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Plant Canopy Affects Sprinkler Irrigation Application Efficiency of Container-grown Ornamentals

Richard C. Beeson, Jr.[1]
Mid-Florida Research and Education Center, IFAS, University of Florida, 2725 S. Binion Road, Apopka, FL 32703

Thomas H. Yeager[2]
Department of Environmental Horticulture, IFAS, University of Florida, 2517 Fifield Hall, P.O. Box 110670, Gainesville, FL 32611

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Abstract. **Marketable size plants of sweet viburnum (*Viburnum odoratissimum* Ker-Gawl.), waxleaf ligustrum (*Ligustrum japonicum* Thunb.), and azalea (*Rhododendron spp.* L. 'Southern Charm') grown in 11.4-L containers were irrigated with overhead impact sprinklers at container spacings ranging from 0 to 51 cm apart. Water reaching the substrate surface was quantified and the percentage of that applied calculated as percent capture (% capture). Percent capture is defined as the percentage of water falling above the plant within a projected vertical cylinder of a container that reaches the substrate surface. For all species, % capture increased linearly with the decline in adjacent canopy interaction, which results from canopies extending beyond the diameter of a container. Increases in total leaf area or leaf area outside the cylinder of a container, in conjunction with increasing distance between containers, were significantly ($P < 0.05$) correlated with increases in % capture for ligustrum and viburnum. Increases in % capture partially compensated for decreases in percentage of production area occupied by viburnum containers as distances between containers increased, but not for the other two species. Under commercial conditions, optimal irrigation efficiency would be achieved when plants are grown at the minimum spacing required for commercial quality. This spacing should not extend beyond the point where canopies become isolated.**

Irrigation application efficiency can be defined as the percentage of water leaving a sprinkler head that is retained within the rooting volume of a plant. In this formal definition, irrigation application efficiency takes into account irrigation of nontarget areas (outside fringes of production areas), evaporation of water droplets during an irrigation event, and water losses due to drainage from containers. A limited component of this is overhead application efficiency, defined as the percentage of water falling over the production area occupied by containers that is retained in the root ball. This component negates irrigation of nontarget areas, usually constant under near windless conditions, and evaporation, which is minimum in humid regions (Smajstrla and Zazueta, 1994).

For sprinkler irrigated container-grown landscape ornamentals, several factors influence overhead application efficiency. The most important factor is the distance between containers. The percentage of production surface area occupied by a round container decreases quadratically as the space between containers expands (Futura, 1979). When the distance between containers equals that of the container diameter, differences in the percentages of production area occupied resulting from different container diameters and spacing configuration (perpendicular or square vs. triangular configurations) are minimized, with most container sizes and spacing configurations occupying ≈22% of the allocated production area (Futura, 1979). Because irrigation is applied overhead, overhead application efficiency is generally at best equal to the percentage of area occupied by a plant-less container and maximum at pot-to-pot spacing, assuming no canopy influence and no leaching. Overhead application efficiency is also influenced by the uniformity of the irrigation application, application rate (Beeson and Haydu, 1995; Lamack and Niemiera, 1993), total irrigation volume (Beeson and Haydu, 1995), and sprinkler type and canopy characteristics (Beeson and Knox, 1991).

Previously, Beeson and Knox (1991) reported a significant correlation between leaf area directly above a container and percentage of irrigation reaching the substrate surface of a spaced container. For both horizontal, overlapping leaf canopies of pittosporum [*Pittosporum tobira* (Thunb.) Ait. 'Laura Lee'] and diagonally vertically-oriented branch and leaf canopies of the Duc du Rohan cultivar of azalea (*Rhododendron* spp. L. 'Duc du Rohan'), increased leaf area within the projected cylinder of a container was correlated with lower percentages of irrigation reaching the container substrate, whereas total leaf area had minimum effect. This percentage of irrigation reaching a substrate was termed percent capture (% capture). Percent capture is defined as the percentage of irrigation falling above the plant canopy within a projected vertical cylinder of a container that is collected at the substrate surface. For the same plants placed pot-to-pot, in contrast to spaced apart, % capture was negatively correlated with total leaf surface area of a plant. This was proposed to be due to compression of a canopy, pushing leaves normally existing outside the projected cylinder of a container to within this cylinder. Because canopy characteristics can modify the amount of water reaching a substrate surface compared to what falls directly over a container, % capture is multiplied by the percentage of a bed area occupied by a container to calculate overhead application efficiency, assuming no leaching (Beeson and Knox, 1991). In this earlier study, % capture was measured at only two container spacings. The results suggested that reducing compression of plant canopies by spacing containers would result in a greater percentage of overhead irrigation reaching the surface of a container substrate.

