Cyclic Irrigation and Grass Waterways Combine to Reduce Isoxaben Losses from Container Plant Nurseries[1]

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Abstract

This study evaluated the remediating effects of the combination of cyclic irrigation and grass waterways on pesticide loads in runoff water. Cleary's 3336 (thiophanate-methyl), Dursban (chlorpyrifos), and Snapshot TG (trifluralin plus isoxaben) were applied to container nursery beds. The two treatments were continuous irrigation (90 min duration) with runoff emptying through a clay/gravel waterway and cyclic irrigation (three 30 min cycles with 90 min between cycles) with runoff emptying into a grass waterway. Samples of runoff water were collected at the end of the waterways on the day of application and 1, 2, 4, and 8 days after application. Cyclic irrigation reduced runoff water volume 15% compared to continuous irrigation. All pesticides were detected in runoff water on the day of application from both treatments. Isoxaben was detected in runoff water through 8 days after application from both treatments. Isoxaben concentrations and amounts were reduced by the cyclic irrigation/grass waterway treatment on the day of application and as a total for the duration of the study.

Index words: bermudagrass, preemergent herbicide, remediation, runoff water.

Chemicals used in this study: Cleary's 3336, (thiophanate-methyl), dimethyl 4,4'-o-phenylenebis (3-thioallophanate), Dursban, (chlorpyrifos), O, O-diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothioate, and Snapshot TG, (isoxaben and trifluralin), *N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide; a, a, a- trifluoro-2,6-dihitro-*N*, *N*-dipropyl -*p*-toluidine.

Significance to the Nursery Industry

Grass waterways and cyclic irrigation appear to be a means of reducing herbicide losses in runoff water. Cyclic irrigation also reduces the total volume of runoff. Smaller pesticide losses will reduce the possibility of contamination of downstream waters. Smaller runoff losses reflect increased efficiency in irrigating container plants.

Introduction

During the production of containerized plant material pesticides are applied in quantities sufficient to control weeds and to prevent plant injury from insects and pathogens. A majority of the broadcast or spray applied product will land on non-target surfaces (2), and is subject to movement from the application site in runoff waters created by overhead irrigation. Herbicides have been detected in runoff water and in containment pond water and sediments at container nurseries (4, 7). Isoxaben amounts totaling 13% of the applied volume were reported to move from the application site within 5 days of application at a container nursery (9). A fungicide and insecticide were detected in runoff water when overhead irrigation closely followed application (1).

Pesticide amounts in runoff water are reduced when effluent is channeled through vegetated filter strips or grass waterways. Atrazine losses from agricultural fields were reduced 55% when runoff water was directed into a grass filter strip (6), and isoxaben losses were 16% lower on the day of application in runoff water that passed through a bermudagrass waterway at a container nursery (1).

Reducing irrigation volume following pesticide application should be an effective tool in reducing pesticide losses. Cyclic or pulse irrigation is defined as a sequence of timed cycles composed of an irrigation phase and a resting phase (3). Smaller volumes of irrigation are applied at more frequent intervals reducing runoff amount and conserving water resources. Cyclic irrigation reduced NH_4-N losses and effluent volume in container-grown plants (8). The objective of this study was to investigate the effects of combining cyclic irrigation and grass waterways on reducing pesticide amounts in runoff water at a container nursery.

Materials and Methods

Research was conducted at a wholesale container plant nursery in the northwestern region of South Carolina. The nursery has an isolated [2 ha (4.6 A)] growing area that slopes uniformly (approximately 5%) and unidirectionally so that runoff waters can be easily channeled. The site contains eight growing beds each 18 m (60 ft) by 90 m (300 ft) divided by gravel roadways and the production surface is landscape fabric overlaid on plastic. Nursery beds contained a variety of woody landscape species in 10 liter containers spaced 50 cm (20 in) apart over the course of the study.

