Use of anti drift nozzles in control of perennial weeds in vineyard nurseries

Uso de boquillas antideriva en el control de malezas perennes en viveros vitivinícolas

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Abstract

Table grapes are the most widespread fruit species in Chile, requiring a large amount of agrochemical products. Due to this large requirement, agrochemicals such as herbicides need to be applied precisely and in an environmentally safe manner in order to achieve the desired target. Weeds are a limiting factor in vine nurseries, where *Cyperus rotundus*, *Sorghum halepense*, and *Cynodon dactylon* are the hardest species to control. In this case, application though nozzles is of vital importance for a correct herbicide distribution and dosage over the target. However, the use of herbicides in vine nurseries has not been widely practiced and literature on the subject is very scarce. In this project, a comparative study between conventional extended range flat spray (XR) and drift effect nozzles (TT turbo teejet; DG drift guard; AI air injection) was conducted. Weed control with glyphosate and phytotoxicity in *Vitis vinifera* cv. Thompson Seedless self-rooted nursery plants were evaluated, under wind drift conditions of 5.8 km h^{-1}. This wind drift and the low angle of elevation of the nozzle (35 cm) caused the herbicide to reach the vine, generating the same visual plant toxicity damage regardless of the nozzle type used, with an increasing damage from day 7 to 28 after application (DAA). A gradual decrease was observed from 36 DAA onwards. Although no differences between the nozzles with respect to drift damage were detected, the use of the DG nozzle resulted in a lower percentage of sprouting weeds. This may be due to the DG nozzle having significantly reduced drift compared to conventional or standard nozzles, and, in turn, generating smaller droplets than AI, favoring their retention on the leaves.

Keywords

plant toxicity • spray deposits • glyphosate • drifting • weed control • chemical control

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Resumen

El área plantada de vid en Chile es la mayor superficie de frutales, con un efecto en una alta tasa de uso de agroquímicos, sobre todo en los viveros, en los cuales las malezas son un factor limitante, siendo *Cyperus rotundus* L., *Sorghum halepense* (L. Pers) y *Cynodon dactylon* (L. Pers), las especies de más difícil control. Este cambio requiere que las aplicaciones de agroquímicos como los herbicidas sean más precisos y seguros con el medio ambiente, evitando además el daño por deriva, sobre todo por la reducida distancia entre las hileras. Dentro del equipamiento de aplicación, las boquillas son de vital importancia debido a que permiten dosificar la mezcla y distribuirla sobre el objetivo, pero los estudios de aplicaciones en viveros son bastante reducidos, sin encontrarse mucha literatura al respecto. Se realizó un estudio comparativo entre boquillas abanico plano de rango extendido (XR) y antideriva (TT turbo teejet; DG baja deriva; AI inyección de aire) en donde se evaluó la fitotoxicidad en plantas de *Vitis vinifera* cv. Thompson Seedless (auto-enraizadas en vivero) y el control de malezas con glifosato, bajo condiciones de viento (5,8 km·h^{-1}). En estas condiciones de viento, y baja altura de la boquilla (35 cm), la cantidad de herbicida que llega a la vid producto de la deriva genera el mismo daño fitotóxico visual y de materia seca independientemente de la boquilla utilizada, con un aumento del daño visual desde el día 7 al 28 después de aplicación (DDA), y luego un descenso gradual desde el día 36 DDA. Aunque no se notaron diferencias entre las boquillas con respecto al daño por deriva, sí hubo en el control de las malezas, donde la boquilla DG presenta uno de los menores porcentajes de control de re-brotación en las malezas evaluadas, mayormente debido a que no produce gotas tan chicas que pudiesen derivar, ni tan grandes que afecten su permanencia en la hoja.

Palabras clave

Fitotoxicidad • depósitos de aspersión • glifosato • efecto deriva • control de malezas • control químico

Introduction

At present, table grape is the most widespread fruit species in Chile, with ~ 70 cultivars, being Thompson Seedless the most grown with 21,243 ha (22).

Weed management has been identified as one of the main limiting factors in vineyard productivity and extension (28, 35), as these species compete with the vines, resulting in yield losses (10, 13). In nurseries, this situation is critical due to the early growth stage of the plants and their high planting density (10, 24). Additionally, the use of herbicides in vine nurseries has not been widely practiced and literature on the subject is scarse (28).