Potential canopy interference (PCI) is defined as the length of overlap of adjacent plant canopies. It serves as an estimate of the width around the perimeter of a plant canopy where leaf area and therefore leaf area index (LAI) is increased due to the presence of leaves from adjacent plants or compression. If the leaves and branches within this zone of overlap do not fully integrate, but instead push against each other, each canopy becomes compressed. Compression would increase the LAI in the zone of overlap. Where canopy widths are much larger than the distance between plant centers, the length of overlap will be high and compression/LAI may extend into the center of a plant. By definition, PCI nears 0 when canopies are just touching and becomes negative relative to the distance of open space between canopies.

Knowing that the percentage of bed area occupied by a plant declines with increasing container spacing, while % capture increased with container spacing, we hypothesized that there would be some optimum container spacing, wider than pot-to-pot, (0 cm spacing) at which maximum overhead application efficiency was achieved. Thus, our objective was to evaluate the effect of container spacing on % capture and overhead application efficiency to determine optimal spacing. Concurrently, we investigated the impacts of canopy characteristics in conjunction with container spacing on % capture.

Materials and Methods

Three species of common landscape ornamentals grown in 11.4-L commercial containers (25 cm diameter) were studied. Plants were selected for visual uniformity at marketable size from a local commercial nursery and transported to a Research Station 32 km north of Orlando, Fla. (lat. 29°N). Each species represented a different canopy

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[1]Associate Professor.
[2]Professor.

architecture. Sweet viburnum (*Viburnum odoratissimum* Ker-Gawl.) had relatively large, flexible leaves (35 to 50 mm wide and ≈100 mm long) cupped at about a 40° angle parallel to the midrib and an upright, oval, moderately dense canopy. Main branches extended from the central trunk at 45° to 60° angles with subordinate branches extending horizontally. Waxleaf ligustrum (*Ligustrum japonicum* Thunb.) had rigid leaves half the length of viburnum that were slightly concave with a pronounced elevated vase-like canopy with vertically diagonal branching at angles of 45° or less. Subordinate branches extended at acute angles from the main branches. For both species, leaves were generally arranged in opposite pairs along a branch, with each pair generally orientated perpendicular to that of the previous pair. For both species, the leaf pair oriented horizontal and generally parallel to the ground exhibited some rotation perpendicular to the midrib that exposed a greater surface area parallel to the sky. Lower leaves of the more vertically orientated pairs rotated substantially at the petiole: branch junction such that these leaves were nearly parallel to the ground for both species. This was more pronounced in the viburnum with the more horizontal subordinate branches. The azalea cultivar Southern Charm had flexible, obovate-shaped leaves 50 mm in length and ≈20 mm at the widest width. These plants had a short globose canopy shape, although somewhat flattened at the top. Major branches varied from near vertical to horizontal with subordinate branching being mainly horizontal. All leaves were mostly flat and oriented nearly parallel to the ground. General canopy characteristics for each species are provided in Table 1.

For each species, water reaching the container substrate surface was collected from 10 catch plants and measured after each irrigation event. The same catch plants were used at each irrigation event. Water reaching the container substrate was collected as described by Beeson and Haydu (1995). Briefly, disposable diapers (medium boys, Dri Bottoms, Paragon Trade Brands, Federal Way, Wash.) were cut to conform to the interior diameter of a container and weighed while dry. These were placed on the substrate surface prior to an irrigation in a manner that covered >98% of the substrate surface area. After an irrigation was stopped, five minutes was allowed for canopies to drip before diaper pieces were carefully removed, sealed in water-proof polyethylene bags and re-weighed. Diaper pieces used per container had a capacity of ≈1.4 L. Volumes collected ranged from 0.06 to 1.25 L, depending on species and container spacing.

