**Phytoprotection**

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# Effets du taux d'application sur la couverture de fraisiers et sur le contrôle de la punaise terne [Hemiptera : Miridae]

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Résumé de l'article

Des expériences ont été effectuées pour vérifier l'effet de trois volumes d'application de bouillie sur la couverture de fraisiers ( *Fragaria ananassa*: cultivars Kent et Chambly) et sur l'efficacité d'un insecticide contre la punaise terne ( *Lygus lineolaris*). Les expériences ont été réalisées à un taux constant de matière active pour des volumes de bouillie de 500 et 1500 L $ha^{-1}$. La couverture des plants a été mesurée à l'aide d'un traceur fluorescent pour des volumes d'application de 500, 1000 et 1500 L $ha^{-1}$ sur des échantillons pris au sol et sur différentes parties des plants. Les populations de punaise terne ont été évaluées 24 heures avant et après les traitements avec du malathion (4,5 kg m.a. $ha^{-1}$) en utilisant 0, 500 et 1500 L $ha^{-1}$. Les données normalisées pour un taux constant de matière active ont montré qu'une augmentation du volume de bouillie de 500 à 1500 L $ha^{-1}$ n'avait généralement pas d'effet sur les quantités de traceur retrouvées. À quelques occasions, une augmentation du volume d'application a entraîné une baisse des quantités de traceur retrouvées, par exemple sur les feuilles du bas et du sommet du feuillage (Kent) et des sépales (Kent). Le contrôle des populations de punaise terne était acceptable sur le plan commercial à 500 et à 1500 L $ha^{-1}$.

# Effects of water volume rates on spray deposition and control of tarnished plant bug [Hemiptera : Miridae] in strawberry crops

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Field experiments were performed on the effect of three volumes of application on spray deposition and insecticidal efficacy against the tarnished plant bug (*Lygus lineolaris*) in two strawberry (*Fragaria ananassa*) cultivars, Kent and Chambly. The rate of application of malathion was kept constant at 4.5 kg a.i. $ha^{-1}$ for volumes of application of 500 and 1500 L $ha^{-1}$. Plant coverage was measured using a fluorescent tracer applied at volumes of application of 500, 1000 and 1500 L $ha^{-1}$. The tracer was recovered from samples taken from different plant locations and on the ground. Tarnished plant bug populations were evaluated 24 hours before and after insecticidal treatment. When coverage data were normalized for a fixed active ingredient rate, an increase in the volume of application from 500 to 1500 L $ha^{-1}$ frequently had no effect on the amount of tracer recovered at the various locations. On some occasions, an increase in volume of application resulted in a decrease in the amount of tracer recovered, i.e. leaves at the top and bottom of the canopy (Kent), sepals (Kent). Tarnished plant bug population control was commercially acceptable at 500 and 1500 L $ha^{-1}$.

**[Effets du taux d'application sur la couverture de fraisiers et sur le contrôle de la punaise terne [Hemiptera : Miridae]]**

Des expériences ont été effectuées pour vérifier l'effet de trois volumes d'application de bouillie sur la couverture de fraisiers (*Fragaria ananassa* : cultivars Kent et Chambly) et sur l'efficacité d'un insecticide contre la punaise terne (*Lygus lineolaris*). Les expériences ont été réalisées à un taux constant de matière active pour des volumes de bouillie de 500 et 1500 L $ha^{-1}$. La couverture des plants a été mesurée à l'aide d'un traceur fluorescent pour des volumes d'application de 500, 1000 et 1500 L $ha^{-1}$ sur des échantillons pris au sol et sur différentes parties des plants. Les populations de punaise terne ont été évaluées 24 heures avant et après les traitements avec du malathion (4,5 kg m.a. $ha^{-1}$) en utilisant 0, 500 et 1500 L $ha^{-1}$. Les données normalisées pour un taux constant de matière active ont montré

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qu'une augmentation du volume de bouillie de 500 à 1500 L $ha^{-1}$ n'avait généralement pas d'effet sur les quantités de traceur retrouvées. À quelques occasions, une augmentation du volume d'application a entraîné une baisse des quantités de traceur retrouvées, par exemple sur les feuilles du bas et du sommet du feuillage (Kent) et des sépales (Kent). Le contrôle des populations de punaise terne était acceptable sur le plan commercial à 500 et à 1500 L $ha^{-1}$.

