally, they have a proportionally large area of photosynthetic tissue to plant length, a rapid capacity of occupying available sites with incident light, and they do not depend on substrate conditions or water depth (Holm et al. 1991, Kissmann 1997).

Water hyacinth (*Eichhornia crassipes*), water lettuce (*P. stratiotes*), and eared watermoss (*Salvinia auriculata*) prefer similar environmental conditions and are commonly found together in various aquatic plant populations (Holm et al. 1991). Surveys of aquatic plant communities in reservoirs of Companhia Energética de São Paulo, Brazil, documented that *Eichhornia crassipes*, *S. auriculata*, and *P. stratiotes* were always listed among the six most frequent aquatic plant species (Tanaka et al. 2002, Carvalho et al. 2003, 2005, Martins et al. 2003, Cavenaghi et al. 2005). However, water hyacinth plants are highly competitive, tending to dominate other species such as *Azolla* sp., *P. stratiotes* and *Salvinia* spp. (Kissmann 1997).

Water hyacinth leaves can change positions during the life cycle, altering the plant architecture. By observing plants in different locales, it is possible to verify that younger plants free of competition had leaves and pulvinus (swelling at the base of the leaf) oriented in a nearly horizontal position; however, older plants located in the center of a population had an etiolated pulvinus and a nearly vertical leaf position (Holm et al. 1991, Marchi et al. 2005b). In the latter case, high population densities and the presence of other species, like eared watermoss and water lettuce, contribute to foliar architecture alteration of water hyacinth.

Among the methods applied to control these plants, the use of herbicides is an economical and effective management option. Several studies conducted by various researchers have demonstrated the effectiveness of chemical control against these free-floating plants and their safety for aquatic organisms. Several herbicides are commonly used, such as 2,4-D (Joyle and Sikka 1977, Selvan and Lall 1981, Martins et al. 1999, 2002, Nelson and Shearer 2005), glyphosate (Van et al. 1986, Lindgren et al. 1999, Martins et al. 1999, 2002, Fairchild et al. 2002, Neves et al. 2002), diquat and imazapyr (Martins et al. 1999, 2002), and carfentrazone-ethyl (Koschnick et al. 2004).

Poor control of water hyacinth observed in the field can often be attributed to improper contact between the herbicide solution and plant leaves (Martins et al. 2002, Neves et al. 2002). The foliar architecture can directly influence the quantity of spray mix deposited over the plants, Theoretically, leaves oriented in a horizontal position capture drops more efficiently compared to leaves disposed in a vertical position (Spillman 1984, Wirth et al. 1991, Richardson and Newton 2000). One way to potentially improve spray deposition on the target plant is the use of nozzles that promote higher drop dynamics, such as cone nozzles.

Although previous studies have evaluated the effectiveness of herbicides, little information is available regarding the application technology used in aquatic environments, and information on the amount of spray deposition on aquatic plants is practically nonexistent. Therefore, this study aimed to quantify spray deposition provided by TXVK-8 and DG 11002VS tips on *Eichhornia crassipes* plants organized in different population arrangements with *S. auriculata* or *P. stratiotes* plants.

## MATERIALS AND METHODS

This work was conducted at Núcleo de Pesquisas Avançadas em Matologia (NUPAM; Center for Advanced Research in Weed Science), in the Agriculture Sector of Departamento de Produção Vegetal, FCA/UNESP—Botucatu Campus/SP, Brazil. The experiment was a randomized design with four replicates. A 2 by 8 factorial combination was adopted where the spray mix deposition provided by two different types of spray tips were studied in seven different aquatic plant population arrangements. The experimental units consisted of plastic boxes measuring 45 by 60 by 60 cm, devoid of substrate. The various plant proportions studied were established based on the maximum number of plants required to completely fill the surface area of the experimental unit.

The study species, water hyacinth, eared watermoss, and water lettuce, had mean leaf area values of 221.07, 21.27, and 138.48 $cm^2$/plant, respectively. The population arrangements (or proportions) were obtained by combining common water hyacinth plants and the two other species in the same tank (Table 1). Another treatment was also included, consisting of a triple population arrangement that equally distributed the three species (by number) at a 33% proportion.

