Foliar Application of Auxin During Production

Evergreen Hardwood
Deciduous Softwood

Aren Phillips – Assistant Propagation Manager

Spring Meadow Nursery, Grand Haven, MI

Outline

- Background
- Evergreen Hardwood Experiment
  - Materials and Methods
  - Results
- Deciduous Softwood Experiment
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  - Results
- Discussion

Background

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  - Production line of 4 sticking machines in tandem
  - 3-4 people can operate whole line
  - Maximum output of about 2,200 plants per hour, per machine, depending on the cell count of flat being made

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    - Deciduous gripper, one point of contact
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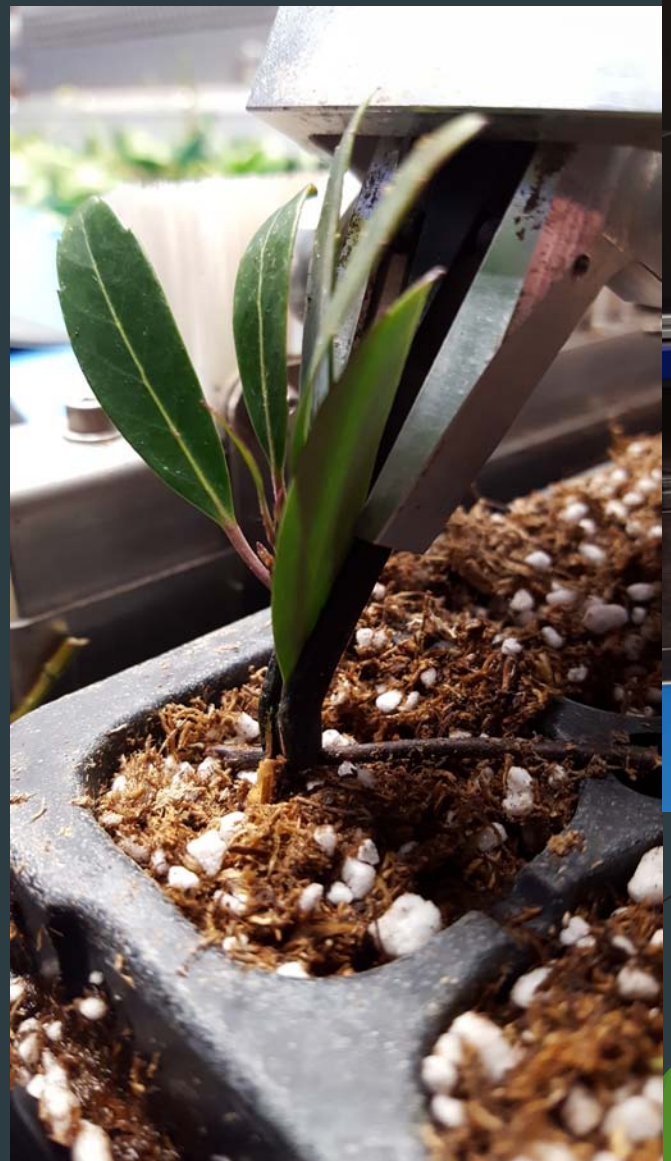

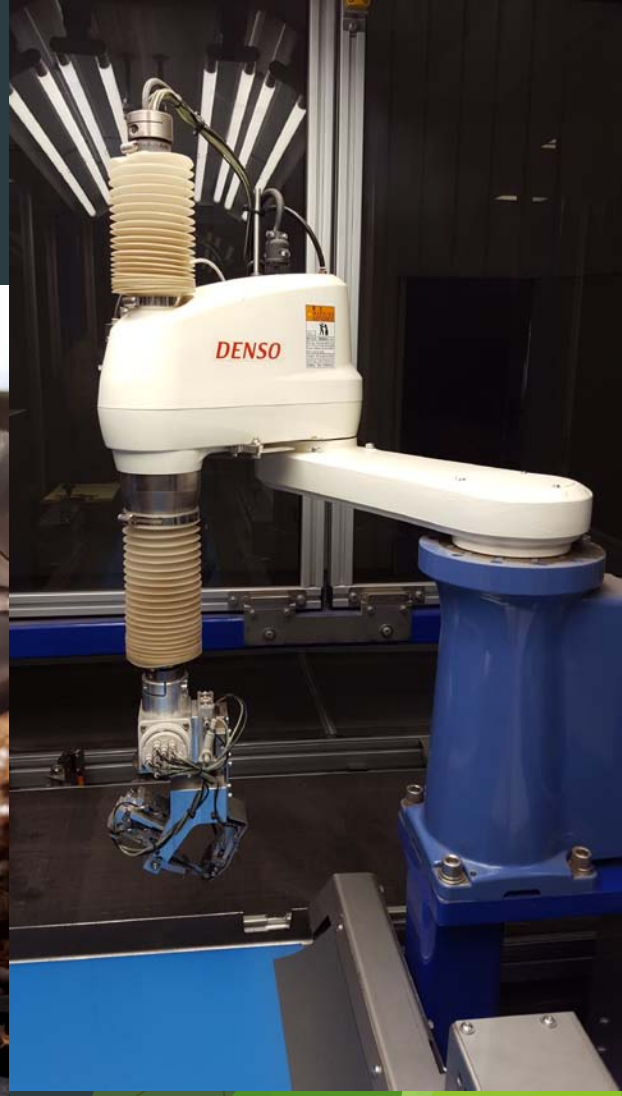

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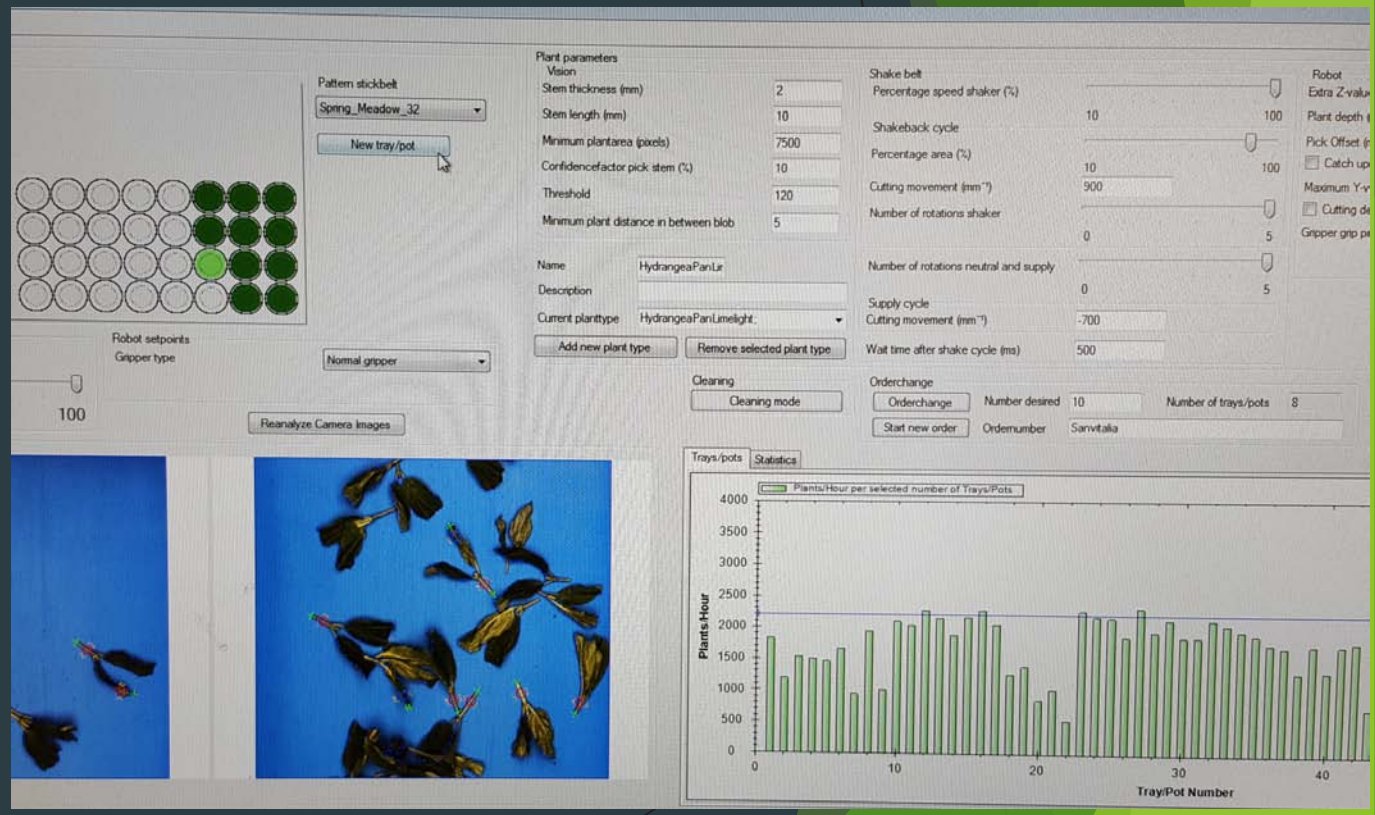
  - Efficiency tracking over time
    - Flat count every 5 minutes



