Comparison of Airborne and Ground Spray Deposits with Hollow Cone Nozzle, Low Drift Nozzle and Drift Retardant

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ABSTRACT

Information is lacking on spray techniques to reduce off-target loss on the ground and via spray drift from the treated area in nursery applications. Airborne deposits at three elevations on sampling towers and on the ground at several distances from the sprayer were investigated with the three spray treatments in an open field without crops. Tests were conducted with an air blast sprayer equipped with conventional hollow cone nozzles (HC), low drift nozzles (AI), and conventional hollow cone nozzles with a drift retardant (HCDR) in an open field without crops. To compare field test results, wind tunnel experiments were conducted to assess spray deposits on the floor beyond 0.4 m downwind distance from the nozzles and airborne deposits at 2.1 m downwind from the spray discharge point with the three spray techniques. Droplet size distributions across spray patterns were measured with a laser particle/droplet image analysis system. There was no significant difference in airborne deposits for the three elevations at both 15 and 30 m downwind from the sprayer between AI and HC methods except for 3.05 m elevation at the 15 m distance although the average airborne deposits with AI were lower than that with HC. The downwind spray deposits on the ground at 15 and 30 m from the sprayer with AI were higher than that with HC and HCDR. Compared with conventional hollow cone nozzles, drift reduction from air induction nozzles or the spray mixture with drift retardant was significant in wind tunnel tests but was not significant in field tests.

***Keywords**: Spray nozzles, Air induction nozzles, Air blast sprayer, Drift, Nursery crops*

INTRODUCTION

Applications of pesticides and other production strategies have ensured adequate and high quality food, fiber, floral and nursery crops to meet the wide variety of canopy structure characteristics, growing circumstance, and marketing requirements. Transport of spray to target plant surfaces with high quality atomization is essential to ensure effective spray application in crop protection. Little information is available on nursery crop production practices whereby applications of required amounts of pesticides achieve effective pest and disease control with minimum chemical loss. Spray trials with drift retardants or air induction nozzles used for nursery tree applications have not been reported in the literature. Questions remain whether drift retardants and air induction nozzles have potential advantages over conventional nozzles in field crops and nurseries, and whether performances similar to air induction nozzles can be achieved by using conventional nozzles with larger orifices and/or operating the sprayer at lower pressure.

Drift retardants were reported to reduce spray drift in many laboratory studies (Ozkan et al., 1992; Smith, 1993). Laboratory tests indicated that drift retardants could increase the volume median diameter of spray initially, but most polymer based drift retardants lost effectiveness when recirculated through pumps (Bouse et al., 1988; Reichard et al., 1996; Zhu et al. 1997). Although there are some disadvantages associated with adding drift retardants to spray mixtures, some nursery growers have expressed interest in using these chemicals if they can reduce potential drift damages to adjacent crops, or contamination of nearby residential areas.

During the past decade, several types of hydraulic low-drift nozzles (also called “air induction nozzles”) were introduced into the market for improving pesticide delivery methods and reducing drift. Most air induction nozzles were configured with two small holes on the nozzle chamber upstream from nozzle orifices. These nozzles have been reported to produce higher volume deposits at lower part of canopies (Zhu et al., 2004) because they could produce greater portion of large droplets than conventional hydraulic nozzles (Koch et al., 2001). Some reports indicated these "low-drift" nozzles did not significantly reduce drift in orchards (Heijne et al., 2002; Landers, 2000).

The objective of this research was to compare airborne and ground spray deposits from an air blast sprayer with conventional hollow cone nozzles, conventional hollow cone nozzle applying a drift retardant spray, and air induction nozzle under both field and wind tunnel conditions.

MATERIALS AND METHODS

Deposits in field. Airborne and ground spray deposits were conducted with a model 1500 air blast sprayer (Durand-Wayland, Inc., LaGrange, GA), operated with five identical nozzles equally spaced on one side of the 0.91-m diameter air outlet. The sprayer produced 40 m/s average air velocity near the nozzles. Spray deposits on the ground and air were compared with three different spray treatments: hollow cone nozzles with water only (HC), hollow cone nozzles with water and a drift retardant (HCDR), and air induction nozzles with water only (AI). Nozzles used for HC and HCDR were five conventional hollow cone nozzles (D5-45, Spraying Systems Co., Wheaton, IL), and nozzles used for AI were five flat fan air induction nozzles (AI110-08, Spraying Systems Co., Wheaton, IL). The flow rate from the sprayer was maintained at 24 L/min for all three methods. To obtain the 24 L/min flow rate, the spray operating pressure was adjusted to 1660 kPa for HC and HCDR, and 830 kPa for AI. The sprayer travel speed was 6.4 km/hr at which the application rate was 700 L/ha if both sides of the sprayer were used.