Sprays were applied using a $CO_2$-pressurized backpack sprayer containing a boom equipped with two spray tips, ConeJet TXVK-8 (conical) and TeeJet DG 11002VS (flat-fan), spaced at 50 cm. The equipment was calibrated individually for each tip to provide a flow rate of 200 L/ha. The same travel direction was adopted for both sprays. Type of dye, mean spray mix consumption values obtained after calibrating each spray tip type, and climatic conditions observed during the applications were recorded (Table 2).

TABLE 1. PROPORTIONS AND NUMBERS OF AQUATIC PLANTS USED IN THE SPRAY MIX DEPOSITION EXPERIMENT.

| | | Number of plants per tank | | |
|---|---|---|---|---|
| Arrangement | Proportion (%) | Water hyacinth | Eared watermoss | Water lettuce |
| Water hyacinth | 100 | 16 | 0 | 0 |
| Water hyacinth/eared watermoss | 75/25 | 12 | 45 | 0 |
| Water hyacinth/eared watermoss | 50/50 | 8 | 90 | 0 |
| Water hyacinth/eared watermoss | 25/75 | 4 | 135 | 0 |
| Water hyacinth/water lettuce | 75/25 | 12 | 0 | 07 |
| Water hyacinth/water lettuce | 50/50 | 8 | 0 | 14 |
| Water hyacinth/water lettuce | 25/75 | 4 | 0 | 21 |
| Water hyacinth/water lettuce/eared watermoss | 33/33/33 | 5 | 60 | 10 |

TABLE 2. TYPE OF DYE, MEAN SPRAY MIX CONSUMPTION VALUES OBTAINED AFTER CALIBRATING THE SPRAY TIPS, AND CLIMATIC CONDITIONS OBSERVED DURING APPLICATIONS.

| | Spray tip | |
|---|---|---|
| Droplet size class | TXVK-8 Fine | DG 11002VS Coarse |
| Dye | Tartrazine Yellow FDC-5 | Brilliant Blue FDC-1 |
| Average mix consumption | 201.9 $L.ha^{-1}$ | 201.5 $L.ha^{-1}$ |
| Work pressure | 3.0 bar | 2.0 bar |
| Application date | 1 Jul 2004 | 1 Jul 2004 |
| Time of application | 0830 h | 0905 h |
| Air temperature | 21.4 C | 21.2 C |
| Relative humidity | 63% | 66% |
| Wind speed | 3.1 $km.h^{-1}$ | 3.3 $km.^{-1}$ |
| Spray angle | 90° | 90° |

Tartrazine Yellow FDC-5 and Brilliant Blue FDC-1 dye solutions were used as tracers for the spray tips because applications with both spray tips were made in the same experimental unit to quantitatively study the mix deposited on a single target under distinct spray situations, according to a methodology used by Souza (2002). A 30-min interval between sprays allowed runoff to occur and allowed the droplets to dry on the leaf surfaces. These dyes do not influence the physical characteristics of the mix, such as surface tension of sprayed droplets (Palladini 2000, Souza 2002) and are not absorbed by the leaves or degraded by sunlight for a period of up to 8 hours (Marchi et al. 2005a).

Immediately after applying the spray mixes, the plants were collected and washed with distilled water to remove and recover dyes deposited during applications. Each leaf part was washed separately with 35 ml distilled water. The samples obtained were placed in labeled amber plastic vials and stored away from heat and light. Absorbance readings for all samples were made in a Cintra model CGB 20 double beam spectrophotometer, operating with a 10-mm optical path-length at 630 nm wavelength for Brilliant Blue FDC-1 dye and at 427 nm for Tartrazine Yellow FDC-5 dye. Absorbance data were mathematically transformed to ppm by reading the absorbance of different standard solutions for both dyes, with previously established concentrations (in ppm).