A hybrid bermudagrass *(Cynodon dactylon* x *C. transvaalensis*) waterway [1.8 m (6 ft) × 90 m (300 ft)] on a 5% slope was installed downslope of four adjacent growing beds in the summer of 1994. Runoff from the other four beds was directed onto an existing clay and gravel roadway which through the placement of berms created a 1.8 m (6 ft) × 90 m (300 ft) waterway. Waterways were 9 m (30 ft) below the beds with the clay and gravel roadway in between. Weirs (90°) were placed at the end of both waterways to allow determination of runoff volumes and for sample collection (Fig. 1).

Cleary's 3336 (thiophanate-methyl), a systemic fungicide, and Dursban (chlorpyrifos), an organophosphate insecticide, were applied to the growing area with an air-blast sprayer at the rate of 0.55 kg ai/ha (0.5 lb ai/A). After spray residue had dried, Snapshot TG (trifluralin plus isoxaben), a preemer-

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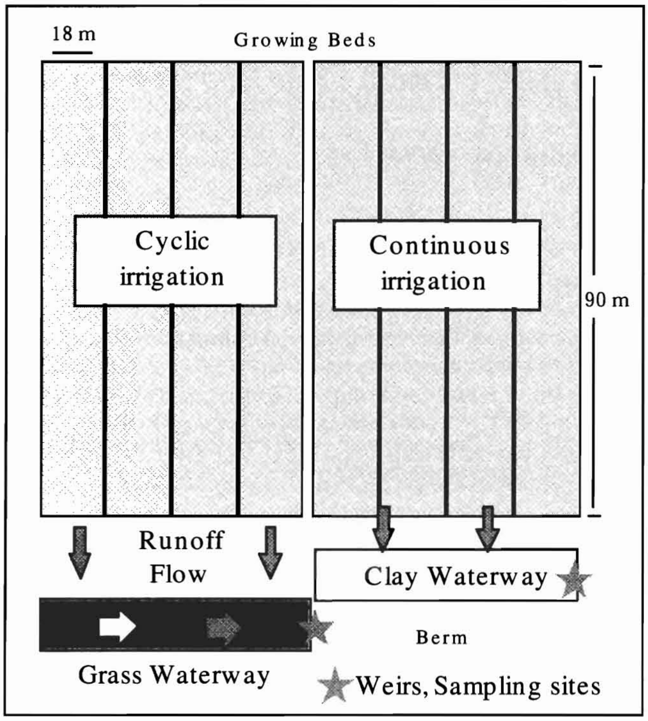


Fig. 1. Site layout of nursery research site.

gent herbicide, was broadcast at rates of 4 kg ai/ha (3.6 lb ai/A) trifluralin and 1 kg ai/ha (0.9 lb ai/A) isoxaben with handheld spreaders. The section of the growing area directed into the clay and gravel waterway was immediately irrigated for 1.5 h [1.9 cm (0.75 in) irrigation]; the section bordered by the grass waterway was irrigated by three 30-min cycles [0.6 cm (0.25 in) irrigation per cycle] with a 90-min interval between cycles, also beginning immediately after treatment. Runoff samples were collected on the day before application, the day of application and 1, 2, 4, and 8 days after application. A 400-ml sample was taken at the beginning of runoff [defined as head of water at weir = 2.54 cm (1 in)] and at 20, 40, 60, 80 and 100 min of runoff flow from the clay and gravel waterway. Samples from the grass waterway were taken at the beginning of runoff (defined as above) and after 20 min of flow for each of the cycles. Samples were collected in silanized glassware (5) and were transported on ice and stored at 4C (39F) until extracted. Two pesticide applications were made, in August and October, 1996.