Catch plants were randomly placed among similar plants at various container spacings within a rectangular area 3.7 × 4.9 m within a square outdoor production area 6.2 m to a side. Irrigation was supplied by two overhead impact sprinklers (model 1345; Nelson's Corp., Peoria, Ill.) set at opposite corners of the production area, with a 9-m application radius. Each impact sprinkler had a rotation of ≈110° before reversing. This configuration afforded complete overlap by the sprinklers within the rectangular area and produced a Christensen's Uniformity Coefficient value of 0.9. Christensen's Uniformity Coefficients >0.85 are considered adequate for overhead irrigation (Haman et. al., 1977). Catch plants were re-randomized at each container spacing. Except at the largest spacing, catch plants were always bordered by, and interspersed among, similar nonmeasured plants. Irrigation was applied at a rate of 43 mm/h for 15 min at each irrigation event. Actual volumes of irrigation falling above the plant canopies were measured using four 62-mm-diameter cups raised above the canopies ≈20 cm on 50-mm-diameter polyvinyl chloride (PVC) pipes. These were about equally spaced within the test area.

Treatments consisted of applying overhead irrigation at various spacings between containers, using a square configuration (containers placed at right angles). Plants were initially spaced pot-to-pot (0 cm). The distance between containers was increased incrementally by 5.1 cm from 0 to 40.6 cm, with a final spacing of 50.8 cm, except for viburnum, which was not measured at the 25.4 cm spacing. Both the 25.4 and 50.8 cm spacings were repeated for the ligustrum and the means of the two replications used in the calculations.

All irrigation events occurred under windless to near windless conditions (wind speed $<0.4\ m\cdot s^{-1}$, <1 mph) beginning shortly after dawn. About one month was required to achieve the right conditions for data collection for each species. Data were collected when sufficient plant material was available and canopy growth was quiescent. Ligustrum data was collected during Feb. 1995, viburnum during late August to mid-Sept. 1995, and azaleas during Feb. 1996.

At the conclusion of data collection for a species, canopy dimensions of widest width, width perpendicular to widest width and average height of the catch plants was recorded, along with width dimensions of border plants (Table 1). Growth indices of catch plants were calculated by multiplying these three dimensions to estimate canopy volume (m^3). Canopies of these plants were then dissected. Leaves and branches outside the vertical cylinder of the container were removed. Leaf area was measured using a leaf area meter (model 3000, LI-COR, Lincoln, Nebr.). Similar measurements were recorded for leaves within the cylinder of the container. For these, leaves within 15 cm of the substrate surface were measured separately and added to leaves higher than 15 cm for inside leaf area.

Based on the canopy characteristics, irrigation volumes applied, and water volumes collected at substrate surfaces, % capture values for each plant replicate at each spacing were calculated using the equation below.

Percent Capture =

$$100^{*}\left[\frac{postirrwt - preirrwt}{avecupvol^{*}\left[\frac{containerarea}{cuparea}\right]}\right]$$

where: *postirrwt* (g) = weight of the diaper pieces after irrigation; *preirrwt* (g) = the pre-irrigation diaper pieces weight; *avgcupvol* (mL) = the average volume collected in the four 62 mm cups above the canopy; *continerarea* (cm^2) = the surface area of the container; and *cuparea* (cm^2) = the surface area of a cup.

Physical canopy interaction (PCI) was calculated for each plant replicate using the equation:

$$PCI = [(xcatchradius + xspeciesradius) - (2 \times containerrad + spacing)]$$

where: *xcatchradius* (cm) = the mean radius of a catch plant canopy; *xspeciesradius* (cm) = the mean canopy radius of all plants used for each species; and *containerrad* (cm) the radius of the containers the plants were grown in.

Overhead application efficiency was also calculated for each plant replicate at each spacing by multiplying it's % capture by the fraction of bed space occupied by the container, given the square spacing used.

Table 1. Canopy characteristics of catch and border plants. Means are based on the 10 catch plant replicants except where noted in footnotes.