Based on the different concentrations of samples, we were able to calculate the spray application volume deposited on the plants using the mathematical expression

$$C1.V1 = C2.V2$$

where C1 is spray mix concentration in ppm at application time; V1 is quantity in ml deposited on the plants; C2 is sample concentration in ppm; and V2 is quantity in mL, of distilled water used to wash the sample. The product of this mathematical expression was multiplied by 1000 to obtain the volume in µl.

Individual leaf area (LA) and pulvinus area (PA) values for common water hyacinth plants were obtained using the estimation equations:

$$LA = 0.720\ (L \times W)$$

and

$$PA = 2.378\ (PL \times PD)$$

respectively, suggested by Marchi and Pitelli (2003), where L = length along the main leaf vein; W = maximum width across the main leaf vein; PL = maximum pulvinus length; and PD = greatest transversal diameter of the pulvinus. After calculating leaf area, plants were placed in paper bags and dried at 60 C to determine plant dry biomass.

Spray mix quantities (µl) were divided by leaf area values or by dry plant biomass to obtain the spray mix quantities deposited in µl/surface unit and µl/g dry biomass in the various study arrangements, respectively. The results for spray mix quantities deposited on the plants were submitted to analysis of variance by the F test, and treatment means were compared by the *t* test at 5% probability.

## RESULTS AND DISCUSSION

The mean individual spray mix deposition values ($\mu L/cm^2$) provided by the TXVK-8 and DG 11002VS tips on *E. crassipes* leaves when associated with different proportions of eared watermoss or water lettuce plants were determined (Table 3). Note that the smallest spray mix deposition values with the TXVK-8 tip were obtained when water hyacinth was used at proportions of 75 and 100% because these deposition values were significantly lower than those observed in the other proportions between species. In addition, no statistical differences occurred between spray mix deposition values when water hyacinth was used at proportions of 25 and 50%, regardless of the second species used in the association.

Similar results were obtained when the mix was sprayed with the DG 11002VS tip; the lowest individual deposition values ($<0.32\ \mu l/cm^2$) were associated with the greatest proportions of water hyacinth (75 and 100%). These results were more evident in the association between water hyacinth and eared watermoss, whereas no differences occurred between spray mix deposition provided by the DG 11002VS tip at the various proportions between water hyacinth and water lettuce.

The highest individual mix deposition values on the leaves of water hyacinth were observed in the triple association between plants, regardless of the type of spray tip used; these values were statistically higher than the various other proportions used.

The TXVK-8 tip provided individual depositions significantly higher than those provided by the DG 11002VS tip, except for the total dominance condition of water hyacinth (100%) and for the association between 75% water hyacinth and 25% water lettuce (Table 3). This result was likely due to higher efficiency of the TXVK-8 tip because the spray mix recovery index with this tip on the collecting plate was approximately 95%. Even then, the spray mix deposition levels on water hyacinth leaves can be considered low because recovery indices were up to 36% for the both spray tips.

The mean individual spray mix deposition values observed on pulvini of water hyacinth plants (Table 4) show that, similar to leaf results, the TXVK-8 tip provided smaller

TABLE 3. MEAN INDIVIDUAL SPRAY MIX DEPOSITION VALUES OBSERVED ON LEAVES OF *EICHHORNIA CRASSIPES* FOR DIFFERENT PROPORTIONS OF *SALVINIA AURICULATA* AND *PISTIA STRATIOTES*.

| | | Individual deposition values (ml/cm$^2$) | |
|---|---|---|---|
| Arrangement | Proportion (%) | TXVK-8 | DG 11002VS |
| Water hyacinth | 100 | 0.40 C a | 0.31 C a |
| Water hyacinth/eared watermoss | 75/25 | 0.42 C a | 0.28 C b |
| Water hyacinth/eared watermoss | 50/50 | 0.65 AB a | 0.44 AB b |
| Water hyacinth/eared watermoss | 25/75 | 0.61 B a | 0.35 ABC b |
| Water hyacinth/water lettuce | 75/25 | 0.34 C a | 0.32 C a |
| Water hyacinth/water lettuce | 50/50 | 0.57 B a | 0.37 ABC b |
| Water hyacinth/water lettuce | 25/75 | 0.60 B a | 0.35 BC b |
| Water hyacinth/eared watermoss/water lettuce | 33/33/33 | 0.7314 A a | 0.4643 A b |
| F Proportion | | 12. 45** | |
| F Tip | | 82.30** | |
| F Proportion × Tip | | 2.38* | |
| C.V. (%) | | 17.50 | |
| LSD | | 0.1118 | |