## INTRODUCTION

Applications of pesticides in strawberry (*Fragaria ananassa* Duch.) fields using standard spraying methods are generally performed using a large volume of water. For example, water volumes of 2000 L $ha^{-1}$ are recommended in Quebec (CPVQ 2000) for the tarnished plant bug (TPB), *Lygus lineolaris* P. de B. [Hemiptera : Miridae], shortly before bloom and 5000 to 8000 L $ha^{-1}$ are recommended in Ontario for cyclamen mites (OMAFRA 1996). In low sparsely leaved crop, run-off may occur at a water volume as low as 100 L $ha^{-1}$ (Johnstone 1973). Therefore, recommended volumes, even in a dense strawberry crop (*i.e.* leaf area index up to 6 - G. Bourgeois, personal communication) is likely to generate some run-off which may contribute to ground water contamination (Matthews 1992). Spraying at higher water volumes can be achieved by increasing pressure at the nozzle, using coarser nozzles or lowering the travel speed of the sprayer. Using high pressure results in the production of many fine droplets that are prone to airborne drift (Miller 1988). Clearly, reducing application rates without affecting insecticidal efficacy could be beneficial both environmentally and economically.

Spray deposition is the amount of active ingredient on the target, and crop coverage is defined as the area of target surface covered by spray droplets. Several techniques have been tested to improve deposition or coverage for fungicides on strawberry foliage using application rates as low as 80 L $ha^{-1}$ (Black *et al.*1990; Giles and Blewett 1991; Labanowska and Clanciara 1988; Pickel and Welch 1988; Taylor and Drouin 1987). However, these more advanced spray technologies are rarely available on the market.

Using conventional boom spraying techniques, Sillibourne (1966) found that fungicide deposition on the fruit was directly proportional to the spray concentration while Fisher and Hikichi (1971) reported that deposition was lower on the fruit than on the other parts of the plants. The lowest deposit coincided with the highest infection level but the difference in deposition did not significantly affect fungicide efficacy.

Two key pests of strawberry are the strawberry bud weevil (SBW), *Anthonomus signatus* Say [Coleoptera : Curculionidae], and the tarnished plant bug (TPB), *Lygus lineolaris* P. de B. [Hemiptera : Miridae] (Bostanian 1994). These pests attack the flower buds and the peduncle respectively, while the *L. lineolaris* nymphs attack the achenes as the fruit begin to develop (Vincent *et al.* 1990). Because these plant parts are the primary targets for insecticide treatments, it is of interest to find out whether pesticide deposition on those parts is affected by volume of application. The same insecticide can be applied to control both the TPB and the SBW (CPVQ 2000).

The objectives of our study were 1) to determine the spray deposition on strawberry plant parts for three volumes of application (500, 1000, and 1500 L $ha^{-1}$) and two cultivars (Chambly and Kent); and 2) to determine the effect of three application rates (0, 500, and 1500 L $ha^{-1}$) on the control of the population of TPB with malathion at a constant application rate. In this paper, the word "deposition" refers to the amount of spray that is retained on the plant parts.

# MATERIALS AND METHODS

## Experimental site

The study was conducted at the Experimental Farm of Agriculture and Agri-Food Canada of L'Acadie (Quebec) (45°18' N, 73°20' W). Two cultivars, Chambly and Kent, were grown on separate fields. Two series of experiments related to the application of a tracer (objective 1) and of an insecticide (objective 2) were independently carried out. The tracer and the insecticide were applied when primary fruit were 10 mm in diam.

Irrigation, fertilization, and weed control were all performed as recommended by CPVQ (2000). Fungicides were also applied as prescribed but were washed off the foliage either by rain or by irrigation before any experimental treatment. No insecticide was applied for routine insect control before the application of the experimental treatments. After post-treatment TPB population monitoring was completed, standard treatments were applied for pest control.