The spray mixture used in two trials was 3 g of Brilliant Sulfaflavine (MP Biomedicals, Inc., Aurora, OH) per liter of water for HC, HCDR and AI. For HCDR, the spray mixture was additionally mixed with STA-PUT$_{TM}$ drift retardant distributed by Helena Chemical Company (Collierville, TN). The drift retardant was liquid formulation with 1% polyvinyl polymer as active ingredient. Concentration of the drift retardant used in the test was 0.49% (v/v).

Airborne spray deposits were determined at three elevations and four distances downwind from the sprayer in an open field without any crops. The field was 200-m long and 30-m wide, and was surrounded by nursery crops. Airborne spray deposits were collected with 20x20 cm nylon screens (Filter Fabrics Inc., Goshen, Ind.) at elevations of 0.91, 1.83 and 3.05 m and distances of 15, 30, 60, and 90 m downwind from the sprayer (Figure 1). At each of the four distances, three vertical towers of 3.20 m height were used to mount screens at three different elevations.

Spray deposits on the ground were collected with 5-cm wide and 245-cm long plastic tapes at 7.5, 15 and 30 m from the sprayer.

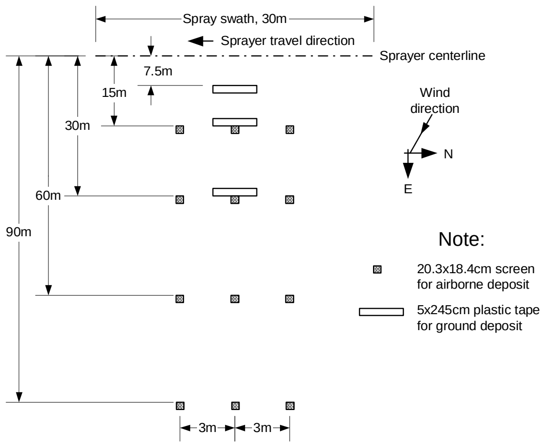

Figure 1. Locations of samples to collect airborne and ground deposits at different distances downstream from the spray line in an open area in the field

A portable weather station was used to monitor wind velocity and azimuth at one-second interval trials in the field. Table 1 lists the average wind velocity and azimuth and their coefficients of variation during the period of sprayer passing the spray swath. Wind directions were almost the same but the wind velocity varied considerably for HC, HCDR and AI.

Table 1. Mean wind velocity and azimuth during field tests with HC, HCDR, and AI during airborne and ground deposit measurements in the field. Coefficients of variation were given in parentheses

Items	HC	HCDR	AI
Velocity (m/s)	2.3 (41)	1.8 (46)	1.3 (31)
Azimuth[a] (degree)	308 (7)	311 (5)	306 (8)

[a] Wind velocity angle measured clockwise from the north to wind direction.

All field target samples were collected 15 minutes after each spray, and placed in clean glass bottles. Spray deposits on all sampling targets were washed with distilled water after they were brought to the laboratory and then were determined with a Model LS 50B luminescence spectrometer (Perkin-Elmer Limited, Beaconsfield, Buckinghamshire, England) for peak fluorescent intensity analysis.

Field data were analyzed by one way ANOVA, and differences among means were determined with Duncan's New Multiple-Range Test. All differences were determined at the 0.05 level of significance.