**Significant at 1% probability.
*Significant at 5% probability.
Means followed by the same upper case letter in the column or the same lower case letter in the row do not differ statistically by the t test (p > 0.05).

spray mix deposition values on water hyacinth pulvini when the plant was used at the higher proportions (75 and 100%) with the other aquatic plants. The deposition values obtained in associations containing 75% water hyacinth and 25% eared watermoss or water lettuce were significantly lower than those obtained with other proportions.

The DG 11002VS tip provided significantly lower spray mix deposition on the surface of pulvini where water hyacinth represented 100% dominance or in an arrangement that included water hyacinth at 75% in association with 25% eared watermoss. The highest deposition values on pulvini were observed in associations where water hyacinth was used at a proportion of 50% with the two other species, regardless of type of tip used to spray the mix. Except under conditions in which water hyacinth was completely dominant (100%) or was employed at 75% with 25% of eared watermoss or water lettuce, the TXVK-8 spray tip provided individual spray mix deposition values significantly higher than those obtained with the DG 11002VS tip on water hyacinth pulvini.

TABLE 4. MEAN INDIVIDUAL SPRAY MIX DEPOSITION VALUES OBSERVED ON PULVINI OF *EICHHORNIA CRASSIPES* FOR DIFFERENT PROPORTIONS OF *SALVINIA AURICULATA* AND *PISTIA STRATIOTES*.

| | | Individual deposition values (ml/cm$^2$) | |
|---|---|---|---|
| Arrangement | Proportion (%) | TXVK-8 | DG 11002VS |
| Water hyacinth | 100 | 0.18 D a | 0.16 CD a |
| Water hyacinth/eared watermoss | 75/25 | 0.18 D a | 0.15 D a |
| Water hyacinth/eared watermoss | 50/50 | 0.51 AB a | 0.35 AB b |
| Water hyacinth/eared watermoss | 25/75 | 0.46 B a | 0.29 B b |
| Water hyacinth/water lettuce | 75/25 | 0.35 C a | 0.26 BC a |
| Water hyacinth/water lettuce | 50/50 | 0.58 A a | 0.41 A b |
| Water hyacinth/water lettuce | 25/75 | 0.43 BC a | 0.30 B b |
| Water hyacinth/eared watermoss/water lettuce | 33/33/33 | 0.42 BC a | 0.27 B b |
| F Proportion | | 21.21** | |
| F Tip | | 44.43** | |
| F Proportion ∞ Tip | | 1.43* | |
| C.V. (%) | | 21.38 | |
| LSD | | 0.1008 | |

**Significant at 1% probability.
*significant at 5% probability.
Means followed by the same upper case letter in the column or the same lower case letter in the row do not differ statistically by the t test (p > 0.05).

The indices of spray mix deposition on pulvini can also be considered low because the TXVK-8 and DG 11002VS tips had recovery indices on the spray swaths between 9 and 28% and 7 and 20%, respectively. Comparatively, the mean deposition values and spray mix recovery indices observed on water hyacinth pulvini were both relatively lower than those observed on leaves. The pulvini are structures located below the leaves; therefore, droplet deposition could be impaired by the occurrence of the so-called "umbrella effect."

Mean spray mix deposition values obtained for water hyacinth plants (Table 5) show that the TXVK-8 tip provided quantitatively similar deposition values in µl/cm². Except for conditions in which water hyacinth was completely dominant and at a 75% proportion with 25% eared watermoss or water lettuce plants, spray mix deposition values obtained on water hyacinth were statistically similar, regardless of species and proportion with which it was associated. The best quantitative spray mix deposition results provided by the DG 11002VS tip were obtained in associations where water hyacinth was used at smaller proportions, including the triple association between aquatic species.

