BOXWOOD (*Buxus sempervirens* 'Suffruticosa')
(*Buxus microphylla* 'Winter Gem')

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**Spray coverage and penetration into Boxwood canopies using an Intelligent and conventional air blast sprayer**

Boxwood is an important commodity plant grown by the Oregon nursery industry. In 2011 Boxwood blight (*Calonectria pseudonaviculata*) was found in Oregon, and although eradication programs were initiated, full eradication was not successful. Boxwood blight is managed using cultural and chemical tactics. There is still commercial demand for cultivars susceptible to boxwood blight, and thus they are still widely grown. *C. pseudonaviculata* can infect all aboveground parts of the boxwood plant. When using fungicides for Boxwood Blight management, thorough coverage of the foliage and penetration into the canopy is essential for good disease management.

**Table 1.** Sprayer settings used in the boxwood coverage trial, and observed volumes per acre from the trial.

| Tractor speed (mph) | Nozzle set (Calibrated volume) | Sprayer mode[xy] | Mean spray rate Suffruticosa (GPA)[z] | Mean spray rate Winter Gem (GPA)[z] |
|---|---|---|---|---|
| 1.1 | TeeJet D5, DC45-HSS (100 GPA) | Standard | 226 | 408 |
| | | Intelligent | 20 | 51 |
| 1.1 | TeeJet D10, DC46-HSS (300 GPA) | Standard | 265 | 379 |
| | | Intelligent | 19 | 64 |

[x]All standard treatments were calibrated to apply 100gal/A at tractor PTO rated speed.
[y]Treatments in automated mode applied at a spray rate of 0.12fl oz/ft$^3$ of canopy.
[z]Rates calculated from an assumed spray area of 85 ft$^2$ per replicate, actual sprayed areas varied in size.

A spray coverage trial was conducted on 27 August 2020 in a planting of 10-11 year old boxwood bushes located at the Botany and Plant Pathology Field Lab, Corvallis, OR. The boxwood plantings consisted of two rows of boxwood bushes spaced about 5.5 ft apart that were about 150 ft long and oriented east to west. Within each row, boxwood bushes were spaced approximately 30 in from each other so that there were about 60 boxwood plants per row. Bushes were sheared to a height of approximately 16 inches. Two different cultivars were used in this study, *B. sempervirens* 'Suffruticosa' and *B. microphylla* 'Winter Gem'. Suffruticosa plants were tightly sheared into a roughly ovoid shape while Winter Gem plants were sheared into a roughly cube shape (Figure 1). The sprayer used in the study was a standard Pak-blast airblast sprayer (Rears Mfg., Coburg, OR) retrofitted with the Intelligent Spray System (ISS). The ISS uses a Lidar sensor, Doppler ground speed sensor, embedded computer, and individual pulse width modulation valves at each nozzle to release spray only when a target is sensed. In addition the ISS modulates spray volume based on the canopy density sensed by the Lidar sensor. Using the spray controller installed in the tractor the sprayer could be switched between using the ISS and standard mode where the sprayer would be fully on or off.