Characteristic	Viburnum	Ligustrum	Azalea
Height of catch plants (cm)	87.8 ± 5.3	75.4 ± 8.4	38.5 ± 3.1
Mean width of catch plants (cm)	76.9 ± 10.1	72 ± 8.3	48.0 ± 4.8
Width : width ratio of catch plants[z]	0.82 ± 0.09	0.87 ± 0.06	0.84 ± 0.7
Width : width ratio range of catch plants	0.68 to 0.98	0.75 to 0.95	0.76 to 0.98
Growth index of catch plants (m^3)	0.516 ± 0.077	0.394 ± 0.095	0.088 ± 0.011
Leaf area outside container of catch plants (cm^2)	16,676 ± 2,101	3,214 ± 534	2,631 ± 393
Leaf area inside container of catch plants (cm^2)	5,051 ± 673	2, 544 ± 476	2,216 ± 211
Total leaf area of catch plants (cm^2)	21,728 ± 2062	5,759 ± 805	4,847 ± 346
Leaf area below 15 cm above the substrate of catch plants (cm^2)	259 ± 149	537 ± 205	NA
Mean canopy radius per species (cm)[y]	41.5 ± 2.2	38.6 ± 2.9	26.0 ± 0.7
Mean variability among cup volumes[x]	4%	8%	6%
Range[w]	2% to 6%	3% to 17%	4% to 8%

[z]Ratio of widest canopy width to width perpendicular to this widest width.
[y]Mean radius of all plants (border and catch plants) used at the pot-to-pot (0 cm) spacing. Mean and standard deviation based on 90 plants.
[x]Cup volumes were the four cups raised above the plant canopy to measure actual irrigation amounts. Variability was calculated as the average of the deviations of each cup from the mean of the four cups times 100.
[w]Range is the lowest and highest mean variability considering all irrigation events per species.
[NA]Not applicable.

Data were analyzed separately for each species. Spacing effects on % capture, overhead application efficiency and relationships of canopy variables on % capture were analyzed using multi-variable regression (SAS Institute, Cary, N.C.). Relations between PCI and % capture for each species were analyzed using multi-variable regression (SAS). Lines were calculated for % capture as a function of positive PCI (canopies overlapping), negative PCI (canopies independent) and the entire data set per species. Slopes of the resulting lines were then compared using single-degree-of-freedom contrasts where appropriate (Snedecor and Cochran, 1980). Multi-variate regression was also used to analyze the relationship between PCI and overhead application efficiency for each species.

Results and Discussion

Percent capture. The % capture increased linearly ($P < 0.0001$) with increases in container spacing for viburnum (Fig. 1A). For marketable-size viburnum at a pot-to-pot spacing (0 cm), an average of 45% of the water falling over the cylinder of a container was actually collected within the container. The fate of the remaining water is unknown. If the remaining water had been channeled into adjacent containers, it is likely at least one of these would have been a randomly distributed catch plant, which constituted 16% of the plants at the pot-to-pot spacing. Yet the highest % capture at the 0 cm spacing was 65%, ranging to a low of 7%. Once container spacing was ≈23 cm (the width of the container and a common spacing in Florida for this size container), on average, 78% of the irrigation falling above the cylinder of the container was collected at the substrate surface, although the % capture ranged from ≈50 to near 125% (Fig. 1A).

For ligustrum, % capture also increased linearly ($P < 0.0001$) with increased spacing (Fig. 1B). At the 0 cm spacing, a mean of 59% of the irrigation falling above the containers was captured compared to 45% for the viburnum. For ligustrum, 9 of the 10 plants had % capture between 25% to 95%. Only one plant had a % capture >100% (Fig. 1B). Beeson and Knox (1991) reported that total canopy leaf area had a more negative impact on % capture as canopies interacted at pot-to-pot spacings than the leaf area within the cylinder of a container. This was consistent across species. Mean total leaf area of the viburnum was 21,728 cm^2 while that of the ligustrum was 5,758 cm^2. Thus, the much lower % capture of viburnum at the pot-to-pot spacing was consistent with the results reported by Beeson and Knox (1991).

Unlike the response of increasing % capture with increasing distances between containers for the other two species, % capture increased quadratically ($P < 0.0006$) with increased distance between containers for the azalea, indicating a decline in % capture at the last two widest spacings. (Fig. 1C). Unlike the other two species, % capture rarely exceeded 85% and never more than 92%. Mean % capture at 0 cm spacing was around 58% and ranged from 43% to 67%. Mean total leaf area of the azaleas was 4,847 cm^2, more comparable to the ligustrum than the viburnum with comparable % capture means to the ligustrum.

