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Non-Target Deposition of Methiocarb Applied to a Foliage Plant Staging Area

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Abstract

Foliage plant production is one of the fastest growing agricultural commodities in the US and parts of the world. Application of spray-applied pesticides is necessary in order to produce marketable crops. However, due to inefficiencies in spray application, significant amounts of active ingredient may land on surfaces other than the intended plant. This study characterized non-target deposition of a spray-applied pesticide, methiocarb, on ground surfaces associated with a foliage plant production nursery. Methiocarb was applied to four different production scenarios within a commercial nursery using an air-cannon sprayer. Deposition on ground surfaces was measured using Teflon spray targets placed at intervals throughout the length of the rows and aisles. Results indicated that from 15.9 – 29.7% of the applied pesticidal active ingredient may be deposited on non-target ground surfaces within typical foliage nursery situations. Deposition was generally greater in aisles that were not covered by foliage. Results also demonstrated significant differences in deposition due to differing plant forms, ranging from 15.9% for the loose, large-leaved LP to 28.1% for the small-leaved, tight canopied SF. While this study focused only on methiocarb, results may also be applicable for any pesticide that is spray-applied using an air-cannon type of sprayer.

Introduction

Foliage plant production represents a significant economic impact throughout the U.S. and the more affluent portions of the world. Since World War II, the tropical foliage industry has been one of the fastest growing segments of American agriculture, increasing from a wholesale sales value of approximately $13 million in 1949 to over $700 million in 1997 (Smith, et.al., 1981; Smith, 1980; Greenhouse Grower, 1999). Florida dominates the U.S. market for tropical foliage, with over $386 million in sales (USDA-NASS, 1998). The demands for foliage plants will likely increase throughout the developed world as consumers have more income available for such luxury consumption.

As the demand for foliage plant production increases, opportunities for significantly impacting environmental resources may also increase due to management practices associated with the increased production intensity. Pesticide inputs and potential effects are of particular concern due to their inherent toxicity to many non-target organisms. Many pesticide application practices are very inefficient in placement of materials only on areas where they are needed. Deposition of pesticides on non-target surfaces results in material, labor, and financial wastes. In addition, non-target deposition can inadvertently expose non-target organisms to the applied pesticide, either directly or indirectly through surface water runoff and/or drift.

Previous studies have shown that broadcast application of granular formulated pesticides can result in significant non-target losses due to pot spacing and plant growth form. Gilliam et al. (1992) reported non-target deposition of granular, broadcast applied herbicides to empty containers ranged from 23-30% when the containers were placed pot-to-pot, and increased to 79-80% when the containers were spaced on 30 cm centers. Mahnken and Sckroch (1992) reported higher herbicide concentrations (relative to per-pot applications) leaving simulated nursery sites that were treated by broadcast applications, and suggested that those higher concentrations were likely due to deposition of the herbicides on ground surfaces surrounding the pots. Numerous studies have reported losses of pesticides in runoff water (Briggs et al., 1998; Briggs et al., 2002; Wilson et al., 1996; Wilson et al. 1995). In all of those studies, pesticide losses were greatest during runoff events that occurred shortly after application.

While some research has quantified non-target deposition of granular formulated pesticides in ornamental nurseries, little work is available on anticipated non-target deposition of spray-applied pesticides. Depending on application rates, greater deposition on non-target surfaces might be expected given the small droplet size and more uniform deposition patterns associated with spray application relative to granular materials. Depending on the water solubility of the pesticide, significant amounts may be available for losses in runoff water.

The objective of this study was to characterize non-target deposition of a spray-applied pesticide under a variety of typical commercial shade-house nursery conditions using methiocarb as a surrogate.