Extraction and analysis. The pH of water samples was adjusted to 2.2–2.3, to fully protonate hydroxyl side chains, using 6N HCl. Duplicate 150-ml (5-oz) aliquots were filtered through Whatman #5 qualitative paper on a Buchner funnel, and extracted using C_{18} solid phase columns (Burdick and Jackson, 500 mg), that had been activated with 10 ml acetone, followed by 10 ml distilled deionized water, using a vacuum manifold (7). Samples were eluted with 2 ml acetone and filtered through 0.2 µ nylon acrodiscs (Gelman) prior to placement in autosampler vials. Analysis was performed utilizing a Hewlett Packard 1090 HPLC fitted with a C_{18} reverse phase column (Rexchrom S3-100-ODS, 3µm, 100A). The solvent system was acetonitrile:water with 2% acetonitrile, 50:50 to 80:20 over 20 minutes at a flow rate of 0.5 ml/min, 100% acetonitrile for 20–25 min, and 50:50 starting solvent from 25–30 min. The injection volume was 30 µl, and each sample was injected twice. The diode array detector was set at 206 nm. Percent recoveries and limits of detection are listed in Table 1. Samples were quantified by comparison to standards (20 µg/ml) prepared with analytical grade herbicide.

Table 1. Percent recoveries and limits of detection for pesticides used in study.

Pesticide	Percent recovery (± s.d.)	Limit of detection
		--------- ppb ---------
Thiophanate-methyl	103 ± 15	26
Isoxaben	121 ± 12	36
Chlorpyrifos	88 ± 6	45
Trifluralin	78 ± 6	51

Total amount of pesticide detected in runoff water was calculated by multiplying runoff volume by concentration for specific sampling times. Runoff volume was determined by measuring the height of flow at the weir and calculating discharge in liters per second by the equation $Q = KH^{2.5}$ (Q = flow rate, l/s; H = head on weir (cm); K = 13.8, a constant specific for units of measurement and weir angle notch). Sample data from the two replications in time were combined and means were analyzed (ANOVA) using the General Linear Models Procedure.

Results and Discussion

Runoff volume from the cyclic treatment averaged 29,900 liters (7900 gal), or approximately 60% of the irrigation volume. Volumes were lowest from the first cyclic cycle (6800 liters; 1800 gal), highest for the intermediate cycle (11733 liters; 3100 gal) and slightly lower in the last cycle (11,355 liters; 3000 gal), perhaps because of greater evaporation potential later in the day (Fig. 2). Runoff volume from the continuous irrigation treatment averaged 35,200 liters (9300 gal), 71% of applied amount (Fig. 2). Cyclic irrigation reduced the total volume of runoff by 15% compared to continuous irrigation.

Analysis of runoff samples taken on the day before application indicated no detectable pesticide residues for either

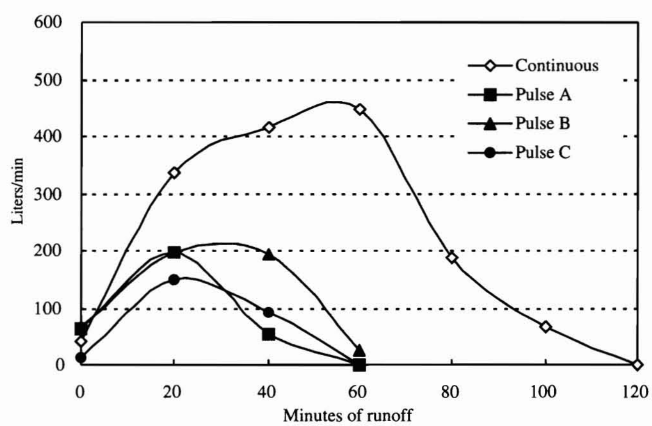
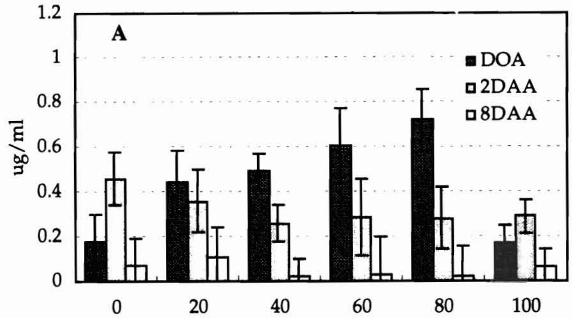


Fig. 2. Runoff volume in liters per minute by runoff duration in minutes for the continuous and cyclic irrigation treatments.