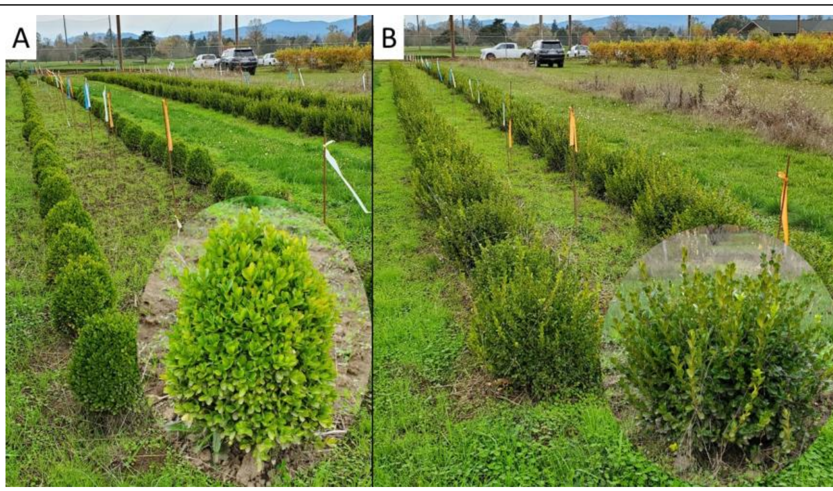


**Figure 1.** Rows of "Suffruticosa" (A) and Winter Gem (B) boxwood bushes with insets of individual plants.

Plots consisted of three boxwood bushes in both rows (i.e. a 2 bush by 3 bush plot for a total of 6 bushes). Plots were sprayed from both the north and south sides. In each plot, water sensitive cards were placed in the middle plant of the northern row of bushes. Two water sensitive cards were placed on the outside of the boxwood canopy approximately 5 to 8 in off the ground, one facing north and one facing south. Another two cards were clipped together back-to-back then inserted about 4in into the center of the boxwood bush from above so that one of the cards was facing north and one of the cards was facing south. These cards were placed in the center bush of the northern row of bushes. All north facing cards were closer to the sprayer than south facing cards. After spraying was completed, cards were allowed to dry for 30min before being placed in zip top plastic bags. Water sensitive cards were then scanned and analyzed for percent coverage and deposit density (deposits/cm$^2$) using DepositScan software. Percent coverage was analyzed using a generalized least squares model to account for unequal variance among replicates. Deposit density data was log transformed and analyzed using a linear model. Contrasts were conducted using marginal means with comparisons between treatments separated into each boxwood cultivar. All data was analyzed in R version 3.5.1.

**Table 2.** Percent coverage and deposit density on 'Suffruticosa' boxwood bushes from each sampling location in the BPP Field Lab trial.

| Sampling location | Spray treatment | Percent coverage$^z$ | Deposit density$^z$ |
|---|---|---|---|
| North Inner | 100GPA Standard | 0.3 (-9.2-9.8) A | 1.9 (0.6-5.7) A |
| | 100GPA Intelligent | 0.4 (-9.1-9.9) A | 5.6 (1.9-17.0) A |
| | 300GPA Standard | 8.0 (1.5-17.5) A | 68.9 (22.8-208.2) B |
| | 300GPA Intelligent | 0.2 (-9.3-9.6) A | 3.1 (1.0-9.4) A |
| South Inner | 100GPA Standard | 0.005 (-9.5-9.5) A | 0.3 (0.1-0.9) A |
| | 100GPA Intelligent | 0.02 (-9.5-9.5) A | 0.3 (0.1-1.0) A |
| | 300GPA Standard | 0.06 (-9.4-9.5) A | 0.5 (0.2-1.6) A |
| | 300GPA Intelligent | 0.01 (-9.5-9.5) A | 0.3 (0.1-0.9) A |
| North Outer | 100GPA Standard | 100.0 (90.5-109.5) B | 0.1 (0.03-0.3) A |
| | 100GPA Intelligent | 78.4 (68.9-87.9) A | 15.2 (5.0-45.8) B |
| | 300GPA Standard | 99.3 (89.8-108.8) B | 0.2 (0.08-0.7) A |
| | 300GPA Intelligent | 72.1 (62.6-81.6) A | 25.9 (8.6-78.3) B |
| South Outer | 100GPA Standard | 97.4 (87.9-106.9) C | 0.8 (0.3-2.4) A |
| | 100GPA Intelligent | 38.5 (29.1-48.0) B | 99.3 (32.9-300.2) B |
| | 300GPA Standard | 99.3 (89.8-108.7) C | 0.2 (0.1-0.5) A |
| | 300GPA Intelligent | 17.2 (7.8-26.7) A | 86.0 (28.4-259.9) B |

$^x$All treatments were applied at 100gal/A at tractor PTO rated speed.
$^y$Treatments in automated mode applied at a spray rate of 0.12fl oz/ft$^3$ of canopy.
$^z$Means followed by 95% confidence intervals in parentheses, means within columns followed by different letters are significantly different at $p<0.05$.