Materials and Methods

Study Location. These studies were conducted at Kraft Gardens, a commercial foliage plant nursery located in Fort Pierce, Florida. Four areas within the nursery were selected to evaluate deposition under two spraying scenarios, 1) spray application from one end for shorter rows (15.2 m), and 2) application from both sides for longer rows (22.4 m). These areas are normally used for staging plants before shipment out-of-state. Since plant architecture, size, and spacing influence non-target deposition, areas were chosen to include three different size classes of Weeping Fig (*Ficus benjamina* 'Monique') and one size of Lady Palm (*Rhapis excelsa*) for evaluation. The Weeping Fig categories included: small ficus (SF), medium ficus (MF), and large ficus (LF). Plant size classes and dimensions are listed in Table 1. The Weeping Figs were trained to a single trunk, while the Lady Palm, a clustering-type palm, had multiple cane-like trunks/stems and palmate leaves with five to ten segments, divided almost to the base. All plants within each section were arranged in staggered rows. The SF and LP rows were 21.9 m (72 ft) long. The LF and MF rows were 15.2 m (49.9 ft) long.

Pesticide. Methiocarb was chosen as a representative pesticide. It is the active ingredient in the commercial formulation of Mesurol® 75-W. Mesurol® (Gowan, Yuma, AZ) is an organophosphate insecticide, miticide, and molluscicide. This pesticide is toxic to fish, birds, and aquatic organisms.

Mesurol® 75-W was mixed at a rate of 0.45 kg (1 lb.) per 379 L (100 gal.) of spray mixture. Mesurol® applications were made using a PTO-driven Berthoud Super Puma 1000 canon airblast sprayer calibrated to deliver 17.8 L (4.7 gal.) of spray mixture per minute at a ground application speed of 0.1 m/sec. (0.23 mph). Applications were made from the only accessible end of the shorter rows (MF and LF), while from both ends of the longer rows for the LP and SF areas.

Measurement of Deposition. Each aisle within the selected blocks was surrounded by a row of plants on either side. Three aisles and three adjacent plant rows were chosen within each block of plants. Non-target deposition of pesticides was measured using 5.08-cm x 5.08-cm (2-in. x 2 in.) Teflon spray targets. Targets were fastened to 10 x 10-cm (4-in. x 4-in.) pieces of cardboard using staples. The cardboard gave structural rigidity to the targets, preventing them from curling up and blowing away as the sprayer passed. The teflon targets were placed at each end of the aisles, and at 5.5 m (18 ft) intervals between the two ends for the SF and LP areas; and at 3.8 m (12.5 ft) intervals for the MF and LF. Targets were also placed at the same distance intervals between the pots within an adjacent row on either side of the aisle.

Following application, each target was placed in a 70 ml polyethylene snap-cap vial, transported to the lab, and stored at -18°C (-0.4°F) until extracted and analyzed. A previous unpublished study indicated better recoveries using plastic rather than glass vials. Methiocarb was extracted from the targets by adding 10 ml of monochloroacetic acid buffer (pH 3) to each vial and then vortexing them for two minutes. The containers were then placed in a sonic water bath for 15 minutes, followed by an additional 2 minutes of vortexing. Extracts were filtered through Millex syringe-driven filters (0.22 µm), diluted 1:20 with monochloroacetic acid buffer, and analyzed using a Waters 2695 high pressure liquid chromatograph (HPLC) equipped with a Waters carbamate column, a post-column reaction module (PCRM), reagent managers, and a Waters 474 fluorescence detector. Operating conditions for the post-column reaction steps and a ternary gradient comprised of water, methanol, and acetonitrile was used as described in EPA Method 531.2. The mobile phase flow rate was 1.5 mL min^{-1}.

Estimation of Total Deposition on Ground Surfaces. Total ground deposition within each aisle-row unit was estimated by averaging adjacent concentrations [i.e. (North edge + 5.6 m(N))/2, (5.6 m (N) + Center (11 m))/2, etc.] and assuming that the calculated average concentration was representative of the deposition within that section of the aisle-row unit. The concentration was then multiplied by the surface area for each representative section (Table 1). The average deposition in each section was then summed to estimate total ground deposition within the aisle-row units. Ground deposition was expressed in terms of the percentage of the total amount applied to each unit. The total amount of methiocarb applied to each aisle-row unit based on the application rate was: 5,228 mg (0.18 oz) for SF; 4,964 mg (0.175 oz) for RP; 5,439 mg for MF; and 4,805 mg for LF.