## Experimental sprayer

A band sprayer with a triangular nozzle support was used. Treatments were applied as a 75 cm wide band to rows 150 cm apart at a height of 50-58 cm above the ground (Figure 1). The center nozzle pointed straight down and the side nozzles were tilted such that the outer portion of the spray cones intersected the ground at 90 degrees (Figure 1). Three hollow cone TeeJet™ nozzles were used: D1.5-25 at a pressure of 795 kPa, a D3-45 at a pressure of 1035 kPa, and a D4-45 at a pressure of 965kPa for treatments at 500, 1000 and 1500 L $ha^{-1}$ respectively. The volume of application refer to the sprayed area, not the total field area. The travel speed of the sprayer was 4 km $h^{-1}$. Using only water, volume median droplet diam were 185, 205 and 225 μm for the D1.5-25, D3-45 and D4-45 nozzles respectively (according to Spraying Systems Co. data sheets). The flow rate at the nozzles was checked before each trial. Treatments were applied in the morning, in wind speeds of 2 to 3 m $s^{-1}$ at 2 m above ground level. Under these conditions, drift should have negligible effects on spray deposition (Bache and Johnstone 1992).

## Experimental design and procedure

For each cultivar, the experiments were set up as randomized complete block design with four replicates. Each plot contained four 10 m long rows that were 1.5 m apart. For the Kent cultivar, separate plots were used for the tracer and the insecticide experiments. The tracer experiment was conducted first. Adjacent plots, to be used in the insecticide experiment were covered with a plastic tarpaulin during spraying of the tracer (DayGlo Rocket Red AX at 1 g $L^{-1}$). Treatments with the tracer were applied at 500, 1000 and 1500 L $ha^{-1}$. The insecticide treatments were applied at 500 and 1500 L $ha^{-1}$ and active ingredient rate of 4.5 kg $ha^{-1}$ (Malathion 25W formulation). An unsprayed control was included in each block. For the Chambly cultivar, the same application volumes were tested for the tracer and insecticide (Malathion, 4.5 kg a.i. $ha^{-1}$) treatments. The insecticide treatments were ran-

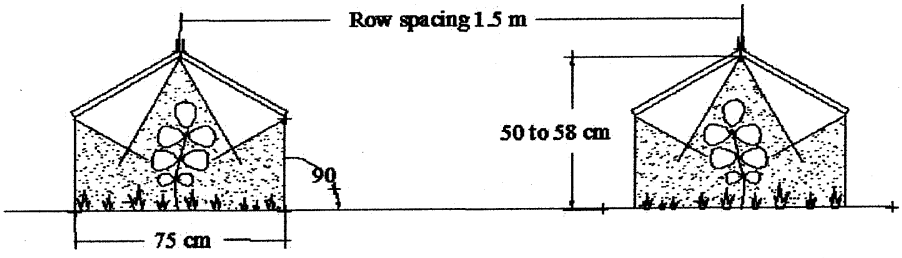


**Figure 1. Band spraying set-up.**

domized over the same plots as the ones used for the tracer treatments. An insecticide treatment was sprayed at 500 L $ha^{-1}$ over the plot where no tracer was applied to detect any interaction between the tracer and the insecticide.

## Sampling

*Spray deposition*

Three types of samples were taken from the plots to determine the spray deposition and to quantify the amount of tracer. In each plot, four Petri dishes (90 mm in diam) were placed on the ground in the centre of the rows and four Petri were placed in-between rows to quantify the loss of spray to the ground. For each plot, four leaf samples from the top of the plant canopy and four others from the bottom of the canopy were collected. Each leaf sample consisted of three centre leaflets. At the bottom of the canopy, the collected leaflets were as close to the ground as possible without touching it. Four samples of 10 primary berries each, (about 1 cm diam, green and/or white) along with the peduncles and the sepals were also collected.

For all type of samples, one blank sample per plot was collected to provide a baseline measure before any spray application. After applying the tracer, plants were allowed to dry for 15 min before sampling. Fruits were pinned on a board with nails to prevent any contact between the samples. Petri dishes were covered and leaflets were placed into acetone-resistant-plastic bags for transport to the laboratory.

*TPB populations*

Tarnished plant bug populations were assessed by the pot saucer method (Schaefers 1972). Twenty taps over the flower/fruit trusses were made per plot 24 h before and after the treatments.