Perennial weeds present in vineyard nurseries cause important problems given that they can survive several seasons via their diverse vegetative propagules (28, 29). This is why proper timing and use of herbicides applied to foliage and translocated to their active growing points, is key to successful control of these weeds, particularly in Chile, where *Cyperus rotundus* L., *Sorghum halepense* L. Pers, and *Cynodon dactylon* L. Pers vigorously grow.

Application effectiveness of herbicides in vineyard nurseries depends on many factors, such as weather, operating care and skills, time of application, spray nozzle, type of equipment and its calibration (1, 8, 16, 25, 32). The size of droplets is the main drift factor in herbicide sprays, but there are different size recommendations intended to reduce it. For example, over 100 μm (21, 23, 34), or larger than 200 microns diameter may be needed to satisfactorily reduce drift (3, 25). On the other hand, Butts *et al.* (2019), tested different sizes and indicated a droplet size of 395 μm in order to maximize weed mortality.

The increase in droplet size when decreasing spray pressure is a common approach to reduce drift (2, 5, 13, 27, 33). This affects the total volume applied, and influences herbicide effectiveness (5, 18), normally decreasing drift, but also coverage (19, 34). These techniques significantly differ from fruit crops, where no such differences in coverage are found (9, 13, 26, 31). Ferguson *et al.* (2018), indicate that droplet size (nozzle type) has relatively little impact on the efficacy of the studied herbicides. For this reason, nozzles designed to produce large droplets without changing pressure have recently appeared in the market (antidrift nozzles).

To evaluate the effect of antidrift nozzles on weed control in vineyard nurseries, a trial was conducted, under wind conditions, assessing toxicity levels of the target plants. Three antidrift nozzles and a conventional extend rage flat fan nozzle were used in the applications of glyphosate on a *Vitis vinifera* L. cv. Thompson Seedless own-rooted plants nursery, in order to control *C. rotundus*, *S. halepense*, and *C. dactylon*.

Materials and methods

A trial was conducted at the Antumapu Campus experiment station, Facultad de Ciencias Agronómicas, Univerdad de Chile, Metropolitan Region, Santiago, Chile (33° 34´ Lat. South; 70° 38´ Long. West).

Thompson Seedless own-rooted nursery table grape plants were used. Weed control and plant toxicity were evaluated using a 44 cm diam. 180W Famasol F70 industrial fan to generate a 5.8 km h^{-1} wind at plant height. The fan was connected to a Staco Incorporate varying frequency input control. Additionally, an 80 cm deep x 60 cm high PVC tube covered with polyethylene was connected to the fan, in order to avoid the effect of wind bursts and the product drifts, while protecting boards on both sides of each treatment (figure 1A and C, page 340). Wind speed was verified with a La Crosse Technology EA 3010U hand wind meter.

Different treatments were sprayed using a conventional long-extended nozzle (XR), and three anti drift nozzles: a pre-hole (DG), a turbulence chamber, or Turbo type (TT), and another with air induction (AI). All of them sprayed AM at a 110° flat fan with a Spraying Systems® equipment at a 0.76 L min^{-1} flow rate on a Solo® 425 flank back pack at 3 bars. A volume rate of 150 L ha^{-1} was applied, at 2.4 km h^{-1}, and a 90 cm spray band, corresponding to the separation between rows in the nursery.

Fifteen treatments were evaluated, corresponding to 4 nozzles types (XR, TT, DG y AI) x 3 perennial weeds (*C. dactylon*, *S. halepense*, and *C. rotundus*) plus a control treatment with no spray for any weed. The experiment unit had 9 plants (3 vines and 6 weed plants of the same species), each one planted in 40 x 40 cm black polyethylene bags (figure 1B, page 340).