Statistical Analysis. Depositional data were analyzed to compare 1) depositional differences between row and aisle at each location, 2) depositional differences with distance from sprayer (separately for rows and aisles), and 3) depositional differences between species at each target location (MF vs. LF and SF vs. LP). In all cases, depositional data for the aisle and row target intervals were ranked and subjected to analysis of variance (ANOVA; P=0.05). Means were separated by calculation of least significant differences. For the single-side applications (MF and LF), a linear regression analysis was also conducted to identify significant trends (P = 0.05) in deposition with distance from the sprayer.

Results

Statistical comparisons between deposition within the long and short rows are not possible because of the differences in spray application (i.e. one end vs. both ends of row). For clarity, results are presented separately for each spraying scenario.

Single –Side Spray. Deposition on ground surfaces within the aisles and within the plant rows did not differ statistically at each respective distance from the sprayer for the LF application (Figure 1). Deposition for the LF application ranged from 24 – 43 mg/m^2 and 13 – 46 mg/m^2 within the aisles and rows, respectively. The only statistically significant difference in deposition with distance from the sprayer was observed within the row at the farthest target location (15.2 m), where deposition was approximately 72% lower than at the location closest to the sprayer. While there was no statistically significant differences in deposition with distance from the sprayer for the majority of the target locations, there was a significant decreasing trend in deposition both within the aisles and within the rows (Figure 1). Within the aisle locations, deposition 3.8–15.2 m from the sprayer appeared to be relatively uniform (Figure 1). A stronger decreasing trend was observed for deposition within the plant rows with increasing distance from the sprayer (Figure 1). These differences in depositional trends are expected given the openness of the aisles, and the obstructions within the rows.

Deposition at each respective target location within the aisles and rows for the MF application differed only at the 3.8-m distance from the sprayer (Figure 1). In that case, deposition within the row was 42% less than within the aisle. Deposition for the MF application ranged from 9 – 54 mg/m^2 in the aisles and 11 – 49 mg/m^2 within the plant rows. In both cases, the lowest amount of deposition was observed at the farthest targets.

While deposition within the aisles and rows did not differ statistically at most respective target locations, deposition with distance from the sprayer did. Within the aisles, deposition at 7.6 and 11.4 m from the sprayer was significantly lower than from the edge and at 3.8 m from the sprayer. Deposition at the farthest location (15.2 m) was significantly lower than at any of the other locations. Within the plant rows, deposition from 3.8 m to the farthest location was statistically similar. Converse to the regression results seen with the LF, a stronger decreasing trend in deposition with increasing distance from the sprayer was seen in the aisles, as opposed to within the rows (Figure 1).

A summary of the statistical analysis comparing deposition at each target interval between the LF and MF is shown in Table 2. Deposition at each location was similar between species at each interval within the rows. Likewise, deposition within the aisles was similar between species, except at the farthest target location (15.2 m), where deposition within the MF aisles was 50% less than in the LF.

A summary of the estimated total mass of active ingredient deposited within each section of the rows and aisles, as well as the total amount deposited, is shown in Table 3. As a percentage of the amount applied deposition on ground surfaces within the aisles ranged from 13.6 – 15.9%; compared to 11.1 - 13.8% within the rows.

Double –Side Spray.

No differences in deposition between rows and aisles was observed at each target interval for the SF (Figure 2). Deposition ranged from 25 – 49 mg/m^2 and 21 – 51 mg/m^2 for the aisles and rows, respectively (Figure 2). Within both the aisles and rows, deposition was greatest at the edges and decreased towards the center of the bed. Deposition within the aisles was significantly lower 5.6-m from the edges and at the center of the beds (11-m), ranging from 15 – 48 percent less than at the edges. Within the plant rows, deposition at the center of the beds was approximately 44% less than at the edges. In this case, deposition 5.6-m from both edges was statistically similar to the edges (Figure 2).