## Measurements

All samples were weighed immediately after harvest. Berries were dissected into three parts: the fruit itself, the first 1.5 cm of peduncle from the fruit and the sepals. The peduncles and sepals were placed into 50 mL glass tubes and the fruit were placed in 250 mL Erlenmeyer bottles, all covered with lids. Leaflets and their plastic bags were placed in 1 L glass jars.

For the Kent cultivar, the surface area of the leaflets (48 samples of three leaflets each) was measured using a Li-Cor portable area meter (Model Li-30000, Lambda Instruments Co.), to establish a correlation between the weight of the leaflets and their area. The same measurements were performed on a subset of the leaf samples for the Chambly cultivar (10 samples of three leaflets each).

Tracer extraction was done by pouring acetone directly on Petri dishes as follows: 20 mL twice, and 10 mL as a third rinsing. The tracer was extracted from leaflets, fruits, sepals and peduncles using 50, 25, 10 and 10 mL of acetone respectively, and mixed for 1 min. The extracts were decanted in glass tubes. Filtration was done to remove dirt particles for the sepal and the peduncle extracts.

The extracts were analyzed by a spectrofluorometer (LS-5, Model C65-30000, Perkin-Elmer). Excitation and emission wavelengths were adjusted to 524 and 551 nm respectively, and both slots were adjusted to 10 mm. Samples were analyzed within 2 h following extraction. The measured emission was then compared to a calibration curve to determine the tracer concentration.

For plant material samples, the weight of tracer retrieved was divided by the weight of the corresponding plant part to obtain a relative weight. To convert the data to a constant tracer application rate (*i.e.* g $ha^{-1}$), all relative weights were divided by the volume of application and multiplied by 1000 to give a uniform tracer application rate of 1 kg $ha^{-1}$. For ground samples, the measured tracer weight from the surface area of the Petri dishes was converted to an equivalent volume of application (*i.e.* L $ha^{-1}$) and this number was expressed as a fraction of the effective application rate for the treatment.

## Statistical analysis

*Tracer application*

Data from leaflets at the top and bottom of the canopy were grouped and analyzed as repeated measures in 1-D space, (*i.e.* multivariate analysis) (SAS 1988). This multivariate analysis tested

for treatment, cultivar and block effects and for interactions. Wilks' Lambda values are considered to be the exact F-Statistics for all hypotheses of the model. All vectors of variation (main effect and their interactions) were tested.

An analysis of variance was also performed on the data from leaflets based on their position within the canopy. The treatment effect and the cultivar effect as well as the interactions were tested. The same statistical procedures were performed for fruit, peduncles, sepals and ground samples (Petri dishes). Differences among means were tested using the DUNCAN's multiple range test (SAS 1988).

*Insect populations*

An analysis of variance with repeated measures (over sampling time) followed by Scheffé's procedure ($P = 0.05$) were done to detect differences in the TPB nymph populations among treatments.

## RESULTS

### Tracer application

For the Kent cultivar, leaf weight and leaf area were significantly related ($R^2 = 0.77$) (Figure 2), indicating that the amount of tracer recovered per unit weight of leaf is linearly related to the amount of tracer on a per unit area of leaf. For the Chambly cultivar, a limited data set suggests that leaf weight and leaf area were also significantly related ($R^2 = 0.93$) (Figure 2).

Ground deposition between rows was 4% of the application rate on average. Under the canopy, ground deposition ranged from 14 to 56% of the volume of application. It was higher ($P < 0.001$) on cv. Kent than on Chambly and there was a significant treatment by cultivar interaction ($P = 0.022$) (Table 1). The effect of application rate on ground deposition under the canopy was not significant ($P = 0.560$) for the Kent cultivar but was ($P = 0.033$) for the Chambly cultivar. Ground deposition was also higher at 1000 L $ha^{-1}$ than treatments at either 500 or 1500 L $ha^{-1}$. No explanation can be given for this treatment effect. Overall, there was no correlation between volume of application and loss of tracer to the ground under the canopy when the tracer was applied at a fixed dose per unit area.