Deposits in wind tunnel. To compare with field tests, drift potential of HC, HCDR and AI at wind velocities of 1.0, 2.5 and 5.0 m/s was determined in a wind tunnel with 3.7 m long, 0.61 m wide and 0.91 m high test section (Figure 2). Details of the structure of the wind tunnel and measurement of wind velocity were described by Reichard et al. (1992). The nozzles were mounted in the test section of the wind tunnel at 0.67 m above the wind tunnel floor, midway across the width of the tunnel and 2.5 m upwind from the downstream end of the test section. For the AI nozzle, the long axis of the spray pattern from the nozzle was across the width of the tunnel. A 5-cm thick sponge panel was mounted on each sidewall of the wind tunnel to prevent droplets rebounding from the sidewall to the test section. Flow to nozzles was controlled with a solenoid valve. A timer was used to keep the valve open five seconds during each test. Liquid was delivered to the nozzle at 830 kPa for AI and 1660 kPa for HC and HCDR from a diaphragm pump. The same spray mixtures used in field tests were used in the wind tunnel.

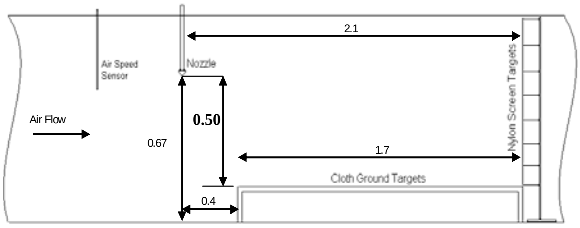

Figure 2. Wind tunnel setup for evaluation of airborne and ground spray deposits at wind velocities of 1, 2.5 and 5.0 m/s. Dimensions in meters but not to scale

A combination of 1.70-m long and 0.10-m wide strips of a muslin fabric and plastic were used to collect spray drift downwind from the nozzle. The plastic strip covered the upper surface of a 1.70 m-long, 0.10-m wide and 1.9-cm thick plywood board, and the fabric strip was evenly divided into 17 pieces that were clipped over the top of the plastic to the plywood. The plastic strip prevented spray deposits transferring from the fabric to the plywood. The target was placed in the center of the wind tunnel and with its long axis parallel to the wind direction. The upwind side of the target was placed 0.40 m downstream from the nozzle to avoid collecting unusually large droplets during the brief period of starting or stopping spray.

A nylon screen strip with seven 10x10 cm pieces was hung vertically at the downstream end of the plywood to collect samples of airborne droplets above the downstream end of the fabric strip for each test.

The combination of each 10x10 cm fabric and plastic sample was placed into a clean glass bottle and each screen sample was placed in another clean bottle at 5 minutes following each spray run. The fluorescence intensity of each sample was then determined with the Model LS 50B luminescence spectrometer. Each test was repeated three times. Data were averaged from three replications for each test condition.

Droplet size measurement. Droplet sizes from nozzles for AI at 830 kPa, and HC and HCDR at 1660 kPa which were similar to wind tunnel test settings were measured with the VisiSizer particle/droplet image analysis system (Oxford Lasers, Oxfordshire, UK). Droplet size distributions were determined at 0.5 m below the nozzle orifice across the spray pattern width with 5 cm interval.

RESULTS AND DISCUSSION

Airborne and ground deposits in field. Screen collectors for 0.91, 1.83 and 3.05 m elevations at 15 m downwind from the sprayer in the field collected most airborne deposits from AI, HC and HCDR among the four different downwind sample locations (table 2). There was no significant difference in airborne deposits for the three elevations at both 15 and 30 m downwind from the sprayer between AI and HC methods except for 3.05 m elevation at the 15 m distance although the average airborne deposits with AI were lower than that with HC. However, with the same screen collector locations, HCDR had significantly higher airborne deposits than AI and HC. At 61 and 91 m downwind distances, the airborne spray deposits at the three elevations were very low and not significantly different among the spray methods with AI, HC and HCDR.

In conjunction with the airborne spray deposits, figure 3 shows downwind spray deposits on ground plastic tapes at three distances from the air blast sprayer in field 2 for AI, HC, and HCDR, respectively. At 7.5 m downstream from the sprayer, the downwind spray deposits on the ground were 0.34, 0.68, and 0.92 $\mu L/cm^2$ for AI, HC, and HCDR, respectively while they were 0.29, 0.11, and 0.23 $\mu L/cm^2$ at 15 m from the sprayer. The downwind spray deposits on the ground at 15 and 30 m from the sprayer with AI were higher than that with HC and HCDR. At 15 m downwind from the sprayer, there were more airborne deposits at all three elevations than ground deposits for HC and HCDR while it was opposite for AI.