Contrary to results for SF, deposition at each respective target location within the aisles and rows for the RP application was statistically similar at the edges only, ranging from 30 – 56 mg/m^2, respectively (Figure 2). Deposition 5.6 m from the edges and at the center of the beds was statistically lower within the rows than in the aisles, ranging from 11 – 20 mg/m^2 and 5 – 8 mg/m^2, respectively. As with SF, methiocarb deposition on ground surfaces decreased with distance from the edges. Within the aisles, deposition 5.6 m from the edges and at the center was significantly lower than at the edges (Figure 2). Deposition within the plant rows was similar at the three center locations. Deposition (within rows) at 5.6-m from the southern end of the rows was also statistically similar to that seen at the southern edge.

A summary of the statistical analysis comparing deposition at each target interval between the SF and LP is shown in Table 2. In this case, significant differences in deposition between species were apparent at each interval. Within the aisles, deposition in the center of the bed and at

5.6 m from the southern end was significantly lower for the LP than at the other locations, relative to SF. Deposition on ground surfaces with SF was from 1.25 – 3 times greater relative to the LP. Within the rows, deposition at the northern end of the row did not differ between species. However, deposition at all other intervals within the row was significantly lower for the LP relative to SF. Deposition within the rows of SF at the 5.6-m and center locations was 2.6 – 7.6 times greater than in the RP block.

A summary of the estimated total mass of active ingredient deposited within each section of the rows and aisles, as well as the total amount deposited, is shown in Table 3. As a percentage of the amount applied deposition on ground surfaces within the aisles ranged from 9.4 – 14.3%; compared to 6.5 - 13.8% within the rows. Within both the aisles and rows, deposition was lower on LP ground surfaces, which might be explained by the increased coverage of ground surfaces by the foliage.

Conclusions

Results from this study indicated that from 15.9 – 29.7% of the applied pesticidal active ingredient may be deposited on non-target ground surfaces within typical foliage nursery situations. Deposition was generally greater in aisles that were not covered by foliage. These results also demonstrated the significant differences in deposition that might be expected due to differing plant forms, ranging from 15.9% for the loose, large-leaved LP to 28.1% for the small-leaved, tight canopied SF. While this study focused only on methiocarb, results may also be applicable for any pesticides that is spray-applied using an air-cannon type of sprayer.

Depending on the pesticide, ground-deposited residues may be available to move off-site in surface runoff water where they may harm non-target fish, birds, and aquatic organisms. Pesticide applicators should be familiar with the toxicity of the pesticide to non-target organisms as indicated on the label or other sources. Applications of very toxic compounds should be made as far in advance of irrigation or inclement weather as possible to allow more time for breakdown and aging of pesticide residues, which may reduce the exposure of non-target organisms. Pesticide application equipment should be calibrated and well maintained to prevent over-application to non-target areas as well as to the crops. Lastly, more efficient application methods are needed to reduce this product wastage and potential risks to non-target organisms.

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Table 1. Study area and plant dimensions.

Measurement	*Ficus benjamina* 'Monique'						*Rhapis excelsa*	
	Small		Medium		Large			
	m (ft)	*SD*	m (ft)	*SD*	m (ft)	*SD*	m (ft)	*SD*
Plant Height	1.09 (3.6)	*0.03 (0.1)*	1.73 (5.67)	*0.15 (0.51)*	1.98 (6.50)	*20.8 (0.68)*	0.7 (2.3)	*0.15 (0.5)*
Trunk Length	0.58 (1.9)	*0.03 (0.1)*	0.70 (2.30)	*0.06 (0.21)*	0.77 (2.53)	*8.9 (0.29)*	NM	*NM*
Pot Height	0.24 (0.8)	*NV*	0.33 (1.08)	*NV*	0.38 (1.25)	*NV*	0.34 (1.1)	*NV*
Canopy Width	0.58 (1.9)	*0.03 (0.1)*	1.19 (3.92)	*0.15 (0.49)*	1.39 (4.57)	*20 (0.66)*	0.64 (2.1)	*0.09 (0.3)*
Pot Spacing	0.64 (2.1)	*0.03 (0.1)*	1.34 (4.40)	*NV*	1.98 (6.50)	*NV*	0.69 (2.3)	*NV*
Aisle Width	0.41 (1.3)	*NV*	0.87 (2.9)	*NV*	0.43 (1.4)	*NV*	0.3 (0.98)	*NV*
Row Width	0.58 (1.9)	*NV*	1.19 (3.9)	*NV*	1.39 (4.6)	*NV*	0.64 (2.1)	*NV*
Aisle/Row Length	21.9 (72)	*NV*	15.2 (49.9)	*NV*	15.2 (49.9)	*NV*	21.9 (72)	*NV*
Aisle Surface Area (m^2)*	0.41 (4.4)†		0.87 (9.4)†		0.43 (4.6)†		0.3 (3.2)†	
Row Surface Area (m^2)*	0.58 (6.2)†		1.19 (12.8)†		1.39 (14.9)†		0.64 (6.9)†	
Total Surface Area (m^2)*	0.99 (10.7)†		2.06 (22.2)†		1.82 (19.6)†		0.94 (10.1)†	
Active Ingredient Applied (Total-mg)**	5,228		5,439		4,805		4,964	
Active Ingredient Applied (Aisles-mg)**	2,164.48		2,297.09		1,135.34		1,584.2	
Active Ingredient Applied (Rows-mg)**	3,063.38		3,141.99		3,670.06		3,379.63	