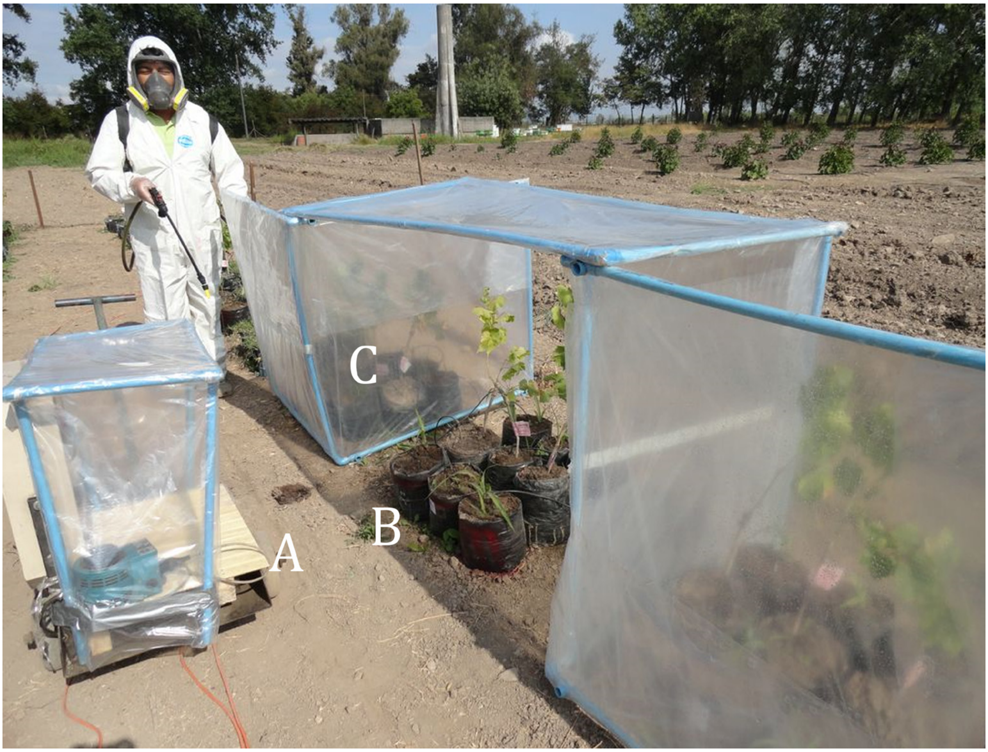

Figure 1. Installed experiment. (A) ventilator with plastic deflector, (B) experimental unit, (C) screen protecting other treatment.

Figura 1. Montaje del experimento, (A) ventilador con sus deflectores plásticos, (B) unidad experimental, (C) pantallas protectoras de los otros tratamientos.

Each experimental unit bag was planted with one tubercle of *C. rotundus*, one bud of *S. halepense* and 10 cm stolons of *C. dactylon*, all collected in the Antumapu campus. The bags with the weeds were placed in front and behind the vine plants to be sprayed with glyphosate (Touchdown IQ 500 ®) (figure 1B). The statistical analysis used completely random blocks with 4 replicates, and the Di Rienzo, Guzmán y Casanoves test (DGC, $p \leq 0.05$) was used to compare means, using InfoStat™ program (11). The herbicide was applied according to the adequate rate and dose for the optimum control of each weed (table 1, page 341).

To determine the effect of the herbicide on the three weed species and vine plants, visual symptoms of damage caused by glyphosate at 7, 14, 21, 28, 35, and 42 days after application (DAA) were evaluated, where 0% control represents healthy plants and 100% total control or dead plants, scale proposed by the European Weed Research Society (30). For statistical comparison, % were transformed to Bliss grades.

To measure the effect of glyphosate on plant development, weeds and vines were harvested at 42 DAA, Aerial and root growth were estimated by dry weight assessment (dried at 70 °C for 48 hours).

Table 1. Weed stages for control and doses of glyphosate sprayed.
Table 1. Estados de control y dosis empleados en los ensayos de control de malezas.

Weeds	Phenological stages	Phenological stage (DAE*)	Doses (L ha^{-1}**)
Cyperus rotundus	9 - 11 leaves	25	3.3
Sorghum halepense	4 leaves	25	1.3
Cynodon dactylon	10-15 cm stolons	40	2.2

* Days after emergence. ** Doses of glyphosate sprayed for weed control in Univiveros®.
* Días después emergencia. ** Dosis de glifosato aplicados en control de malezas en el vivero.