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  - Foliar treatment after sticking is not the industry standard with evergreens and flowering shrubs
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- Main question:
  - “Can a foliar treatment of rooting hormone replace a basal quick dip treatment without a loss of plant quality or rooting percentage?”

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    - Easy to keep track of numbers
    - Easy handling
    - Easy hormone treatment

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    - Easy hormone treatment
  - Bundles are treated with a basal quick dip ranging from 1000-7500 ppm
    - Dip ‘n Grow (IBA/NAA)
  - Directly stuck into cells in soilless media
  - Laid on floor in propagation greenhouse

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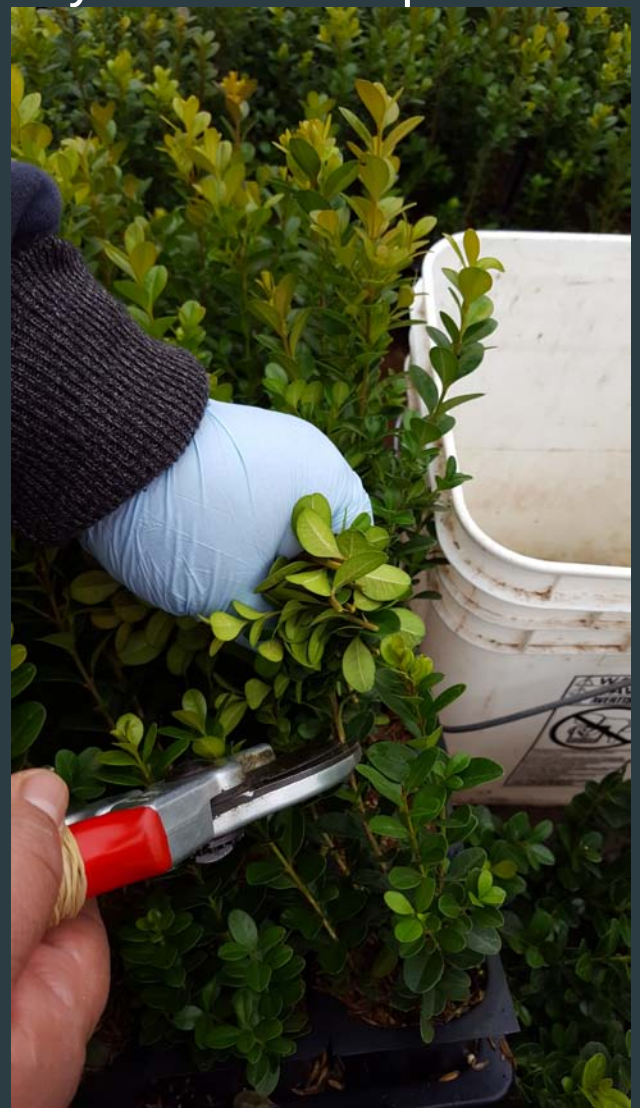

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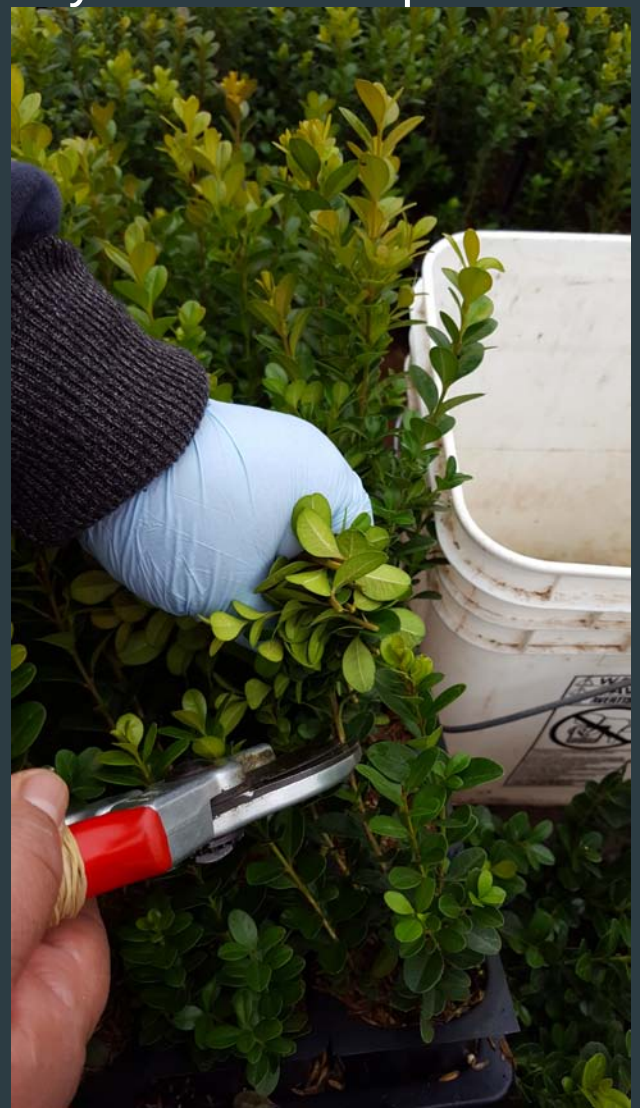