Deposition on leaflets was not significantly affected by leaf position within the canopy ($P = 0.717$), or by cultivar ($P = 0.170$) for leaflets at the top of the canopy (Table 1). This was expected because under comparable meteorological conditions and spray application methods, the deposition on the top

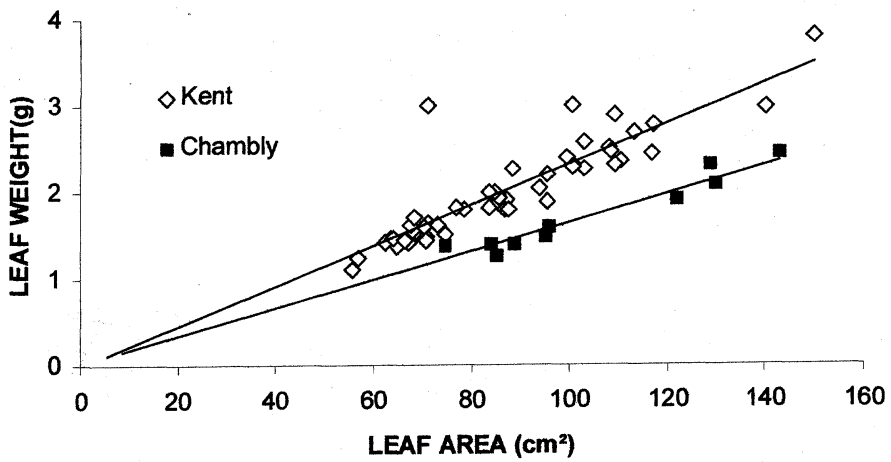


**Figure 2. Relationship between the weight and the area of the centre leaflet.**

**Table 1. Spray deposition (mean ± SE) on the ground and on plant parts**

| | Chambly[a] | | | Kent[a] | | | |
|---|---|---|---|---|---|---|---|
| | Application volume [L ha$^{-1}$] | | | | | | *P* value for cultivar effect |
| Site of deposition | 500 | 1000 | 1500 | 500 | 1000 | 1500 | |
| Ground deposition under canopy [% of applied a.i.] | 14 ± 6 a | 41 ± 9 b | 21 ± 5 a | 56 ± 11 a | 47 ± 10 a | 54 ± 9 a | < 0.001 |
| Top leaflets [µg g$^{-1}$][b] | 66 ± 80 a | 101 ± 31 a | 54 ± 37 a | 140 ± 87 a | 73 ± 28 b | 71 ± 31 b | 0.219 |
| Bottom leaflets [µg g$^{-1}$] | 51 ± 50 a | 83 ± 48 a | 67 ± 46 a | 132 ± 66 a | 82 ± 30 b | 74 ± 25 b | 0.007 |
| Fruit [µg g$^{-1}$] | 2.2 ± 1.7 a | 2.2 ± 0.9 a | 3.2 ± 1.2 a | 5.1 ± 1.6 a | 4.6 ± 1.3 a | 3.7 ± 1.4 a | < 0.001 |
| Peduncles [µg g$^{-1}$] | 23 ± 13 a | 21 ± 9 a | 23 ± 7 a | 34 ± 12 a | 27 ± 7 a | 24 ± 7 a | 0.115 |
| Sepals [µg g$^{-1}$] | 46 ± 29 a | 42 ± 13 a | 52 ± 16 a | 58 ± 28 a | 51 ± 10 ab | 42 ± 14 b | 0.534 |

[a] For each cultivar, values within rows, followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

[b] Relative weight of tracer.

exposed leaves should be the same regardless of the state of the canopy. For the leaves at the bottom of the canopy, deposition was higher on cv. Kent than on Chambly ($P = 0.003$) (Table 1). This was attributed to the canopy of the Chambly cultivar being much denser (visual estimation) than that of the Kent. This difference in canopy density is more an experimental artifact than a systematic difference between cultivars. For the Chambly cultivar, deposition on leaves at the bottom ($P = 0.144$) and at the top of the canopy ($P = 0.348$) was not affected by treatment but it was for the top ($P = 0.012$) and the bottom ($P = 0.013$) leaves of Kent. For treatments on Kent, the 500 L ha$^{-1}$ rate gave significantly higher deposition than treatments at 1000 or 1500 L ha$^{-1}$. This is likely caused by run-off that was initiated at the low application volume due to a relatively sparse canopy. At the point where the volume of application is large enough to initiate run-off on a surface, the volume of spray retained on that surface is a maximum (Tadros 1987). Therefore, it is hypothesised that for the Kent cultivar, excessive run-off reduced the amount of tracer retained on the leaves.