Re-sprouting was also evaluated by comparison to untreated controls, after vegetative structures were cultured in Petri dishes with wet absorbent paper and kept in a growth cabin at 20 °C for 7 days.

Results and discussion

Plant toxicity

Every nozzle, regardless of the weed, caused damage by drift. However, visual toxicity on the vines after glyphosate treatment under a 5.8 km h^{-1} wind breeze did not present significant differences ($P \leq 0.05$) between the nozzles. That is, at each DDA and weed, the DG, TT, and AI anti drift nozzles, affected the plants in the same way as the conventional XR nozzle. Similar results were obtained by Guler *et al*. (2007) in tests in wind tunnels at 9 km h^{-1}, and at 18 km h^{-1} using AI and XR nozzles. Also, Rosales-Robles *et al*. (2013) found no differences in sorghum (*Sorghum bicolor* L. Moench.) at 15 and 30 DAA with 3 different herbicides.

On the other hand, vine toxicity was related to the dose of glyphosate applied for weed control, where significant differences were obtained with the 3.3 L ha^{-1} of Glyphosate that affected 38.84% of *C. rotundus*, compared to 29.03 and 28.48% of *S. halepense* and *C. dactylon* treated with 1.3 L ha^{-1} and 2.2 L ha^{-1}, respectively (figure 2, page 342). This indicates that the greater the concentration of glyphosate, the greater the plant toxicity damage, as widely documented (6, 20). Additionally, it should be noted that several herbicides, including glyphosate, are very toxic to young vines and should be applied only preventively and by multiple applications during the previous year to planting (29).

The analysis performed on the three weeds (figure 2, page 342), showed a gradual increase in visual damage from 7 to 28 DAA; while on 36 and 42 DAA a decrease of visual damage occurred. This indicates a recovery of the vines from glyphosate toxicity caused by drift, evidenced by growth of new leaves, with damage becoming gradually less noticeable. Significant differences ($p \leq 0.05$) in the percentage of vine toxicity were found only for applications regarding *Sorghum halepense*.

The windless conditions (5 km h^{-1}), and the low altitude of the nozzles (35 cm) could probably diminish drift.

Dry weight of the vine plants

Vine aerial and root dry matter after application of glyphosate, at each dose (treatment), with different nozzles, are presented in table 2 (page 342), Control plants produced greater foliar and root dry matter, compared to those exposed to glyphosate, but significant differences were only found for root weight with the higher dose applied to *Cyperus rotundus* (3.3 L ha^{-1}).

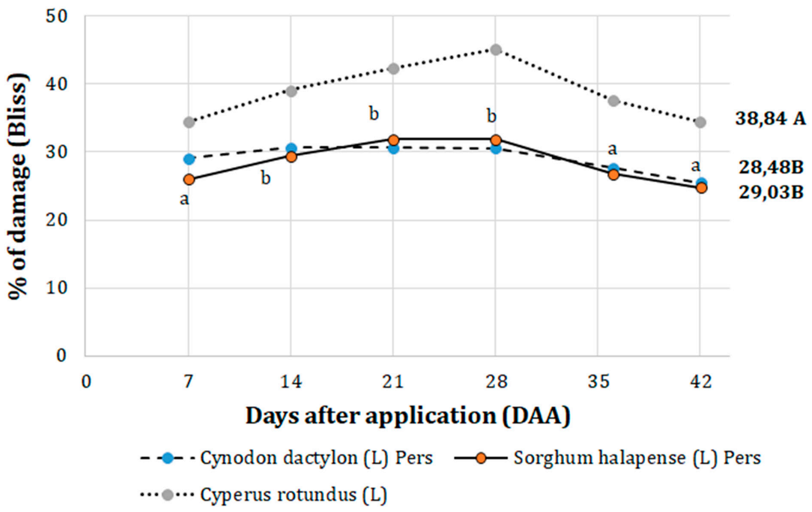

Figure 2. Damaged vines(%) after treatment with glyphosate. Different letters at *Sorghum halepense* (L) Pers, indicate significant (p≤0.05) differences between DAA. Capital letters indicate significant differences (p≤0.05) for the average damage of the weeds.