NM: *Not measured due to bushiness and multiple trunk character of plants, but is approximately equal to plant height.* NV: *Considered constant with no variation. *Divide total surface area by 4 to calculate surface area within each interval of targets.* **Calculated by multiplying [travel time to cover aisle or row width (s)] · [application rate ($L \cdot s^{-1}$)] · [890 mg-methiocarb · L^{-1}-spray mixture].
† ft^2.

Table 2. Summary of statistical analysis comparing deposition at each target location between the study groups.

Single Side Application Deposition Study					
	Distance from Sprayer				
Comparison	0	3.8	7.6	11.4	15.2
LF:MF (aisles)	NS	NS	NS	NS	*
LF:MF (rows)	NS	NS	NS	NS	NS
Double Side Application Study					
Aisles	Distance from Sprayer				
	North Edge	5.6 (N)	11	5.6 (S)	South Edge
SF:RP (aisles)	NS	NS	*	*	NS
SF:RP (rows)	NS	*	*	*	*

Refer to Figures 1 and 2 for corresponding data. * Statistically significant difference (ANOVA, P = 0.05).

Table 3. Calculated mass of active ingredient (methiocarb) deposited on non-target ground surfaces during spray applications to medium- (MF) and large- (LF) sized Weeping Fig and for small Weeping Fig (SF) and Lady Palm (LP).

Plant/Scenario	Distance Interval within Row or Aisle				Total Deposition (mg)	% Applied
	0 – 3.8	3.8 – 7.6	7.6 -11.4	11.4 – 15.2		
MF (aisle)	136.6	77.4	57	41.7	312.7	13.6
MF (row)	147	78.9	69.9	53.6	349.4	11.1
LF (aisle)	56.3	41.1	41.5	41.3	180.2	15.9
LF (row)	200.9	134.4	95.6	74.9	505.9	13.8
Plant/Scenario	Distance Interval within Row or Aisle				Total Deposition (mg)	% Applied
	NE – 5.6(N)	5.6(N) – 11	11 -5.6(S)	5.6(S) – SE		
SF (aisle)	88.2	63.1	65.4	91.9	308.5	14.3
SF (row)	114.5	73.4	93.9	140.9	422.7	13.8
RP (aisle)	55.1	24.8	22.1	46.4	148.4	9.4
RP (row)	109.5	19.5	23.2	67.3	219.5	6.5

Note: NE = north edge, SE = south edge.