Deposition on fruits was higher on cv Kent than on Chambly ($P < 0.001$) but was not affected by treatment for both cultivars ($P = 0.188$ for Chambly, and $P = 0.120$ for Kent) or by interactions between cultivar and treatments (Table 1). To explain the difference between cultivars, photographs taken during the experiments were visually examined to determine if sepals covered the fruit differently. No difference was observed.

For the peduncles, no significant effects were detected (Table 1). On sepals, spray volume had a significant effect on deposition for the Kent cultivar only ($P = 0.038$) but not for the more densely foliated Chambly cultivar. For the Kent, there was a general trend of decreasing coverage with an increase in application volume. Again, excessive run-off leading to reduced deposition was the cause.

## Insecticide application

Over 97% of the TPB sampled (all treatments and replicates confounded) from the Kent (N=469) and Chambly (N=466) cultivars were nymphs. Because damage is mainly caused by nymphs (Mailloux and Bostanian 1988; Schaefers

1980), only nymphs were included in the statistical analysis. In the Kent plots, nymph populations were similar ($P>0.05$) before the treatment (Table 2). In the Chambly plots, there was a significant difference among plots before the treatment (Table 2): the average population was higher in the 1500 L ha$^{-1}$ plot, at 28.8 nymphs per 20 taps. However, 24 h after the treatments, the number of TPB nymphs in the plots of both cultivars treated with 500 and 1500 L ha$^{-1}$ was significantly less ($P<0.05$) than in the control plots (Table 2).

## DISCUSSION

Considering the results for both deposition on plant parts and TPB control, an application volume of 500 L ha$^{-1}$ is recommended. Given the behavior of SBW (Vincent *et al.* 1990), it should be expected that equally good control of SBW could be obtained at 500 L ha$^{-1}$ since peduncle and sepal coverage was either not affected by spray volume or increased as application volume decreased.

The difference in leaf deposition between the Kent and Chambly cultivar suggested that application volume should be reduced when foliage density is low. As pointed out, deposition is at its maximum for an application volume where run-off starts to occur. This helps in providing a better definition of the "spray to run-off" concept. Increasing application volume to the point where run-off starts to be observed is a sound "spray to run-off" approach while increasing beyond this point is counter-productive.

Because deposition on foliage is at least as good using 500 L ha$^{-1}$ as it is using 1500 L ha$^{-1}$, better fungicide efficacy could be acheived using 500 L ha$^{-1}$. However, no measurements of the uniformity of deposition at a scale smaller than the leaf samples were performed. Recovering more tracer from a collection of leaves does not imply that the leaf surfaces were evenly covered.

Lower volumes of application can be achieved by decreasing the pressure at the nozzle but this technique has its limits. If pressure is too low, droplet size will be fairly large and the spray pattern from the nozzles will be uneven (Matthews1992). Switching to smaller nozzles is a better approach to maintain a better coverage of the target by breaking the spray liquid into a large number of finer droplets. However, this approach must be balanced against the increased risk of pesticide drift.

The overall result regarding deposition is that using an application volume ranging between 500 and 1500 L ha$^{-1}$ at a fixed rate of active ingredient has no impact on deposition of active ingredient on target sites. Therefore, the use of a more suitable water volume does not open the possibility of reducing insecticidal rates.

**Table 2. Effect of application volume on density (n=20 samples) of tarnished plant bug nymphs on strawberry plants, l'Acadie, Quebec, in Kent and Chambly plantations**

| Cultivar | Spray volume [L ha-1][a] | 24 h before treatment | 24 h after treatments |
|---|---|---|---|
| Kent | 0 | 8.8 a[b] | 8.5 a |
| | 500 | 9.3 a | 0.0 b |
| | 1500 | 7.0 a | 0.3 b |
| Chambly | 0 | 19.8 a | 13.9 a |
| | 500 | 19.0 a | 0.2 b |
| | 1500 | 28.8 b | 0.2 b |

[a] Treatment with Malathion 4.5 kg a.i. ha$^{-1}$ in plots sprayed with 500 and 1500 L ha$^{-1}$. Control plots were not sprayed.

[b] Within columns, means with same letters are not significantly different at $P = 0.05$ (Scheffé's test).

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