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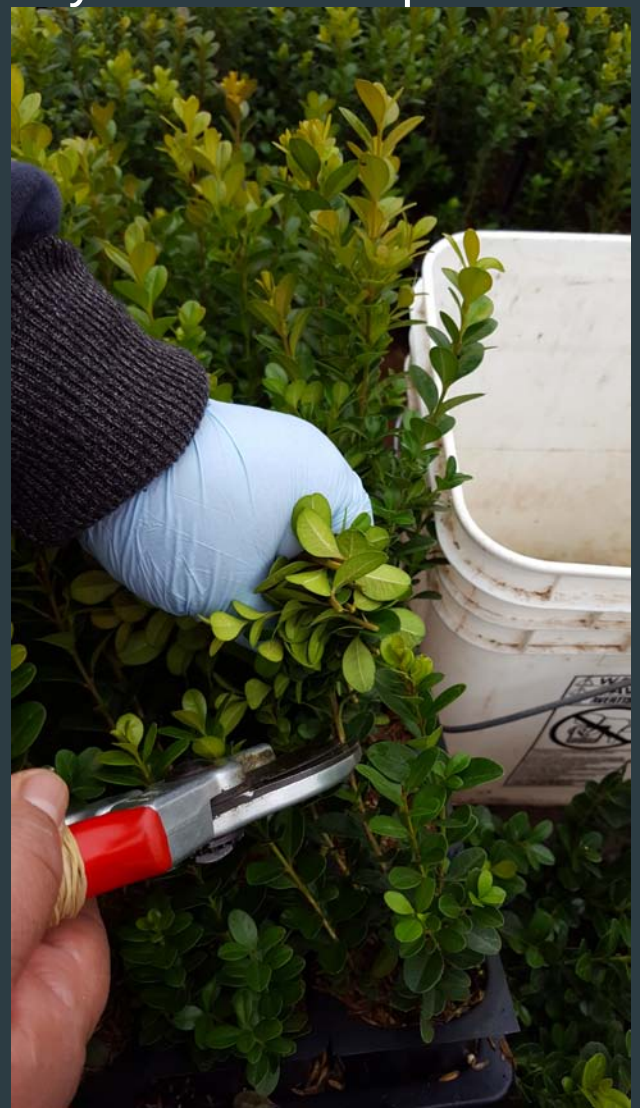

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Methods and Materials: Evergreen

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Methods and Materials: Evergreen

- Materials
  - Cuttings were taken and treated on site between October and December 2016
    - All cuttings were taken from stock plants
    - 20 varieties of hardwood evergreen cuttings within these genera:
      - *Buxus*
      - *Cephalotaxus*
      - *Chamaecyparis*
      - *Ilex*
      - *Juniperus*
      - *Microbiota*
      - *Taxus*
      - *Thuja*

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      - Two second stem dip before sticking
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      - Applied directly after sticking, after flats are in the greenhouse
      - Foliar spray to the point of dripping (40ml per flat, spray bottle by hand)
      - half the basal quick dip rate of IBA (Hortus IBA water soluable salts) +Kinetic as a surfactant

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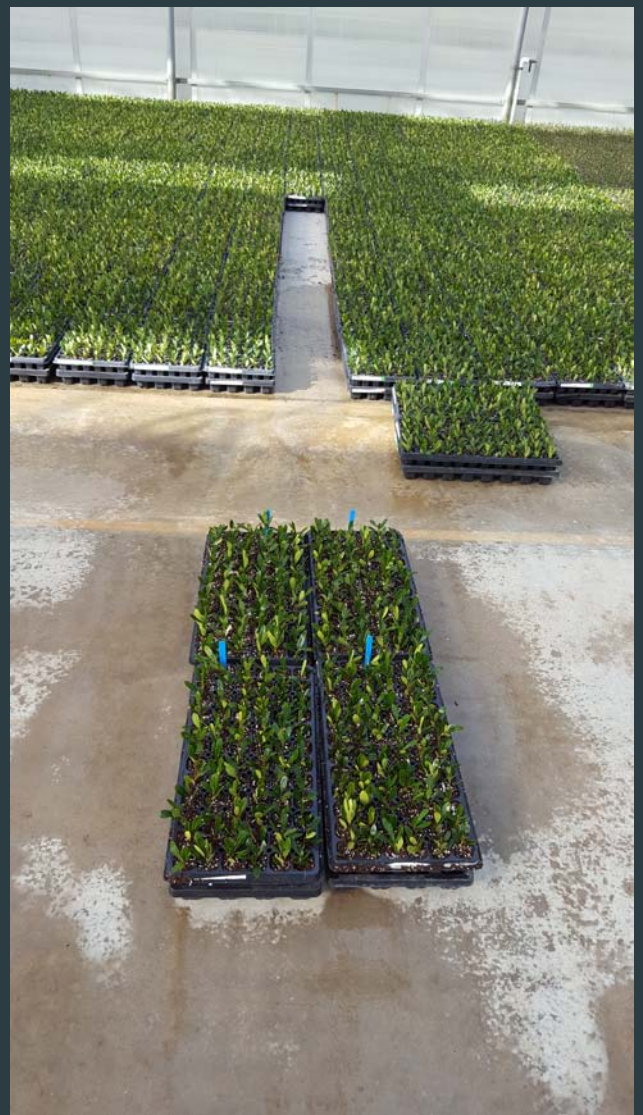
      - Foliar spray to the point of dripping (40ml per flat, spray bottle by hand)
      - half the basal quick dip rate of IBA (Hortus IBA water soluable salts) +Kinetic as a surfactant
    - Foliar Twice
      - Same as above
      - Treated directly after sticking and one week later

Methods and Materials: Evergreen

- All treatments were placed in the commercial production group



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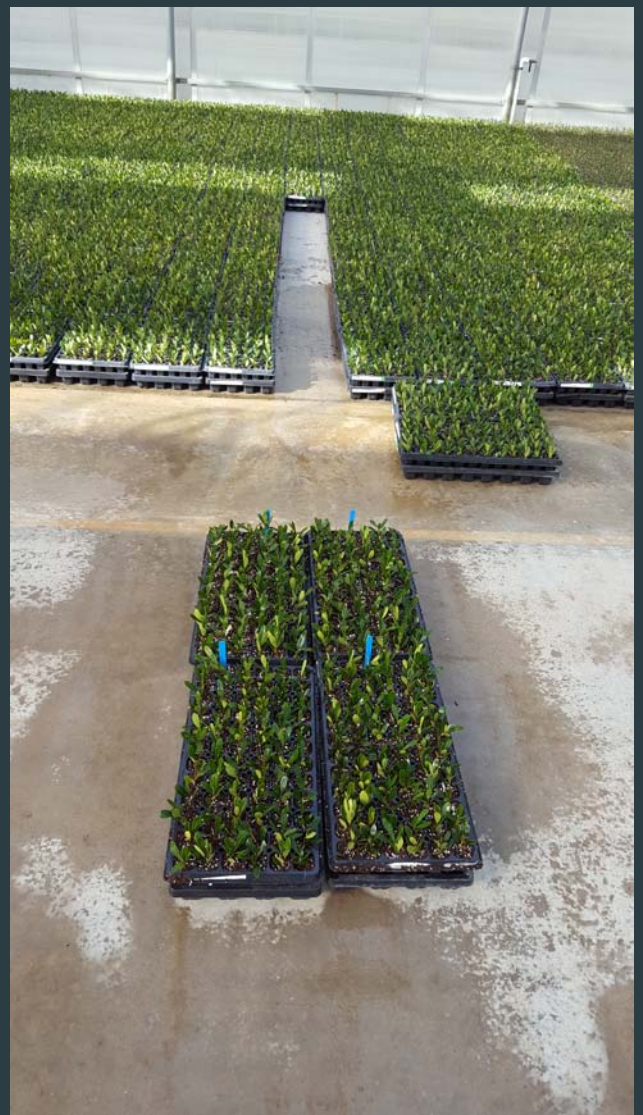