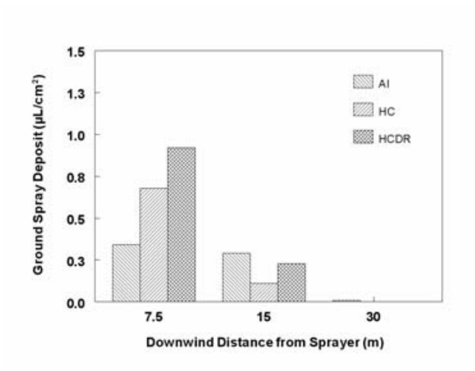

Figure 3. Downwind spray deposits on the ground at three distances downstream from the air blast sprayer with AI, HC and HCDR in the field

Statistical analysis indicated that the wind velocity during the airborne spray test with HC was significantly higher than that with AI and HCDR while difference in wind velocities for treatments between AI and HCDR was not significant. However, the spray mixture with drift retardant in the field had the highest airborne spray deposits among the three spray methods. Zhu et al. (1997) reported nonionic polymer drift retardants could lose their effectiveness and performed almost the same as water after 2 to 3 recirculations through a centrifugal pump. The laboratory measurements illustrated that the average $D_{V.1}$, $D_{V.5}$ and $D_{V.9}$ of droplets on the main spray sheet 0.5 m below the nozzle orifice from HCDR were slightly higher than HC (table 3), and the $D_{V.5}$ at locations within 10 cm from the nozzle centerline for both HC and HCDR was almost equal and ranged from 30 to 82 µm (Figure 4). Bouse et al. (1988) reported increases in portions of spray volume in both droplet diameter smaller than 99 µm and larger than 415 µm for water soluble polymer drift retardants discharged by conventional hollow cone nozzles in the air flow of 53 m/s.

Table 3. Average spray droplet sizes at 0.5 m below the nozzle orifice for AI across 90 cm spray pattern width at 830 kPa, and HC and HCDR across 5 cm main spray sheet at 1660 kPa without air blast

Nozzle	Average Droplet Size (µm)		
	$D_{V.1}$	$D_{V.5}$	$D_{V.9}$
AI[a]	158	407	824
HC[b]	150	202	290
HCDR[c]	157	222	332

[a] AI – Air induction nozzle with water only
[b] HC – Hollow cone nozzle with water only
[c] HCDR – Hollow cone nozzle with water and drift retardant

Table 2. Average airborne deposits on screens at three elevations and four downwind distances from the sprayer with three spray methods in the field. Coefficients of variation that is standard deviation divided by mean were given in parentheses

S[a]	H[b]	Spray deposit (µL/cm²)		
(m)	(m)	AI[c]	HC[d]	HCDR[e]
15	0.91	0.263 (37)b[f]	0.418 (62)b	0.807 (16)a
15	1.83	0.174 (61)b	0.389 (95)ab	0.641 (30)a
15	3.05	0.066 (33)b	0.359 (119)a	0.561 (29)a
30	0.91	0.002 (97)b	0.006 (110)b	0.104 (53)a
30	1.83	0.001 (120)b	0.014 (104)b	0.081 (56)a
30	3.05	0.002 (130)b	0.011 (87)b	0.073 (69)a
61	0.91	0.000 (173)a	0.001 (105)a	0.000 (23)a
61	1.83	0.000 (90)a	0.001 (156)a	0.000 (95)a
61	3.05	0.000 (173)a	0.001 (130)a	0.000 (82)a
91	0.91	0.000 (173)a	0.000 (26)a	0.000 (43)a
91	1.83	0.000 (91)a	0.000 (96)a	0.000 (132)a
91	3.05	0.000 (152)a	0.000 (85)a	0.000 (151)a

[a] Downwind distance
[b] Elevation
[c] AI – Air induction nozzle with water only
[d] HC – Hollow cone nozzle with water only
[e] HCDR – Hollow cone nozzle with water and drift retardant
[f] Means in a row followed by different letters are significantly different ($p<0.05$).