Figura 2. Porcentaje de daño en plantas de vid días después de la aplicación (DDA) de glifosato. Letras diferentes en *Sorghum halepense* (L) Pers, indican diferencias significativas según la prueba de comparaciones de DGC (p≤0,05). Letras mayúsculas, indican diferencias significativas entre el promedio de daños de las malezas.

Table 2. Mean dry weight of aerial and underground parts of the vines after spraying glyphosate with antidrift (TT, DG, and AI) and conventional (XR) nozzles.

Table 2. Peso seco promedio de la parte aérea y subterránea de las vides tras aplicación de glifosato con boquillas antideriva (TT, DG y AI) y convencional (XR).

	Cynodon dactylon 2.2 L ha^{-1}		*Sorghum halepense* 1.3 L ha^{-1}		*Cyperus rotundus* 3.3 L ha^{-1}	
Nozzles	**Foliar (g)**	**Roots (g)**	**Foliar (g)**	**Roots (g)**	**Foliar (g)**	**Roots (g)**
Control	31.78 a	18.37 a	26.89 a	13.98 a	27.36 a	17.32 a
XR	24.75 a	11.10 a	25.91 a	11.81 a	16.57 a	9.25 b
TT	24.67 a	12.99 a	24.82 a	12.76 a	18.06 a	8.26 b
DG	22.87 a	10.92 a	20.26 a	10.70 a	15.80 a	6.48 b
AI	23.98 a	11.33 a	19.86 a	10.98 a	17.00 a	8.49 b

Different vertical letters indicate significant differences (p≤0.05) between nozzles, according to a DGC test.
Letras verticales diferentes indican diferencias significativas (p≤0,05), acorde al test DGC.

It can be observed that the higher dose (3.3 L ha^{-1}), caused smaller total and leaf dry weights as the vines presented the greatest percentage (38.84%) of toxicity. At 2.2 L and 1.3 L ha^{-1}, the plants did not present significant differences in damages or dry weight (25.61% and 23.55%, respectively). This is in agreement with others studies (6, 20).

Weed control

Percentage of control of the three weed species with glyphosate using 4 different nozzles is presented in figure 3. A MANOVA analysis indicated, for each evaluation date, that significant differences were found in all cases, excepting 42 DDA, for *Sorghum*. Similar results were obtained by Wilson *et al.* (2008) with *Digitaria sanguinalis* L. Scop using drift reduction nozzles and a conventional flat fan, and also by Ferguson *et al.* (2018), when evaluating the effect of 5 drift reduction technologies. Differences were not observed for coarse sprays, appearing to provide the highest herbicide efficacy across a wide range of herbicides like Clodinafop, Imazamox plus Imazapyr, and Glyphosate.