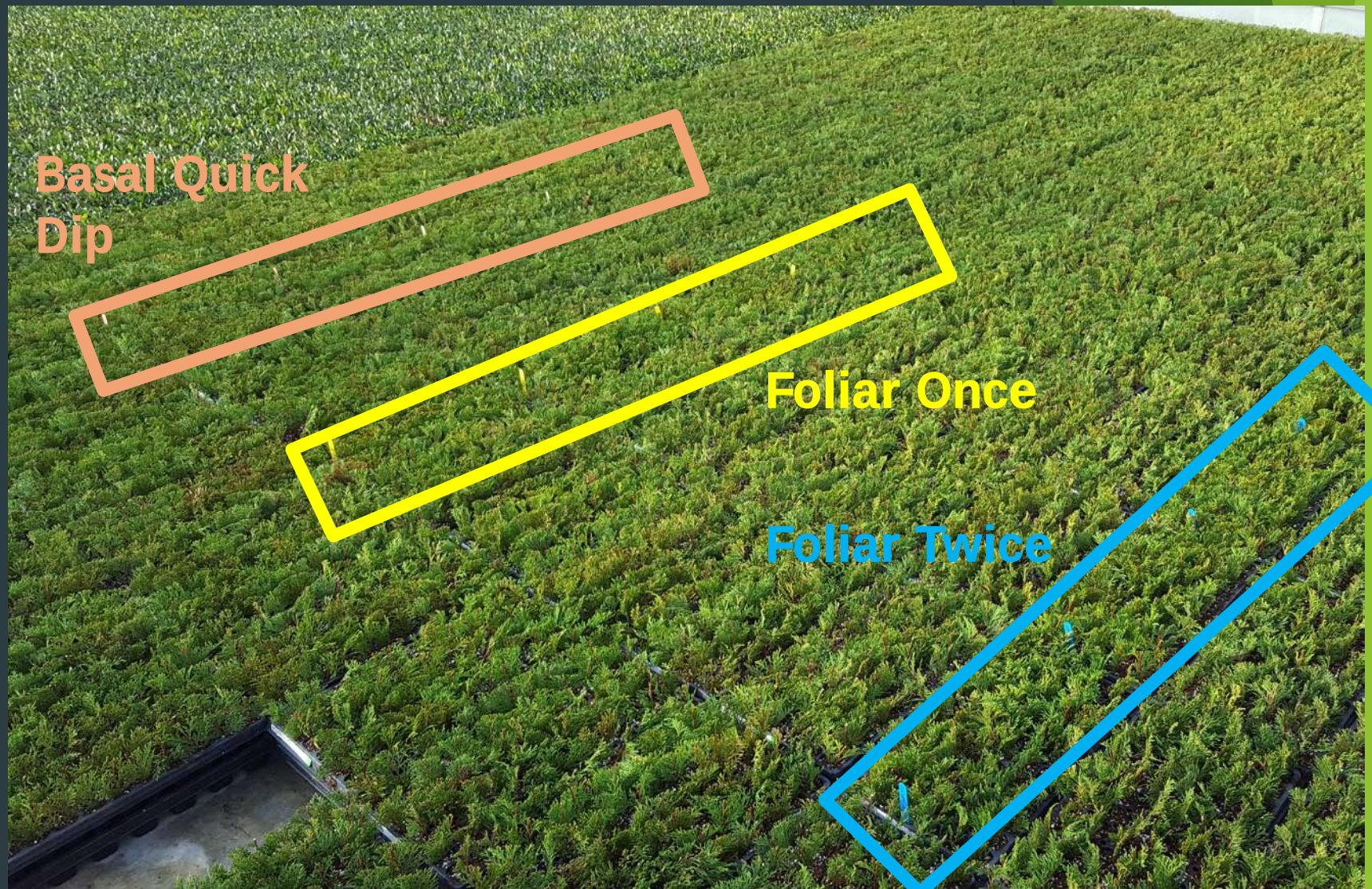

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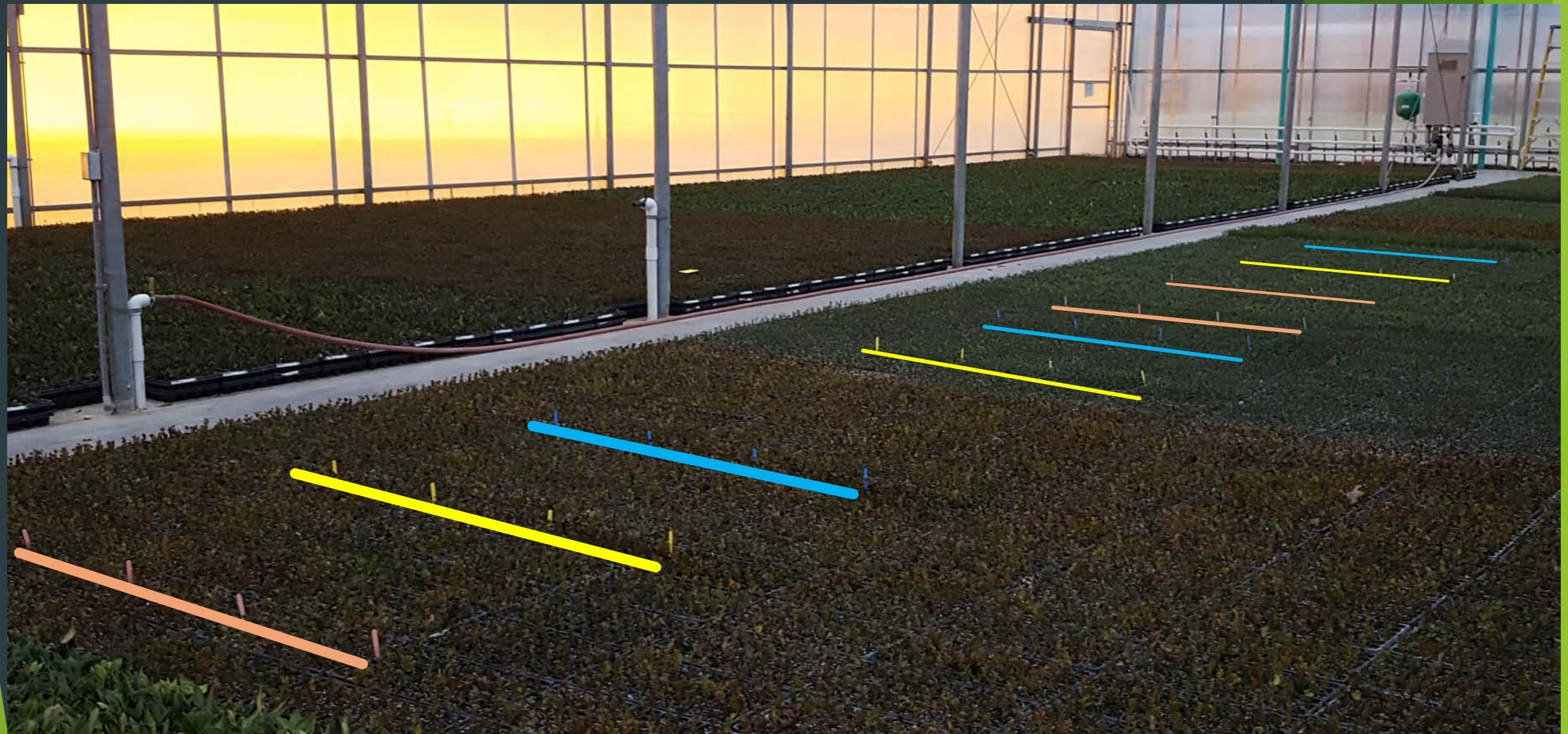

Methods and Materials: Evergreen

- Evaluation
  - Rooting evaluated twice
    - Evergreen hardwood cuttings are a very long crop
      - 72-cell plugs take 3-6 months to root
      - this was a chance to measure rooting rates over time

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    - First evaluation
      - when roots of commercial production group filled cells half way
      - number of weeks from sticking is variety dependent
    - Second evaluation
      - when commercial production group is rooted enough to be transplanted to its finished size