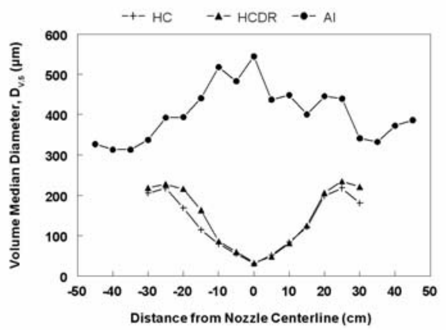

Figure 4. Comparison of volume median diameter ($D_{V.5}$) across spray pattern width 0.5 m below the nozzle orifice for HC and HCDR at 1660 kPa and AI at 830 kPa under laboratory conditions without air blast

Likewise, the air induction nozzles did not provide significant drift reduction, compared to using the conventional hollow cone nozzles in the field. For water droplets, the critical relative velocity at which the droplet will continue to breakup is given by the equation (Lefebvre, 1989),

$$U_R = \frac{784}{\sqrt{D}} \quad (1)$$

where, U_R is the critical relative velocity in m/s and D is droplet diameter in micrometers. For the air blast sprayer, the air velocity near the nozzle is about 40 m/s as indicated above. According to equation (1), any droplets larger than 350 µm in diameter from AI, HCDR and HC would be further breakup by the aerodynamic pressure produced by the parallel air flow from the air blast sprayer. Data in table 3 illustrate that more than 50% of droplets from AI at 830 kPa was larger than 403 µm, and more than 90% of droplets from HC at 1660 kPa was smaller than 290 µm, and more than 90% of droplets from HCDR at 1660 kPa was smaller than 332 µm, respectively. Obviously, a great portion of droplets from AI in the air blast sprayer might have encountered some breakup due to air shearing effect. Therefore, AI and HCDR might not achieve their advantages of producing large droplets as normally claimed to reduce drift potential from the air blast sprayer in the nursery field tests.

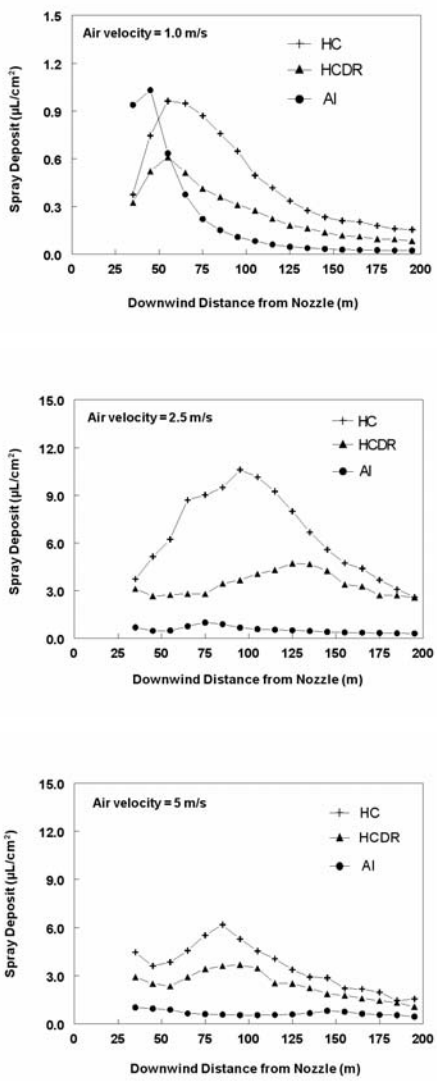

Figure 5. Spray deposits on targets 0.5 m below the nozzle at different horizontal distances downwind from spray discharge point for AI, HC, and HCDR with air velocities of 1.0, 2.5 and 5.0 m/s in wind tunnel

Airborne and ground deposits in wind tunnel.

In contrast to the field tests, the wind tunnel test showed that AI had the lowest downwind spray deposits on the floor between 0.4 and 2.1 m from the spray discharge point at 1.0, 2.5 and 5.0 m/s wind velocities among the three spray methods, followed by HCDR, and then HC (Figure 5). For example, at 1.0 m downwind from the nozzle, the average spray deposit on the floor from HC was 2.0 times higher than HCDR and 5.9 times higher than AI at 1.0 m/s air velocity, and was 2.7 times higher than HCDR and 16.4 times higher than AI at 2.5 m/s air velocity, respectively.