The reduction in the proportion of water hyacinth plants increased the total spray mix deposition on the plants (µl/plant), regardless of the species with which it was associated and of the tip used in the spray (Table 5). A 4-fold increase in the proportion of water hyacinth plants in relation to eared watermoss or water lettuce plants showed reductions of 66.37% and 64.52% in mix deposition provided by the TXVK-8 tip, respectively. Mix deposition reductions of 53.74% and 51.70% were obtained with the DG 11002VS tip, respectively. The TXVK-8 tip provided superior individual and total spray mix deposition values when compared with those provided by the DG 11002VS tip, especially in the various association proportions between water hyacinth and water lettuce.

Silva (2000) obtained similar results studying the spray mix deposition provided by a Teejet DG 11002VS tip on different population densities of yellow nutsedge (*Cyperus rotundus* L.) plants; a 4-fold increase in population density of yellow nutsedge plants (from 300 to 1200 plants/m²) also conditioned mix deposition reductions (from 14.57 to 10.32 µl/plant, a 27.17% reduction). The inference can be made that solitary yellow nutsedge plants in the field or border plants could receive a higher amount of product than those located in the middle of plant clusters.

In addition to plant dispersal, the architecture of leaves and pulvini may also influence the amount of spray mix deposition on water hyacinth plants. The leaf blade position relative to the direction of the spray may facilitate or even impair the contact between the droplet and the leaf surface (Marchi et al. 2005b). Theoretically, horizontally oriented leaves are more efficient at capturing droplets than those oriented toward the vertical position (Spillman 1984, Wirth et al. 1991, Richardson and Newton 2000).

Marchi et al. (2005b) evaluated the spray mix deposition without adjuvant provided by TX 12 and DG 11002VS tips on water hyacinth leaves arranged under different combinations between vertical and horizontal angles. They observed that the mean deposition values on the entire leaf and on the adaxial surface decreased as the vertical angle increased (regardless of spray tip used), and that the smallest deposition values were always related to a 90° vertical angle (regardless of horizontal angle used). In addition, the authors commented that droplet deposition or retention was practically absent on the abaxial surface of the leaves.

The numbers of water hyacinth plants used were equivalent to 33 and 45 plants/m² for the proportions of 75 and 100%, respectively, which characterizes high-density populations and conditions where plant architecture assumes near-vertical positions. The low individual and total spray mix

TABLE 5. MEAN SINGLE AND TOTAL SPRAY MIX DEPOSITION VALUES OBSERVED IN *EICHHORNIA CRASSIPES* PLANTS FOR DIFFERENT PROPORTIONS OF *SALVINIA AURICULATA* AND *PISTIA STRATIOTES* USED IN THE "COMMON WATER HYACINTH SITUATION."

| | Single deposition (ml/cm²) | | | Total deposition (ml/plant) | | | |
|---|---|---|---|---|---|---|---|
| "Water Hyacinth Situation" | Proportion (%) | TXVK-8 | DG 11002VS | TXVK-8 | Reduction (%) | DG 11002VS | Reduction (%) |
| Water hyacinth | 100 | 0.58 Ba | 0.47 Da | 85.83 Da | 66.37 | 70.46 Fa | 53.74 |
| Water hyacinth/eared watermoss | 75/25 | 0.60 Ba | 0.42 CDa | 120.65 Da | 52.73 | 86.23 EFa | 43.39 |
| Water hyacinth/eared watermoss | 50/50 | 1.16 Aa | 0.80 Ab | 163.00 Ca | 36.14 | 114.14 CDEb | 25.07 |
| Water hyacinth/eared watermoss | 25/75 | 1.07 Aa | 0.64 ABCb | 255.25 ABa | — | 152.33 ABb | — |
| Water hyacinth/water lettuce | 75/25 | 0.70 Ba | 0.57 BCDa | 99.84 Da | 64.52 | 87.63 DEFa | 51.70 |
| Water hyacinth/water lettuce | 50/50 | 1.15 Aa | 0.78 Ab | 178.18 Ca | 36.38 | 122.11 BCDb | 32.69 |
| Water hyacinth/water lettuce | 25/75 | 1.03 Aa | 0.64 Bb | 281.39 Aa | — | 181.42 Ab | — |
| Water hyacinth/eared watermoss/water lettuce | 33/33/33 | 1.15 Aa | 0.73 ABb | 226.58 Ba | 19.48 | 147.13 ABCb | 18.90 |
| F Proportion | | | 17.17** | | | 39.31** | |
| F Tip | | | 79.57** | | | 80.80** | |
| F Proportion × Tip | | | 2.04* | | | 4.01** | |
| C.V. (%) | | | 17.03 | | | 16.86 | |
| LSD | | | 0.1891 | | | 35.53 | |