Methods and Materials: Evergreen

- Evaluation
  - Developed a rooting score for hardwood cuttings, on a scale of 0-5:
    - 0 – dead, necrotic stem
    - 1 – live cutting, no sign of swelling
    - 2 – stem shows signs of swelling, breaking, or root initials
    - 3 – visible roots, but few and small
    - 4 – long roots originating from base of stem
    - 5 – long roots originating from length of stem

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  - Rooting percentage (based on transplanting guidelines)
    - Rooting scores of 0-3 were unrooted
    - Rooting scores of 4-5 were rooted

Methods and Materials: Evergreen

- Evaluation
  - *Ilex* x Castle Spire® (1000 ppm basal quick dip, 8 weeks after sticking)

Methods and Materials: Evergreen

- Evaluation
  - No sign of response on #1, swelling and root initials on #2

Methods and Materials: Evergreen

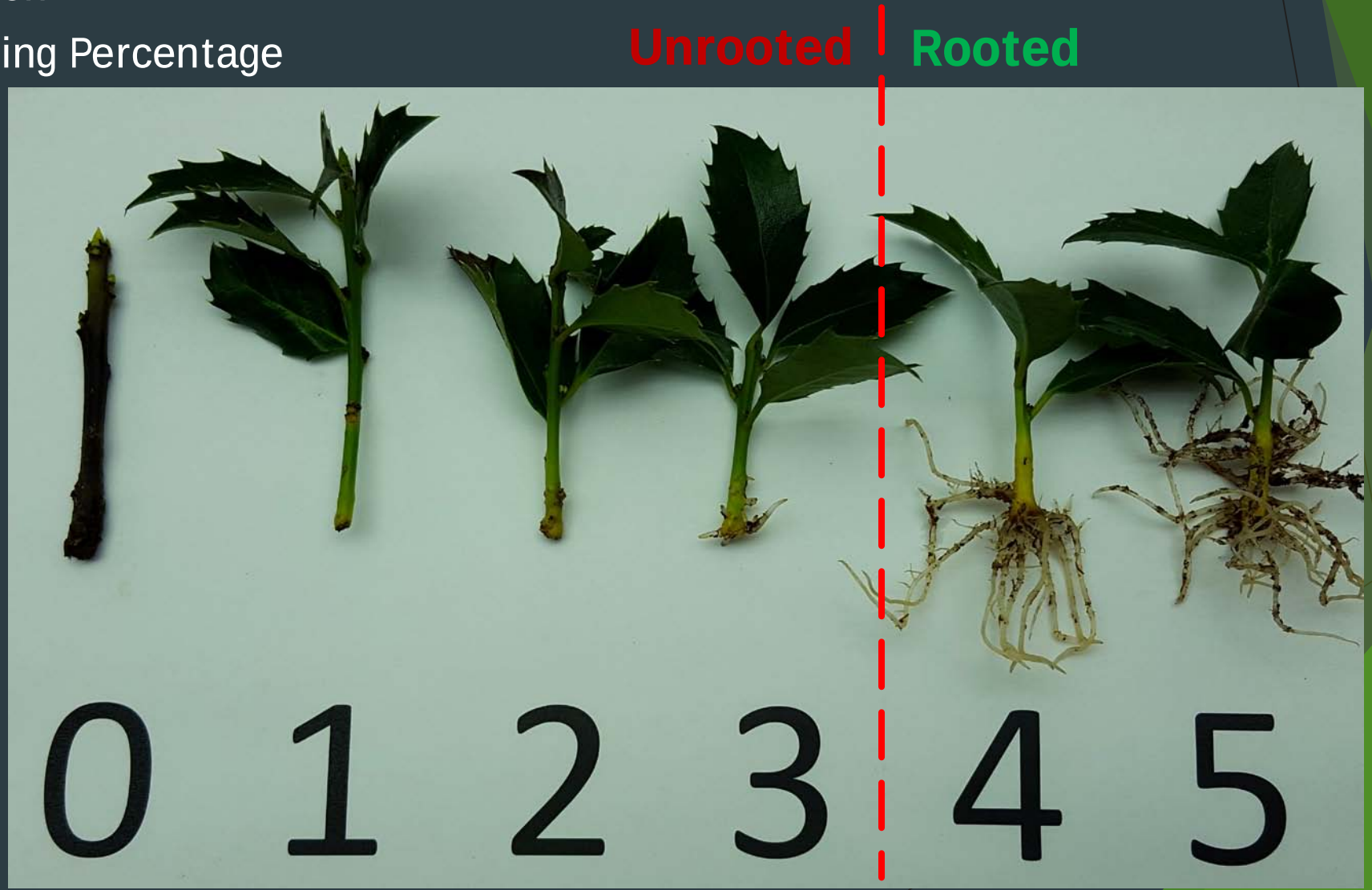
- Evaluation
  - #4 and #5 delineated to reflect differences in treatment, if any

- Foliar application: Auxins flow from leaf to base of stem

- Basal quick dip: Auxins are absorbed along the length of the stem

Methods and Materials: Evergreen

- Evaluation
  - Rooting Percentage



Methods and Materials: Evergreen

- Evaluation
  - About 16,000 plugs were evaluated

Results: Evergreen

- Background:
  - Is a foliar treatment comparable to a basal quick dip treatment?
    - Rooting quality
    - Rooting time
    - Rooting percentage

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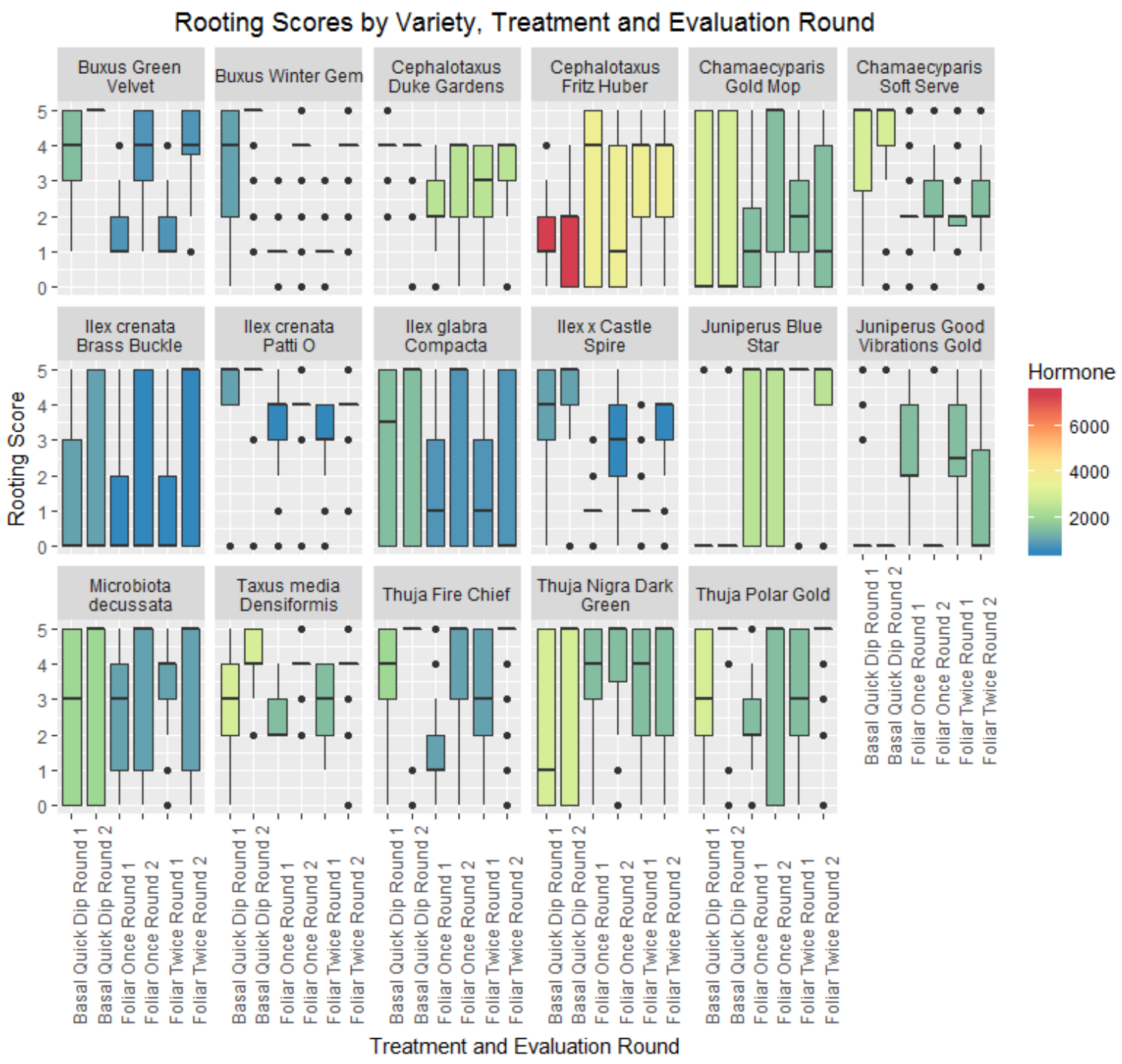
- Background:
  - Is a foliar treatment comparable to a basal quick dip treatment?
    - Rooting quality
    - Rooting time
    - Rooting percentage
  - RStudio statistical software
    - One way ANOVA (ANalysis Of VAriance)
    - Tukey HSD test (Tukey's Highly Significant Difference test)