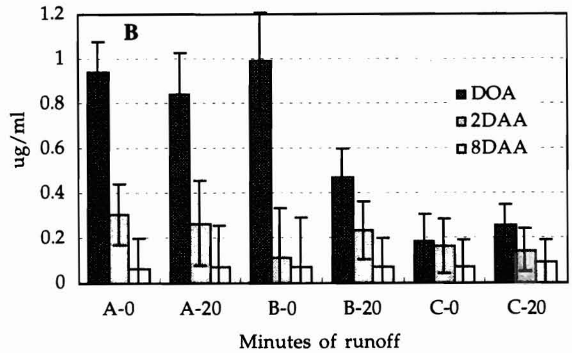


Fig. 3. Isoxaben concentrations in µg/ml on the day of application (DOA), and 2 and 8 days after application (DAA), for minutes of runoff duration. A. Continuous irrigation. B. Cyclic irrigation/grassed waterways (A = first cycle; B = second cycle; C = third cycle). Vertical bars represent ± SE.

replication. All applied pesticides were detected on the day of application in runoff samples from continuous irrigation and from the first cyclic sample. Greatest concentration of isoxaben detected was 1.19 µg/ml from the first cyclic sample and greatest concentration of thiophanate-methyl detected was 0.67 µg/ml from the 80 min continous irrigation sample. While trifluralin and chlorpyrifos were detected in runoff water, concentrations approached the limit of detection of analytical equipment. Trifluralin and chlorpyrifos were detected on the day of application in runoff samples through 80 min from the continuous irrigation treatment and in only the initial cyclic sample. Thiophanate-methyl was detected in all cyclic and continuous irrigation samples on the day of application only. Isoxaben was detected through 8 days after application in all runoff samples with amounts decreasing on each subsequent sampling days and approaching the limit of detection by the end of the study (Fig. 3).

Isoxaben concentration was higher in the cyclic irrigation/grass waterway treatment in early samples (when runoff volumes were the lowest), on the day of application, but lower for the last sample (B-20) of the second cycle and for both samples of the third cycle (Fig. 3). Concentrations of isoxaben were consistently lower on other sampling days from the cyclic/grass waterway treatment than the continuous irrigation treatment. Concentrations of thiophanate-methyl, chlorpyrifos and trifluralin were not different between the treatments (data not shown).

The total amount of isoxaben detected in runoff water on the sampling days was 45g (9% of applied) from continuous irrigation and 31g (6% of applied) from the cyclic/grass waterway treatment (Table 2). Wilson et al., (9) detected 11% of applied isoxaben as transported in runoff water within five days of application. Isoxaben losses were 23% of amount applied when the volume of irrigation following herbicide application was 50% greater than in this study (1). Total isoxaben amounts that moved in runoff water were reduced 30% by the cyclic irrigation/grass treatment. On the day of application isoxaben amounts from the cyclic irrigation/grass treatment were 66% of the amount recovered from the continuous irrigation treatment.

Total amounts of thiophanate-methyl recovered were 7 g (2.1% of applied) from the continuous irrigation treatment and 5 g (1.5% of applied) from the cyclic irrigation/grass waterway treatment. In a study in which irrigation volume following application was 50% greater than in the current research, 13% of applied thiophanate-methyl was lost (1). Total amounts of trifluralin and chlorpyrifos recovered were less than 0.01% of applied from both treatments. Negligible quantities of chlorpyrifos and trifluralin detected in runoff water correspond to earlier research (1, 9). Reductions by the cyclic irrigation/grass waterway treatment in total amounts of isoxaben and thiophanate-methyl recovered are attributable to reduction in runoff volumes from the cyclic treatment.