**Significant at 1% probability.
*Significant at 5% probability.
Means followed by the same upper case letter in the column or the same lower case letter in the row do not differ statistically by the t test ($p > 0.05$).

deposition values on water hyacinth obtained in this study are probably related to leaf and pulvinus architecture at application time; reductions in deposition on the leaf surface were observed regardless of tip type used in the spray and regardless of species population associations. In situations where hyacinth is growing in dense monocultures on in dense mixtures with other free-floating plants, the changes in leaf architecture can result in a strong potential for reduced deposition and uptake of herbicides.

Taking these factors into account would provide a much greater understanding of what affects the spray mix deposition and may eventually lead to a suite of herbicides uptakes during the management of water hyacinth plants.


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## LITERATURE CITED


Carvalho, F. T, M. L. B. T. Galo, E. D. Velini and D. Martins. 2003. Plantas aquáticas e nível de infestação das espécies presentes no reservatório de Barra Bonita, no rio Tietê. Planta Daninha (Special Ed.) 21:15-19. Special Edition.

Carvalho, F. T., E. D. Velini and D. Martins. 2005. Plantas aquáticas e nível de infestação das espécies presentes no reservatório de Bariri, no rio Tietê. Planta Daninha 23(2): 371-374.

Cavenaghi, A. L., E. D. Velini, E. Negrisoli, F. T. Carvalho, M. L. B. T. Galo, M. L. B. Trindade, M. R. Corrêa and S. C. A. Santos. 2005. Monitoramento de problemas com plantas aquáticas e caracterização da qualidade de água e sedimento na UHE Mogi-Guaçú. Planta Daninha 23(2):225-231.

Fairchild, J. F., A. L. Allert, J. S Riddle and D. R. Gladwin. 2002. Efficacy of glyphosate and five surfactants for controlling giand salvínia. J. Aquat. Plant Manage. 40:53-57.

Holm, L. G., D. L. Plucknett, J. V. Pancho and J. P. Herberger. 1991. The world's worst weeds: distribution and biology. Krieger Publishing Co. Lalabar, FL. 609 p.

Joyle, J. C. and H. C. Sikka. 1977. Residual 2,4-D levels in the St. Johns River, Florida. J. Aquat. Plant Manage. 15:72-82.

Kissmann, K. G. 1997. Plantas Infestantes e Nocivas: Tomo I. 2a Edição, BASF S.A., São Paulo. 825 p.

Koschnick, T. J., W. T. Haller and A. W. Chen. 2004. Carfentrazone-ethyl pond dissipation and efficacy of floating plants. J. Plant Aquat. Manage. 42:103-108.

Lindgren, C. J., T. S. Gabor and H. R. Murkin. 1999. Compatibility of glyphosate with Galerucella calmariensis: A biological control agent for purple loosestrife (Lythrum salicaria). J. Plant Aquat. Manage. 37:44-48.