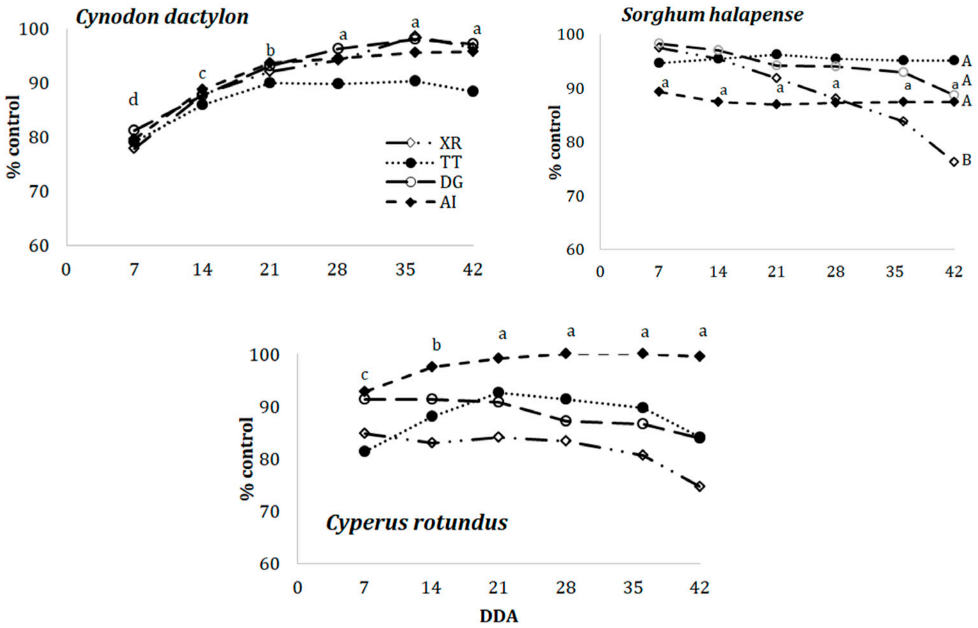

Figure 3. Control of three weed species with glyphosate sprayed with 4 different nozzles at the border of sprayed band. Different lower-cases letters indicate significant differences (p≤0.05) between DDA, and capitals letters indicate significant differences between nozzles, according to DGC tests.

Figura 3. Control de tres especies de malezas aplicadas con glifosato mediante 4 diferentes boquillas antideriva, en el borde de la banda de aplicación. Letras minúsculas diferentes indican diferencias significativas (p≤0,05) entre DDA y letras mayúsculas es entre las boquillas, acorde al test DGC.

This means that to generate enough coverage with the different nozzles is possible, while maintaining the effectiveness of weed control with glyphosate. It should be noted that the treated weeds were next to the vines and that they received less coverage given the fan nozzles used.

Control of *C. dactylon* increased with time. At 7 DAA, the mean control was 63.4%, while at 42 DAA it achieved 80.08%. It is important to note that the greatest control (81.09%) occurred at 36 DAA, followed by a small, not significant decrease of 1.01% at 42 DAA.

Control percentage of *S. halepense* (figure 3, page 343) showed no significant differences between DAA, except for the XR nozzle that, at 42 DAA showed a decrease in this weed´s control.

A greater, but not significant control of *C. rotundus* with glyphosate occurred with the AI nozzle (having a Venturi effect).

Dry matter of weed plants

Aerial and root dry weight of the three weed species after treatment with glyphosate and the untreated control under the described wind breeze using the TT, DG, and AI anti drift, and the XR conventional nozzles, are presented in table 3. Control plants presented greater dry matter levels than treated plants. However, dry weights did not differ between the used nozzles.

Plant structures

Stolon length of *C. dactylon*, bud number of *S. halepense*, and tubercles of *C. rotundus* after spraying glyphosate with several nozzles and the untreated control plants at 42 DAA, are presented in table 4 (page 345). Untreated plants presented greater growth values than those sprayed. However, no significant differences between the nozzles were detected.

Weed sprouting

Weed sprouting of the three weeds treated with glyphosate using several nozzles is presented in table 5 (page 345).

For *C. dactylon*, the treatments with XR and TT nozzles presented the greatest levels of stolon sprouting at 42 DAA, probably due to their smaller droplets.

Table 3. Mean foliar and root dry weight of three weed plants at the border of sprayed band, after spraying glyphosate using TT, DG, and AI anti drift, and XR conventional nozzles.

Tabla 3. Peso medio de materia seca de tres malezas ubicadas al borde de la banda de aplicación tras aplicación de glifosato con boquillas antideriva (TT, DG y AI) y convencional (XR).

Nozzles	Foliar (g)	Roots (g)	Foliar (g)	Roots (g)	Foliar (g)	Roots (g)
	Sorghum halepense		***Cyperus rotundus***		***Cynodon dactylon***	
Control	45.82 a	26.61 a	40.98 a	23.85 a	27.45 a	---
XR	6.87 b	7.46 b	7.42 b	6.66 b	7.96 b	---
AI	6.20 b	6.49 b	4.57 b	1.22 b	7.00 b	---
DG	2.34 b	2.91 b	2.18 b	1.12 b	5.72 b	---
TT	1.33 b	2.12 b	0.68 b	0.66 b	5.64 b	---

Different vertical letters indicate significant differences (p≤0.05), according to a DGC test.
Letras verticales diferentes indican diferencias significativas (p≤0,05), acorde al test DGC.

Table 4. Mean growth of structures of three weed plants (at the border of sprayed band) at 42 DAA after treatment with glyphosate using several nozzles under a 5.8 km h^{-1} wind breeze.