Percent capture and canopy characteristics. Using multi-variate regression analysis, both spacing and leaf area outside the cylinder of a container (LA-out) had a significant ($P < 0.05$) effect on the % capture measured for viburnum [% capture = 3.59(space) + 0.0041(LA-out) – 22.8, $R^2 = 0.417$]. This was also true for total leaf area [LA-total; % capture = 3.60(space) + 0.0036 (LA-total) – 32.8, $R^2 = 0.404$) and growth index (GI), % capture = 3.60(space) + 92.92(GI) – 2.62, $R^2 = 0.402$). Leaf area inside the container cylinder (LA-in) did not have a significant ($P > 0.05$) effect on % capture compared to spacing alone. This is consistent with the theoretical basis for PCI and with previous research on pittosporum and

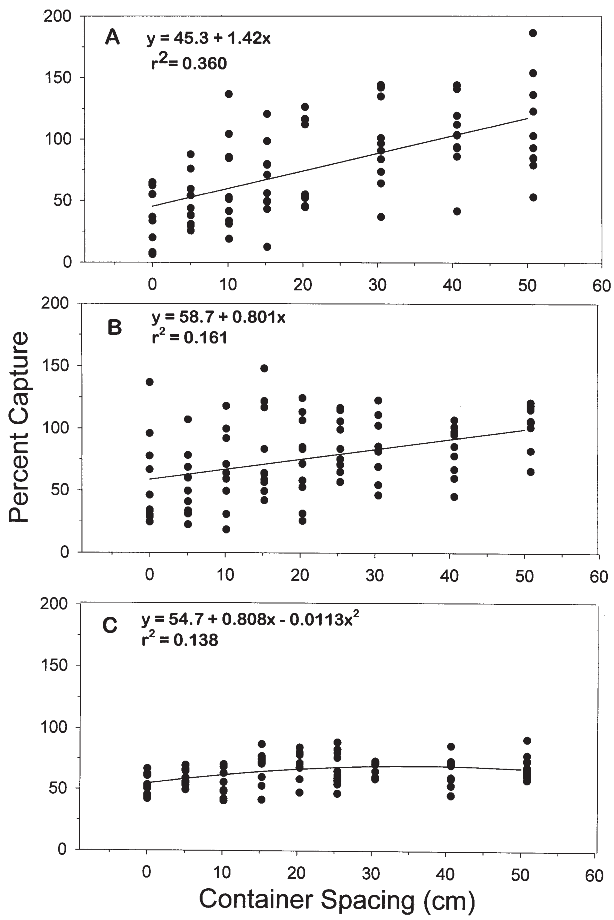

Fig. 1. Percent capture as a function of container spacing for (**A**) viburnum, (**B**) ligustrum, and (**C**) azalea. Each data point represents a plant replicate, with the exception of the 25.4 and 50.8 cm spacing for ligustrum, which are plant means based on two replications for these spacings. The solid line is the best fit curve for each species.