In a recent field study investigating the remediation potential of vegetated waterways utilizing continuous irrigation, grass waterways reduced losses of isoxaben in runoff water on the day of application as compared to clay/gravel waterways (1). However, overall losses were similar for a grass and clay/gravel waterway through 8 days after application, as amounts detected from the grass waterway treatment exceeded those from the clay/gravel waterway on subsequent sampling days. The combination of grass waterways and cyclic irrigation reported in the current study reduced losses of isoxaben on the day of application and as a total amount for the sampling period.

Table 2. Total grams of isoxaben in runoff water on 0, 1, 2, 4, and 8 days after application, and total losses in runoff water for the study.

	Days after application					
Irrigation regime	**0**	**1**	**2**	**4**	**8**	**Total**
	g					
Continuous irrigation	18.9	9.6	10.4	4.2	2.1	45.3
Cyclic irrigation/ grass waterway	12.5	6.6	6.7	3.3	2.3	31.5
LSD ($P = 0.05$)	5.9	13.7	5.5	2.9	4.5	9.8

The combination of grass waterways and cyclic irrigation appears to be an effective means of reducing movement of readily transportable herbicides in runoff water. Vegetative waterways are effective in reducing losses on the day of application or until soil saturation is reached (1). When grass waterways are combined with a cyclic irrigation regime total losses of herbicides in runoff water are mitigated.

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Cold Hardiness of Weigela Cultivars[1]

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Abstract

Laboratory freezing tests of stem hardiness were conducted to develop cold hardiness profiles for 18 weigela (*Weigela* sp.) cultivars during the fall and winter of 1994–95. Tests were performed on containerized plants held in a temperature-controlled greenhouse to prevent exposure to potentially lethal temperatures. No cultivar survived below –6C (21F) in the October 3 test. Subsequent differences in rates of acclimation resulted in cultivars differing in hardiness by as much as 13C (23F) on November 14. Taxa also differed greatly in their maximum midwinter low temperature tolerance with 'Centennial' and 'Eva Supreme' hardy to –44C (–47F) and –28C (–18F) in mid-January, respectively. None of the cultivars deacclimated substantially in response to a week of artificially-imposed diurnal freeze/thaw cycles in early February. Taxa with the greatest midwinter hardiness also maintained the greatest hardiness in early March. Overall, 'Centennial', 'Java Red', and ' Samba' were the most cold hardy cultivars tested, while 'Boskoop Glory', 'Bristol Snowflake', and 'Variegata' were the least hardy. Cold injury of susceptible weigela cultivars appears to be a consequence of late hardening and/or insufficient midwinter hardiness rather than rapid deacclimation in response to periods of warm temperatures in mid- to late-winter.

Index words: woody plant, freeze tolerance, acclimation, deacclimation.

Significance to the Nursery Industry

Weigela cultivars provide a useful option for landscape professionals and gardeners seeking pest-resistant, summer-flowering shrubs adapted to a range of growing conditions. However, the limited cold hardiness of some cultivars predisposes them to considerable winter injury in northern climates. We found substantial differences in hardiness among 18 cultivars evaluated and have identified those cultivars best suited to cold environments. Our results underscore the importance of rigorously evaluating the cold hardiness of new introductions. Production and marketing of cold tolerant cultivars for use in northern states will result in reduced maintenance pruning, higher survival rates and lower replacement costs, and improved customer satisfaction.

Introduction

The genus *Weigela* is comprised of approximately 12 species of deciduous shrubs as well as numerous interspecific hybrids (1, 2, 8). Valued primarily for their attractive spring floral display, hundreds of cultivars have been selected in the last century with flower colors ranging from pure white to ruby red (8). Of these, only a few dozen are readily available from commercial growers (11).

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