Tabla 4. Promedio de estructuras reproductivas de tres malezas (ubicadas al borde de la banda de aplicación) a 42 DDA de glifosato con diversas boquillas en presencia de viento de 5,8 km h^{-1}.

Nozzles	*C. dactylon* stolon length, cm	*S. halepense* bud number	*C. rotundus* tubercles
Control	54.06 a	26.00 a	32.63 a
XR	29.68 b	8.08 b	4.00 b
TT	30.05 b	3.54 b	4.33 b
DG	33.30 b	2.96 b	5.67 b
AI	29.68 b	6.88 b	1.58 b

Different letters in columns, indicate significant differences (p≤0.05), according to a DGC test.
Letras diferentes en las columnas, indican diferencias significativas (p≤0,05), acorde al test DGC.

Table 5. Weed sprouting at 42 DAA of glyphosate in comparison with the untreated controls under a 5.8 km h^{-1} wind breeze.

Tabla 5. Porcentaje de brotación, 42 DDA en relación con el tratamiento testigo en aplicaciones de glifosato en condiciones de viento.

Nozzles	*Cynodon dactylon*	*Sorghum halepense*	*Cyperus rotundus*
XR	28.90 a	33.24 a	30.72 a
TT	27.96 a	21.61 b	15.00 b
DG	13.83 b	16.94 b	17.72 b
AI	9.50 b	27.21 a	26.69 a

Different letters in columns, indicate significant differences (p≤0.05), according to a DGC test.
Letras diferentes en las columnas, indican diferencias significativas (p≤0,05), acorde al test DGC.

It should be stated that this weed has a creeping habit, with many leaves per stolon (4, 7, 29) making coverage and control, quite difficult, facilitating regrowth. Increasing droplet size with the DG and AI nozzles produced a smaller sprouting percentage (DG: 13.83% and AI: 9.5%).

In *S. halepense* and *C. rotundus*, the use of the XR and AI nozzles resulted in the greatest sprouting rates in relation to the untreated controls (XR: 33.24 - 30.72 % and AI: 27.21-26.69% respectively). These two nozzles represent the smaller and bigger droplets, respectively. Jordan *et al*. (2009), state that XR nozzles produce between 11.7 and 22.3 percent of drops between 177 and 218 um, considered to be too small, decreasing the number of drops that impact the surface to be treated. For this reason, it may have been possible that the XR nozzle could not cover adequately under the 5.8 km h^{-1} wind breeze, causing an insufficient quantity to achieve the underground vegetative plant structures.

On the other hand, AI nozzle only produces between 1.5 and 3.3% of fine droplets, but the almost vertical leaves of these weeds cause the large drops to fall to the ground, reducing herbicide absorption and translocation. Similar results have been reported in similarly structured weed species, like *Avena fatua* L., and *Cirsium arvense* L. Scop. In these cases, the use of adjuvants would be advisable. Despite the negative results obtained with AI regarding the sprouting of *C. rotundus*, this nozzle provided good results in percentage control (figure 3, page 343) (although not significant) and on the number of reproductive structures (table 4, page 345).

Conclusions

With the wind conditions of the experiments, the amount of glyphosate that reached the vine plants via drifting caused the same visual toxicity damage and reduction of plant dry matter (aerial and roots), independently of the nozzle type used. The possible drift effect was diminished by lowering altitude of the nozzle. However, a higher concentration of herbicide generated greater visual toxicity damage in the plants.

Visual toxicity damage gradually increased from 7 to 28 DAA, with a decrease between 36 and 42 DAA.

Even though the weeds were on the edge of the application band, all the nozzles presented a good control of weeds on 42 DDA, measured by either mean foliar and root dry weight, or by re-growth of vegetative structures. However, differences were not significant. Regrowth of *C. dactylon*, was observed due its creeping habit, with many leaves per stolon. The two nozzles with bigger drops (DG y AI) achieved better coverage and thus obtained a better control of this weed. While for *S. halepense* y *C. rotundus*, the nozzles with median sized drops (DG y TT) achieved minor regrowth, as they were not too small for bad coverage and not too big to drip through vertical leaves.

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