Results

- Comparing rooting scores: varieties
  - 17 varieties had data from all treatments at the end of the experiment



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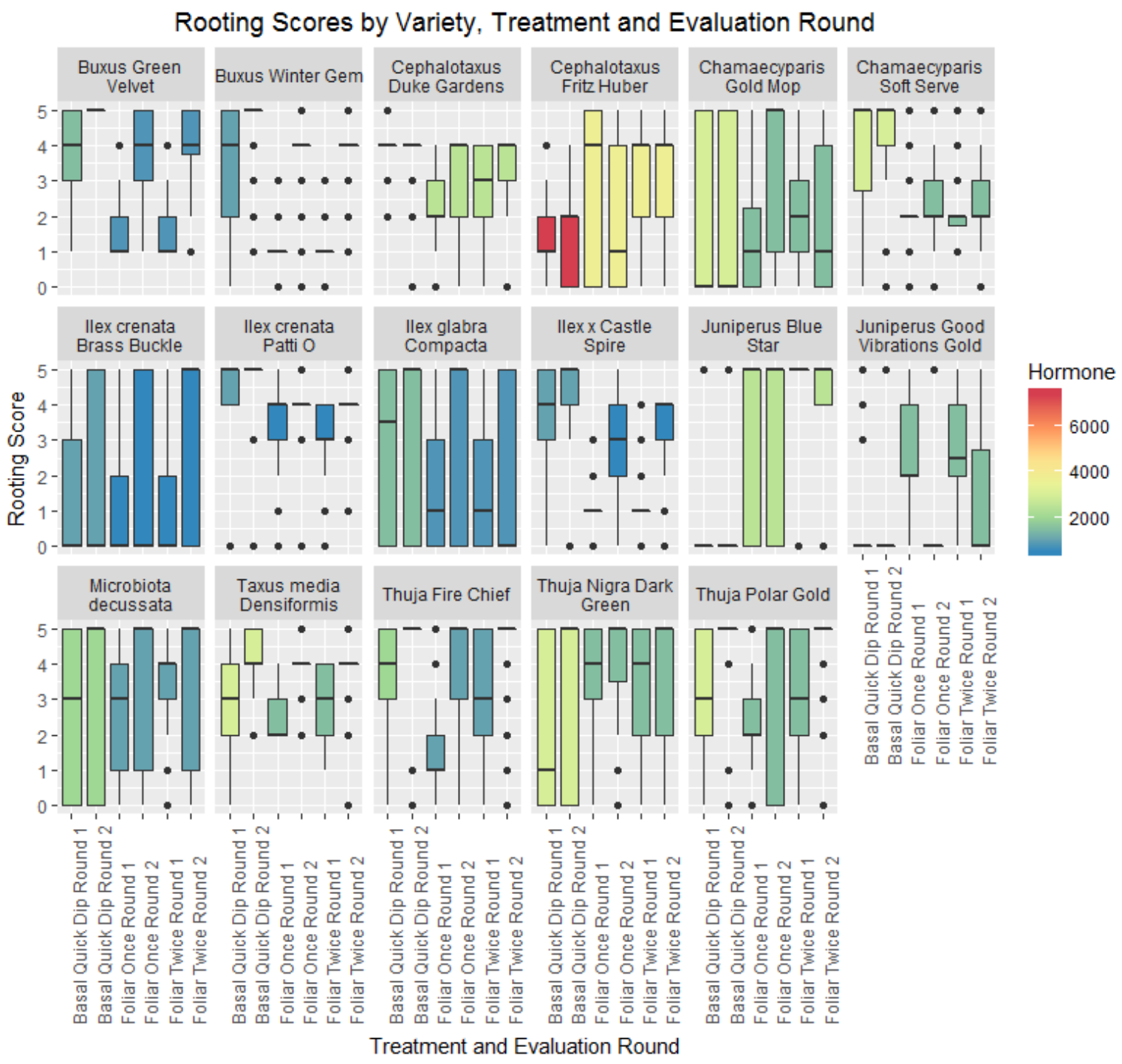
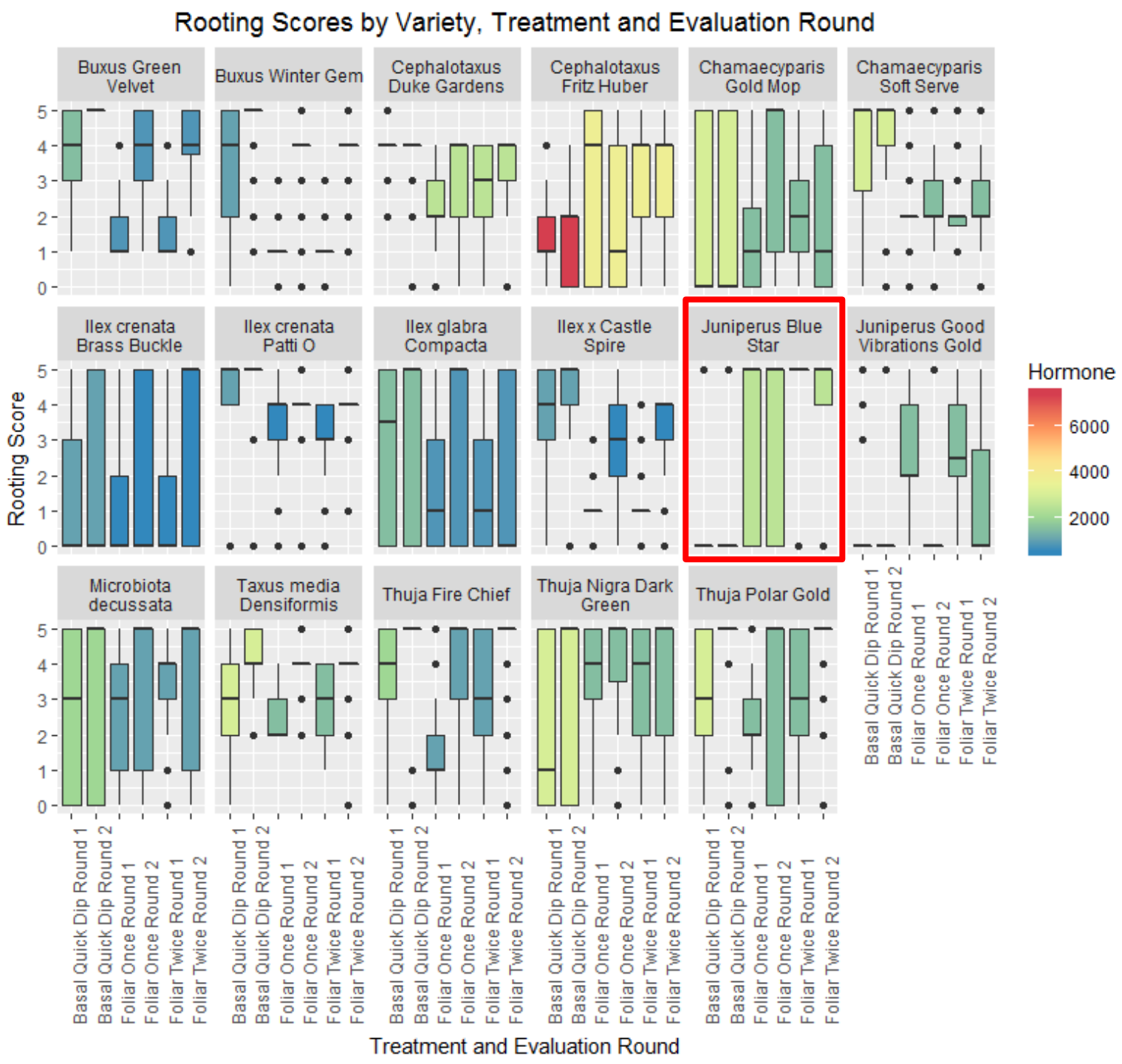
- Comparing rooting scores: varieties
  - 17 varieties had data from all treatments at the end of the experiment
  - Each variety has a boxplot representing the rooting scores for each treatment and each evaluation round