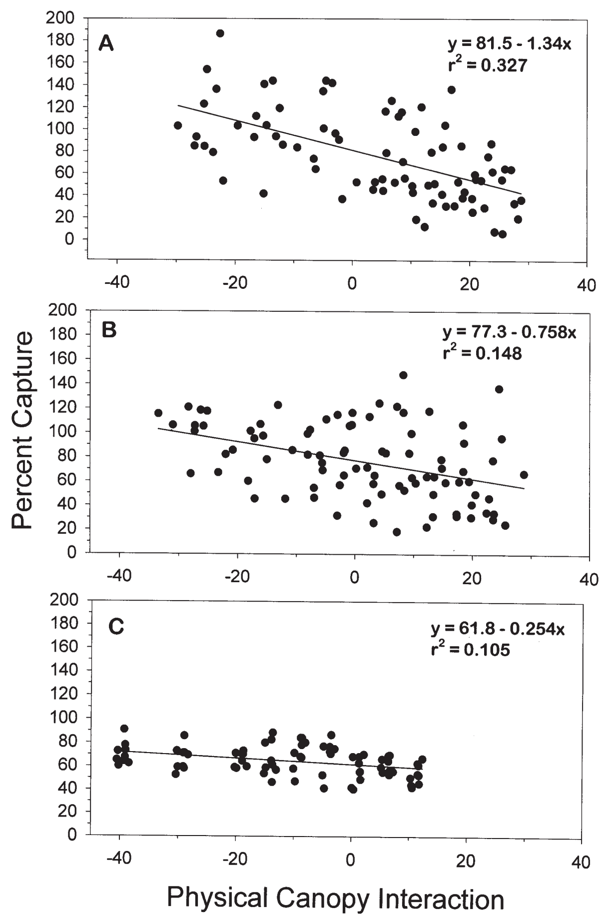

Fig. 2. Percent capture as a function of Physical Canopy Interaction (PCI) for (**A**) viburnum, (**B**) ligustrum, and (**C**) azalea. Each data point represents a plant replicate, with the exception of PCI values derived from the 25.4 and 50.8 cm spacing for ligustrum, which are plant means based on two replications for these spacings. The solid line is the best fit curve for each species.

azaleas (Beeson and Knox, 1991).

Leaf area inside the cylinder of a container was also not a significant variable for predicting % capture for ligustrum, and neither was GI. However both LA-out [% capture = 2.01(space) + 0.0143(LA-out) + 13.2, R^2 = 0.230] and LA-total [% capture = 2.02(space) + 0.0078 (LA-total) + 14.0, R^2 = 0.212] were significant (P < 0.05) factors in predicting % capture for ligustrum. For azalea, none of the leaf area components had a significant (P > 0.05) impact on predicting % capture in conjunction with container spacing. Only the GI parameter had significant (P < 0.05) predictive value (% capture = 0.672(space) + 381.7(GI) + 25.1, R^2 = 0.25).

For the species evaluated, coefficients of the significant variables for estimating % capture were positive. Percent capture generally increased with increasing spacing between containers and increasing outside or total leaf area (viburnum and ligustrum) or greater GI (viburnum and azalea). These results suggest that leaves outside the cylinder of the container channeled water to the substrate surface as spacing increased and zone of overlap between canopies decreases. Although not considered during data collection, compression of canopies due to canopy overlap may have changed leaf angles such that overhead irrigation was channeled more vertically instead of diagonally towards the substrate surface. Such leaf re-orientation was recently observed when similar size viburnum were pulled together to a very close spacing (<8 cm, high PCI). In the same group of plants, overlap in canopies that grew naturally together over time did not appear to change leaf orientation. Rather, leaves and branches in the natural overlap zone tended to interweave. Similar interweaving of mature canopies, with little to no leaf re-orientation was noted when some of these plants were pulled together at spacings about a container radius apart or greater. Thus, leaf re-orientation may explain some of the low % capture at the extremely close spacings, but appears to have been much less prominent over most of the range where PCI was near 0 or greater. Other experiments with several species spaced widely apart and irrigated from sprinkler heights >3m frequently resulted in % captures of 120% or more, indicating some canopies can channel irrigation water onto a substrate surface (Yeager and Beeson, 1996).

In contrast to the results presented here, Beeson and Knox (1991) found LA-in to be best correlated with % capture of spaced pittosporum and azalea. In that study, LA-in was negatively correlated with % capture, as was LA-total at 0 spacing. Azaleas used in the current study were of comparable size to those used by Beeson and Knox (1991). However, containers of spaced plants were only 7.5 cm apart, resulting in significant canopy overlap. Differences between the conclusions drawn in these studies are likely the difference in the breadth of the data analyzed.