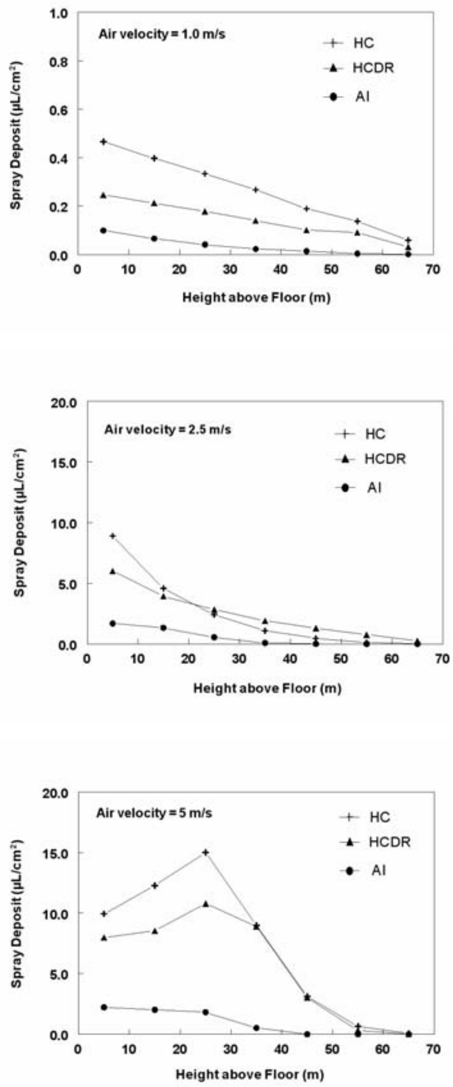

Figure 6. Downwind airborne spray deposits on screens at different heights above the floor in wind tunnel for AI, HC, and HCDR with air velocities of 1.0, 2.5 and 5.0 m/s. The horizontal distance between spray discharge point and screens was 2.1 m

Similarly, the AI had the lowest airborne spray deposit on screens at 2.1 m downwind from the nozzle at 1.0, 2.5 and 5.0 m/s wind velocities among the three spray methods, followed by HCDR, and then HC (Figure 6). The average total airborne deposit on the nylon screens from HC was 1.8 times higher than HCDR and 2.2 times higher than AI at 1.0 m/s, and was 1.8 times higher than HCDR and 11.0 times higher than AI at 2.5 m/s, respectively. However, at 2.5 m/s air velocity, HCDR had higher airborne deposits on screens than the HC when the screen height was 25 cm and higher (Figure 6). The airborne deposits decreased as the screen height increased for all HC, HCDR and AI.

The spray deposits on the floor at 2.5 m/s wind velocity was the lowest while airborne deposits on screens at 5.0 m/s wind velocity was the highest among the three wind velocities for HC, HCDR and AI (Figures 5 and 6). Amount of airborne deposits beyond 2.1 m downwind from the spray discharge point increased as the wind velocity increased.

There was great disagreement in drift potentials between the wind tunnel and field tests. In wind tunnel conditions, the volume median diameter ($D_{V.5}$) of droplets from AI and HCDR at 0.5 m below the discharge point was 1.9 and 1.1 times the $D_{V.5}$ of droplets from HC (table 3). The influence of the fan air velocity from the air blast sprayer on droplet sizes further breaking down in field conditions as discussed above was not the case in the wind tunnel test. Also, the spray direction in wind tunnel was perpendicular to wind direction and was vertically toward the floor. Therefore, the wind tunnel test data represented performances of the HCDR and AI only in the laboratory conditions but not for the whole field conditions.

CONCLUSIONS

1. Field tests indicated although average airborne deposits with AI for elevations of 0.91 and 1.83 m at 15 and 30 m downwind distances from the sprayer were higher than deposits from HC, but statistically they were not significantly different. At the same locations, HCDR had significantly higher spray airborne deposits than AI and HC. Downwind spray deposits on the ground at 15 and 30 m from the sprayer with AI were higher than that with HC and HCDR.
2. In the wind tunnel, spray deposits on the floor at 2.5 m/s wind velocity was the lowest while airborne deposits on screens at 5.0 m/s wind velocity was the highest among the three wind velocities for HC, HCDR and AI.
3. Spray drift potential from the wind tunnel experiments did not agree with the results from the field experiments. Wind tunnel tests indicated that using drift retardant or air induction nozzles could considerably reduce spray drift, but field tests indicated there was no significant difference in airborne and ground deposits among AI, HC and HCDR at wind velocity less than 3 m/s.

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