Percent coverage on Suffruticosa inner cards facing both north and south was low, with no significant differences among treatments for both north facing and south facing cards. The 300 GPA standard mode treatment on the north side was the only inner card with coverage above 1%, however, it was not significantly different from the other treatments at that card position (Table 2). On the outer cards coverage on the north facing cards in treatments applied in standard mode was significantly higher than either applied in Intelligent mode. On the South facing outer cards the intelligent mode treatments both resulted in significantly lower coverage than either standard mode treatment (Table 2). For deposit density on the inner cards facing north, the 300 GPA standard treatment resulted in significantly higher deposit density than all other treatments. For inner cards facing south, all treatments resulted in below one deposit/cm$^2$, on the cards, resulting in in no significant differences among treatments. On the outer cards, both intelligent mode treatments resulted in significantly higher deposit density than either treatment applied in standard mode.

**Table 3.** Percent coverage and deposit density on 'Winter Gem' boxwood bushes from each sampling location in the BPP Field Lab trial.

| Sampling location | Spray treatment | Percent coverage[z] | Deposit density[z] |
|---|---|---|---|
| North Inner | 100GPA Standard | 30.9 (21.4-40.4) B | 134.9 (44.6-407.9) A |
| | 100GPA Intelligent | 3.2 (-6.3-12.7) A | 32.6 (10.8-98.7) A |
| | 300GPA Standard | 47.2 (37.8-56.7) B | 94.9 (31.4-286.7) A |
| | 300GPA Intelligent | 9.3 (-0.2-18.8) A | 49.2 (16.3-148.8) A |
| South Inner | 100GPA Standard | 0.1 (-9.3-9.6) A | 1.5 (0.5-4.6) AB |
| | 100GPA Intelligent | 0.03 (-9.5-9.5) A | 0.4 (0.1-1.2) A |
| | 300GPA Standard | 1.4 (-8.0-10.9) A | 10.7 (3.5-32.3) B |
| | 300GPA Intelligent | 0.03 (-9.5-9.5) A | 0.6 (0.2-1.9) A |
| North Outer | 100GPA Standard | 100.0 (90.5-109.5) B | 0.1 (0.03-0.3) A |
| | 100GPA Intelligent | 79.5 (70.0-89.0) A | 33.4 (11.0-100.9) B |
| | 300GPA Standard | 100.0 (90.5-109.4) B | 0.1 (0.04-0.4) A |
| | 300GPA Intelligent | 88.6 (79.2-98.1) AB | 6.7 (2.2-20.2) B |
| South Outer | 100GPA Standard | 96.8 (87.3-106.3) B | 2.0 (0.7-6.1) B |
| | 100GPA Intelligent | 14.8 (5.3-24.3) A | 91.3 (30.2-276.1) C |
| | 300GPA Standard | 100.0 (90.5-109.4) B | 0.1 (0.03-0.3) A |
| | 300GPA Intelligent | 4.3 (-5.1-13.8) A | 21.3 (7.0-64.3) C |

[x]All treatments were applied at 100gal/A at tractor PTO rated speed.
[y]Treatments in automated mode applied at a spray rate of 0.12fl oz/$ft^3$ of canopy.
[z]Means followed by 95% confidence intervals in parentheses, means within columns followed by different letters are significantly different at $p<0.05$.