Physical canopy interaction. In a preliminary examination of the means, it was noted that % capture generally leveled off where PCI <0 for azaleas and ligustrum, and appeared to substantially slow its rate of increase for viburnum (data not shown). From this, it was hypothesized that there was a difference in % capture when canopies were physically interacting (PCI >0) and when there was no physical interaction. This hypothesis was tested by determining the best fit lines and comparing the slopes where appropriate. In all cases where the relationship between PCI and % capture was significant, the relationship was linear. For viburnum, there was no relationship between % capture and PCI when canopies were not interacting (PCI <0). Percent capture increased linearly with declines when PCI >0 (P < 0.05). However, there was no significant difference (P > 0.05) in the slopes between this line (PCI >0) and the linear increase in % capture with declining PCI values over the entire data set (Fig. 2A). Similar results occurred with

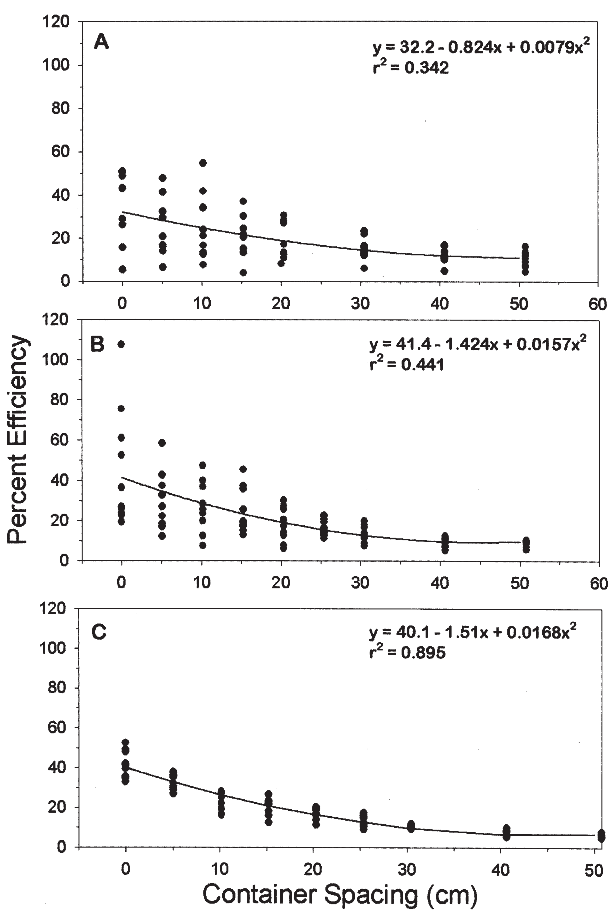

Fig. 3. Overhead application efficiency as a function of container spacing for each (**A**) viburnum, (**B**) ligustrum, and (**C**) azalea. Each data point represents a plant replicate, with the exception of the 25.4 and 50.8 cm spacing for ligustrum, which are plant means based on two replications for these spacings. The solid line is the best fit curve for each species.

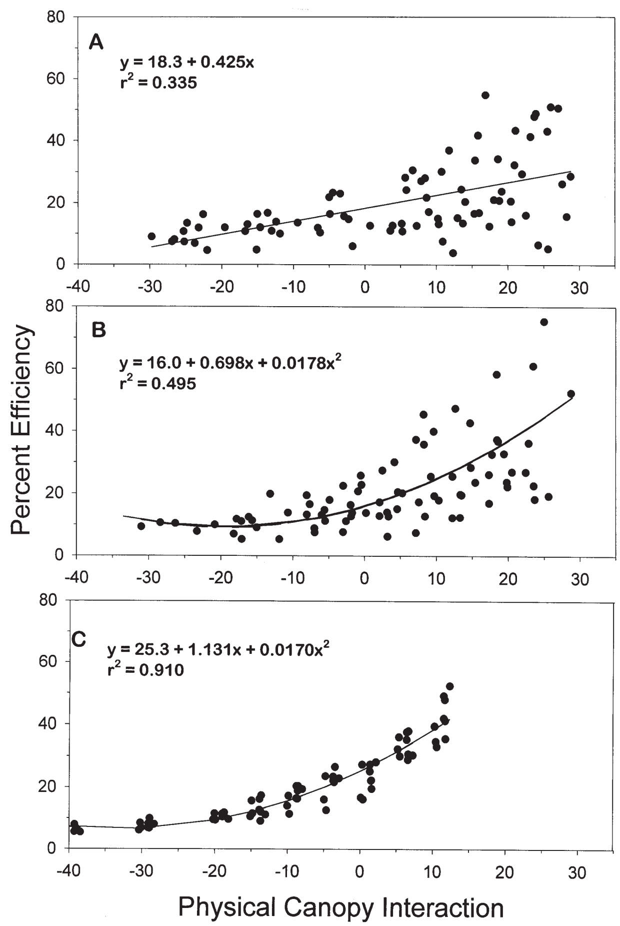

Fig. 4. Overhead application efficiency as a function of Physical Canopy Interaction (PCI) for each (**A**) viburnum, (**B**) ligustrum, and (**C**) azalea. Each data point represents a plant replicate, with the exception of PCI values derived from the 25.4 and 50.8 cm spacing for ligustrum, which are plant means based on two replications at these spacings. The solid line is the best fit curve for each species.