Results

- Comparing rooting scores: varieties
  - Example #1:
    - *Juniperus squamata* 'Blue Star'



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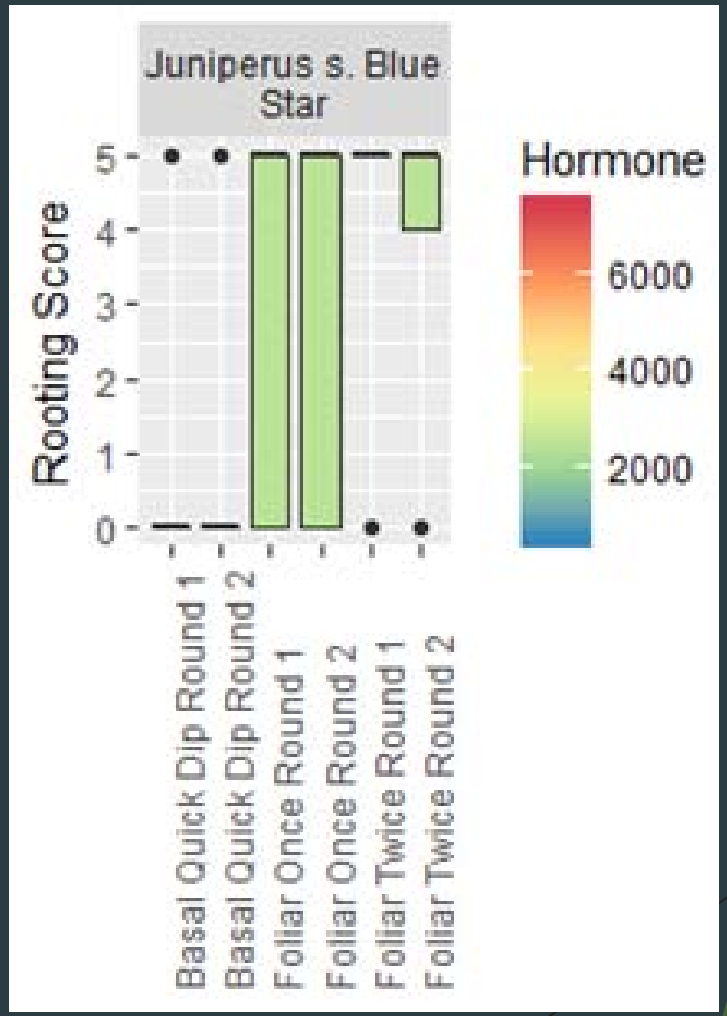

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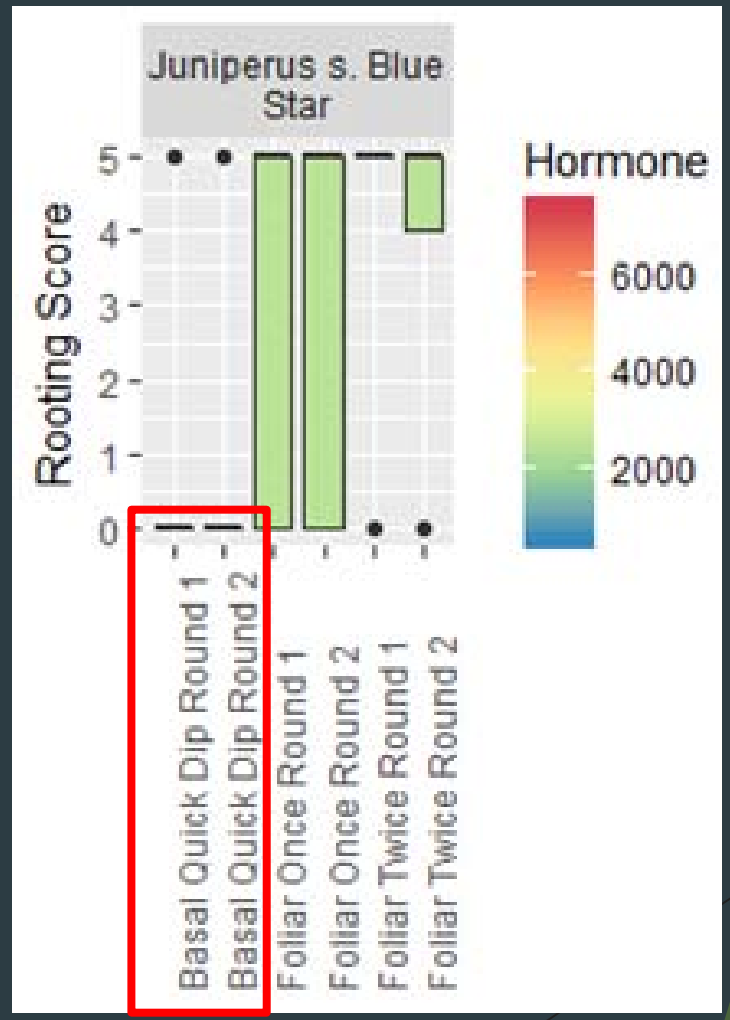
- Comparing rooting scores: varieties
  - *Juniperus squamata* ‘Blue Star’
    - Both rounds for basal quick dip were crop failures (means 0.3-0.4)