Percent coverage on Winter Gem inner cards facing north was significantly higher in for both 100 GPA and 300 GPA in standard mode than for either of those treatments applied in intelligent mode (Table 3). For the inner cards facing south, all treatments resulted in low coverage with no significant differences among treatments (Table 3). On the Winter Gem outer cards facing north both 100 GPA and 300 GPA treatments applied in standard mode resulted in significantly higher coverage than the 100 GPA Intelligent treatment, but not the 300 GPA intelligent treatment (Table 3). For the outer cards facing south, coverage was significantly higher for both 100 GPA and 300 GPA in standard mode than for either of those treatments applied in intelligent mode (Table 3). For deposit density on the Winter Gem inner cards facing north there were no significant differences among all treatments, even though there were significant differences in percent coverage (Table 3). For the inner cards facing south, the 300 GPA standard treatment resulted in significantly higher deposit density than either 100 GPA or 300 GPA Intelligent, but not 100GPA standard mode. For the Winter Gem outer cards facing north, deposit density on both 100 GPA and 300 GPA intelligent mode was significantly higher than either 100 GPA or 300 GPA standard mode (Table 3).

The lower coverage observed on the outside of bushes when the sprayer was used in intelligent mode was likely due to the normal intermittent release of spray when bushes were sensed. For both cultivars, on cards placed outside the bushes, average coverage in standard mode treatments was all from 90-100%. However coverage on cards placed outside the canopy among intelligent mode treatments was highly variable in both cultivars which ranged from an average of 4.3%-88.6%. Intelligent mode causes the sprayer to turn on only when objects are detected. For this study, plots consisted of boxwood bushes in two parallel rows with cards only placed in bushes in the northern of the two rows. While the Lidar sensor of the ISS was located 5ft above the ground and had a clear line of sight to detect bushes in the northern row, spray was released from nozzles approximately 2ft from the ground that was likely blocked on its way to the northern bushes by the southern bushes. In intelligent mode spray is not released in the gaps between plants and as a result, there likely were not enough spray droplets to "wrap around" bushes in the southern row and reach the bushes in the northern row. This is in contrast to the standard mode treatments where spray was released continually through the plot and likely wrapped around the southern bushes through the gaps between bushes to reach bushes in the northern row.

There were noticeable differences in coverage patterns on cards placed within the boxwood canopies between cultivars, likely due to their canopy architecture. For the cards placed within Suffruticosa bushes, only one treatment resulted in spray coverage above 1% (300 GPA Standard, Table 2). This was in contrast to the Winter Gem bushes where coverage on the cards facing north in standard mode was more than 30% for both standard mode rates (Table 3). This higher level of coverage was likely due to the more open canopy architecture of the Winter Gem bushes compared to the Suffruticosa bushes. The Suffruticosa bushes were tightly sheared such that branches were pressed so closely together that leaves in the center of the bush are not visible. This was in contrast to the Winter Gem bushes, where interior leaves are more visible due to its more open growth habit. The more open growth habit of Winter Gem bushes allowed spray to penetrate the canopy more readily. This effect of cultivar growth habit was most clearly seen on the inner cards that were facing north in the two cultivars, but when it came to the inner south-facing cards, there was very little coverage regardless of the cultivar or spray treatment.

In both cultivars, inner cards facing south received little coverage due to the location of the card in relation to the sprayer. The inner cards that were facing south in both cultivars required the spray to travel approximately 8 feet from its point of release and through a row of boxwood bushes before finally contacting the bush in the northern row of bushes, and penetrating to its center where the card was placed. For the spray to travel that far with enough force to penetrate the bushes, higher air velocity/volume and/or more spray volume would likely be required. A sprayer that released the spray closer to the bushes, such as a tunnel or air assisted boom sprayer, would likely be more effective at penetrating the boxwood canopies of both cultivars in a multiple row plot such as the one where the tests were performed.

Future research could examine coverage on cards on the outside of bushes facing perpendicular to the plane of spray (i.e. facing east and west in this trial) to determine if the airblast sprayer was adequately covering all sides of the bushes. In addition, testing other sprayer types could more fully elucidate the spray patterns on the outer and inner canopies of boxwood bushes. From a practical standpoint, we advise boxwood growers to use high volumes when spraying fungicides for boxwood blight management. In addition, locally systemic fungicides should be used when conditions are critical for chemical management such as during wet weather on juvenile growth in the spring.