the ligustrum data set, where there were no significant differences ($P < 0.05$) in the slopes of the linear regression lines between positive PCI and sloped derived from the entire data set (Fig. 2B). Unlike viburnum though, there was a significant ($P < 0.05$) increase in % capture with increasing distance between canopies after they were no longer physically interacting (PCI <0). But this was also statistically similar ($P >$ 0.05) to the slopes of lines from the positive PCI points and the whole data set. The relationship between % capture and PCI for azaleas was like that of the viburnum (Fig 2C). Percent capture did not change significantly ($P > 0.05$) as PCI became increasingly negative. Prior to this, % capture increased linearly ($P < 0.05$) with declines in the positive PCI values as did the line generated from the entire data set. There were no differences ($P > 0.05$) in slope between the positive PCI line and that generated from the entire data set (Fig. 2C). For the three species, % capture significantly ($P < 0.05$) increased with decreasing physical canopy interaction. Thus within the range of the data, the further apart the canopies, the higher the volume of irrigation water that was collected on the substrate surface. While linear increases in % capture with decreasing PCI match the response of % capture with increasing spacing between the containers for viburnum and ligustrum, it did not for azaleas. Percent capture of azaleas began to decline with spacings >36 cm.

Overhead application efficiency. Overhead application efficiency declined quadratically ($P < 0.001$) with increased spacing between containers for the three species (Fig. 3). This is similar to the quadratic declines in percentage of space occupied by a container as the spacing between containers increases (Futura, 1979). Positive increases in % capture as containers were spaced further apart were insufficient to overcome the quadratic decline in percentage of the bed area occupied by a container.

For ligustrum and azalea, similar quadratic ($P < 0.001$) relationships between PCI and overhead application efficiency occurred (Fig. 4, B and C). In contrast, overhead application efficiency declined linearly ($P < 0.001$) as PCI declined for viburnum (Fig. 4A). This indicates that the increase in % capture accrued by decreasing PCI partially countered the steep quadratic decline in the percent area occupied by a container for this species. Viburnum plants had the highest canopy leaf area and density (Table 1) and greatest rate of increase in % capture with declines in PCI (Fig. 2). This suggest that for dense canopies, container spacing to minimize PCI is more advantageous and less critical for water conservation than for plants with low density canopies.

Maximizing overhead application efficiency. The main objective of this research was to determine the spacing between containers at which overhead application efficiency is optimized. It was hypothesized that increases in % capture achieved with increases in container spacing would compensate for declining percentages of a bed area occupied by a container. This did not occur, but it does appear that for some spacings, % capture influences overhead application efficiency.

For all species, highest overhead application efficiency was achieved at ≈0-cm spacing (pot-to-pot). Thereafter, increases in % capture with increasing spacing did not overcome the shrinking percentage of allocated irrigated area occupied by a container. However, commercially acceptable landscape plants cannot be grown pot-to-pot (0 cm spacing). Therefore, optimum application efficiencies would be achieved only by growing these species at the closest container spacing possible that still produced acceptable commercial quality. For low canopy densities, this likely would result in substantial PCI. For dense canopies, minimizing PCI appears to be justified.

In summary, increasing distances between containers increased the volume of overhead irrigated water reaching a substrate surface. The increase was linearly related to decreases in the amount of canopy overlap. Higher percentages of water reaching a substrate surface were correlated with total leaf areas and leaf areas outside the cylinder of a container for the upright spreading species, and canopy volume for the azalea. Spacing for optimal overhead application efficiency should consider the minimum required for commercially acceptable quality, but suggested not to exceed the point where canopies become isolated from each other.

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