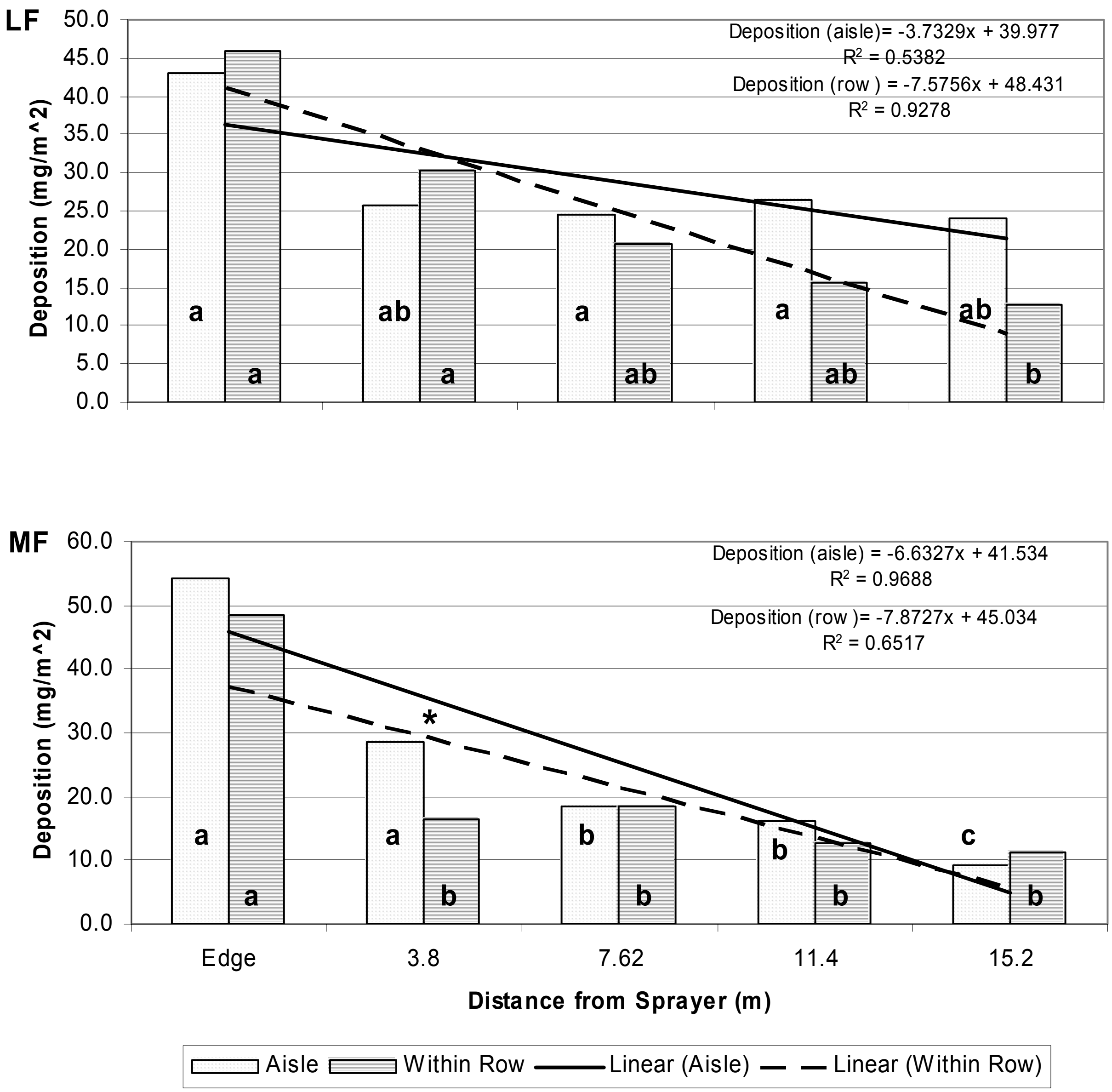

Figure 1. Deposition of methiocarb within aisles and plant rows for medium-sized ficus (MF) and large-sized ficus (LF). "*" indicates statistical difference (ANOVA, $P = 0.05$) between deposition in aisle and row at that location. Letters within bars may only be compared with similar-textured bars (i.e. within aisles only or rows only). Different letters indicate statistical differences ($P = 0.05$) within that treatment (aisle or row), not between treatments.