Marchi, S. R., D. Martins, N. V. Costa, M. A. Terra and E. Negrisoli. 2005a. Degradação luminosa e retenção foliar dos corantes Azul Brilhante FDC-1 e Amarelo Tartrasina FDC-5 utilizados como traçadores em pulverizações. Planta Daninha 23(2):287-294.

Marchi, S. R., D. Martins, N. V. Costa, C. A. Carbonari and M. A. Terra. 2005b. Depósitos de calda de pulverização nas faces adaxial e abaxial de folhas de *Eichhornia crassipes* dispostas em diferentes ângulos. Planta Daninha 23(2):321-328.

Marchi, S. R. and R. A. Pitelli. 2003. Estimativa da área foliar de plantas daninhas de ambiente aquático: *Eichhornia crassipes*. Planta Daninha (Special Ed.) 21:109-112, 2003.

Martins, D., E. D. Velini, A. L. Cavenaghi, C. G. Mendonça and C. G. Mendonça. 1999. Controle químico de plantas daninhas aquáticas em condições controladas—caixa d'água. Planta Daninha 17(2):289-296, issue 2.

Martins, D., E. D. Velini, E. Negrisoli and G. R. Tofoli. 2002. Controle químico de *Pistia stratiotes*, *Eichhornia crassipes* e *Salvinia molesta* em caixas d'água. Planta Daninha (Special Ed.) 20:83-88.

Martins, D., E. D. Velini, R. A. Pitelli, M. S. Tomazella and E. Negrisoli. 2003. Ocorrência de plantas aquáticas nos reservatórios da Light-RJ. Planta Daninha (Special Ed.) 21:105-108.

Nelson, L. S. and J. F. Shearer. 2005. 2,4-D and *Mycoleptodiscus terrestris* for control of eurasian watermilfoil. J. Aquat. Plant Manage. 43:29-33.

Neves, T., L. L. Foloni, L. L. and R. A. Pitelli. 2002. Controle químico do aguapé (*Eichhornia crassipes*). Planta Daninha (Special Ed.) 20:89-97.

Palladini, L. A. 2000. Metodologia para avaliação da deposição em pulverizações. Botucatu, SP, 2000. 111p. Tese (Doutorado em Agronomia/Proteção de Plantas)—Faculdade de Ciências Agronômicas, Universidade Estadual Paulista.

Richardson, B. and M. Newton. 2000. Spray deposition within plant canopies. New Zealand Crop Protection 53:248-252.

Selvan, R. P. and M. Lall. 1981. Chemical control of water hyacinth, pp. 141-148. *In*: Proceedings of the Annual Conference of Indian Society of Weed Science, Oxford.

Silva, M. A. S. 2000. Depósitos de calda de pulverização no solo e em plantas de tiririca (*Cyperus rotundus* L.) em diferentes condições de aplicação. Botucatu, SP. 57p. Tese (Doutorado em Agronomia/Agricultura)—Faculdade de Ciências Agronômicas, Universidade Estadual Paulista.

Souza, R. T. 2002. Efeito da eletrização de gotas sobre a variabilidade dos depósitos de pulverização e eficácia do glyphosate no controle de plantas daninhas da cultura da soja. Botucatu, SP. 69p. Tese (Doutorado em Agronomia/Agricultura)—Faculdade de Ciências Agronômicas, Universidade Estadual Paulista.

Spillman, J. J. 1984. Spray impaction, retention and adhesion: an introduction to basic characteristics. Pestic. Sci. 24:97-106.

Tanaka, R. H, L. R. Cardoso, D. Martins, D. A. S. Marcondes and A. L. Mustafá. 2002. Ocorrência de plantas aquáticas nos reservatórios da Companhia Energética de São Paulo. Planta Daninha (Special Ed.) 20:99-111.

Van, T. K., V. V. Vandiver and R. D. Conant. 1987 Effects of herbicides rate and carrier volume on glyphosate phytotoxity. J. Aquat. Plant Manage. 24:66-89.

Wirth, W., S. Storp and W. Jacobensen. 1991. Mechanisms controlling leaf retention of agriculture spray conditions. Pestic. Sci. 31:411-420.