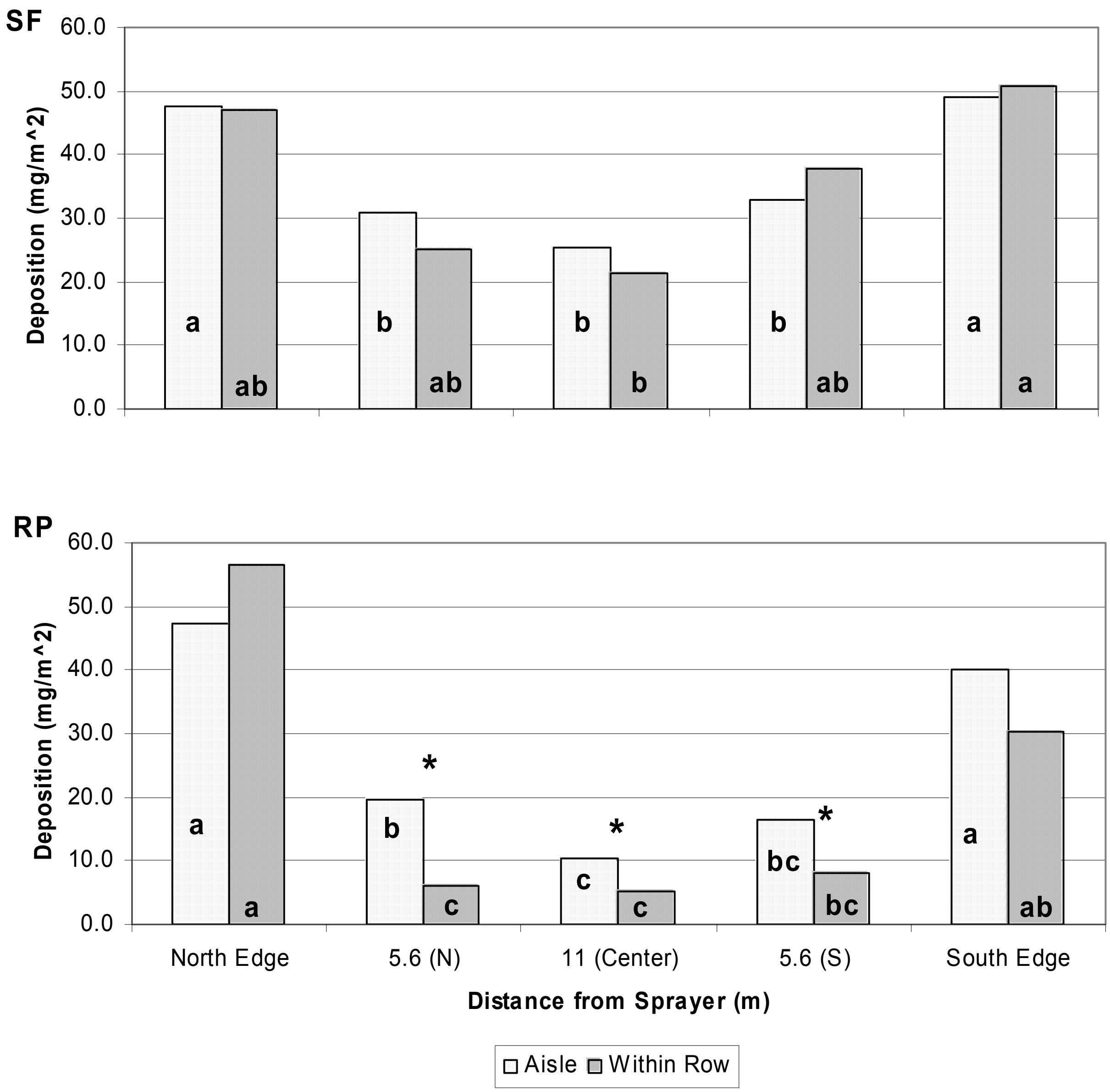

Figure 2. Deposition of methiocarb within aisles and plant rows for small-sized ficus (MF) and raphis palm at Kraft Gardens. "*" indicates statistical difference between deposition in aisle and row at that location. Letters within bars may only be compared with similar-textured bars (i.e. within aisles only or rows only). Different letters indicate statistical differences ($P = 0.05$) within that treatment (aisle or row), not between treatments.