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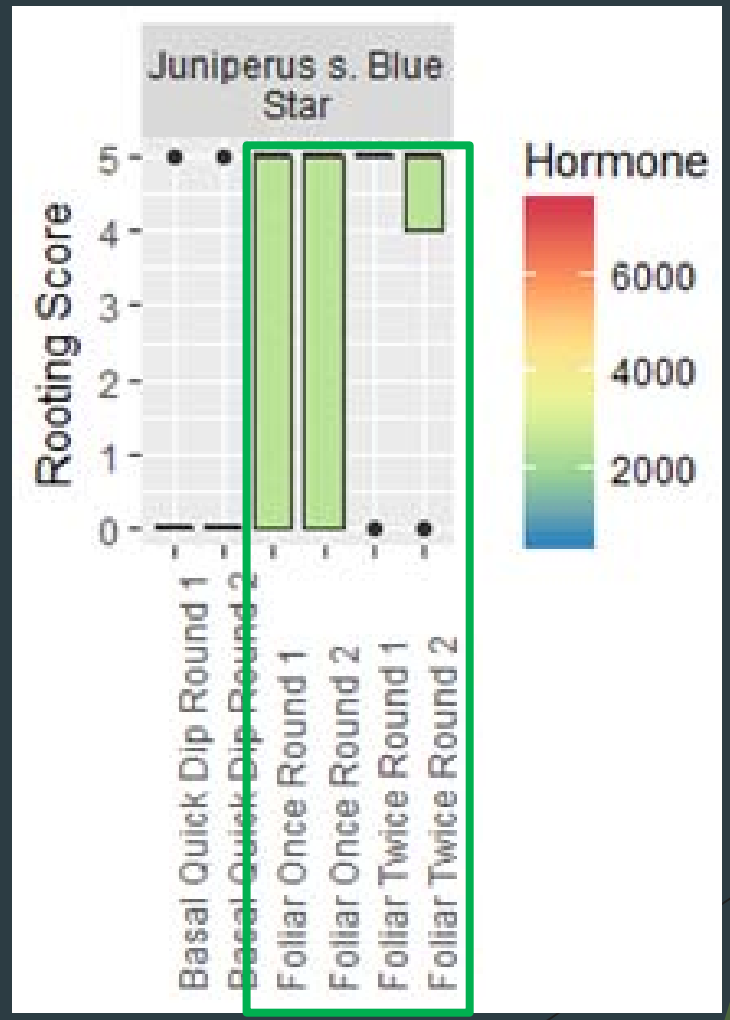
- Comparing rooting scores: varieties
  - *Juniperus squamata* ‘Blue Star’
    - Both rounds for basal quick dip were crop failures (means 0.3-0.4)
    - Both foliar treatments had significantly better rooting scores
      - Foliar once (mean 3.3 and 3.2)
      - Foliar twice (mean 4.0 and 4.2)



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    - Visual difference Round 1
      - basal quick dip (pink)
      - Foliar once (yellow)

Results

- Comparing rooting scores: varieties
  - Example #2:
    - *Ilex x* Castle Spire®

Results

- Comparing rooting scores: varieties
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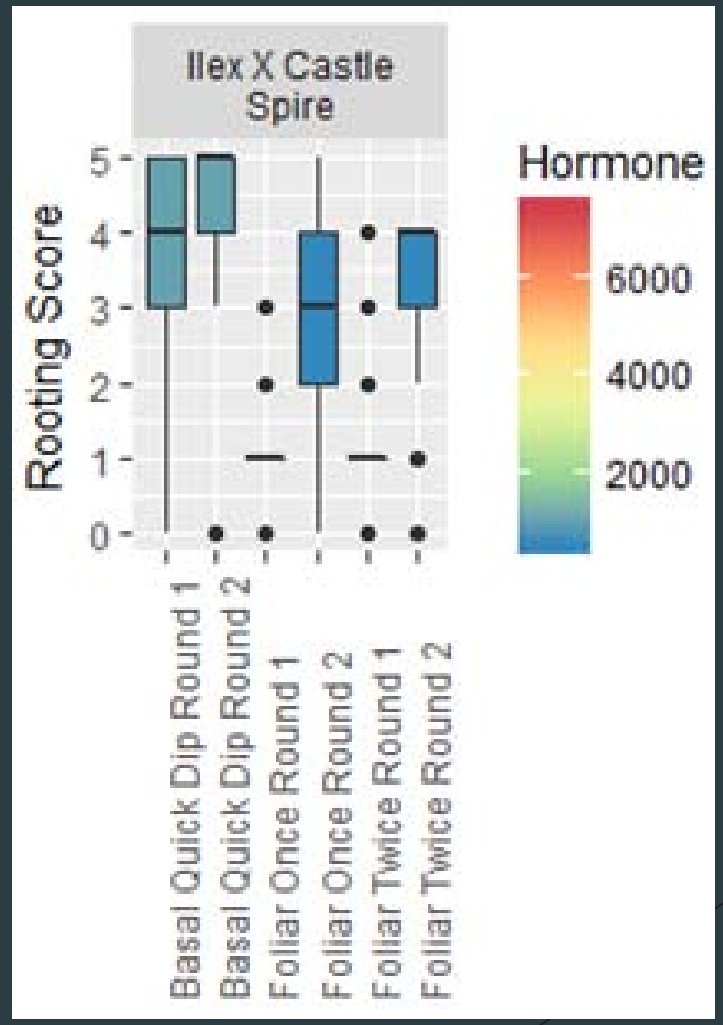
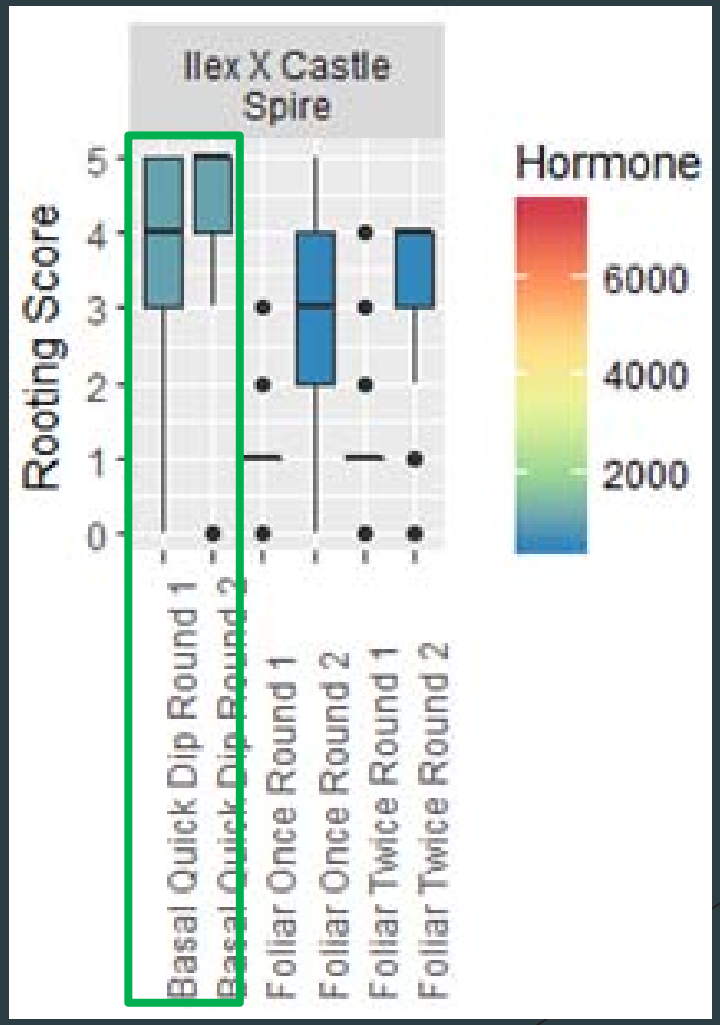


Results

- Comparing rooting scores: varieties
  - *Ilex x* Castle Spire®
    - Both rounds for Basal Quick Dip had significantly higher rooting scores than any foliar treatments or evaluation rounds
      - (mean 3.8 and 4.2)



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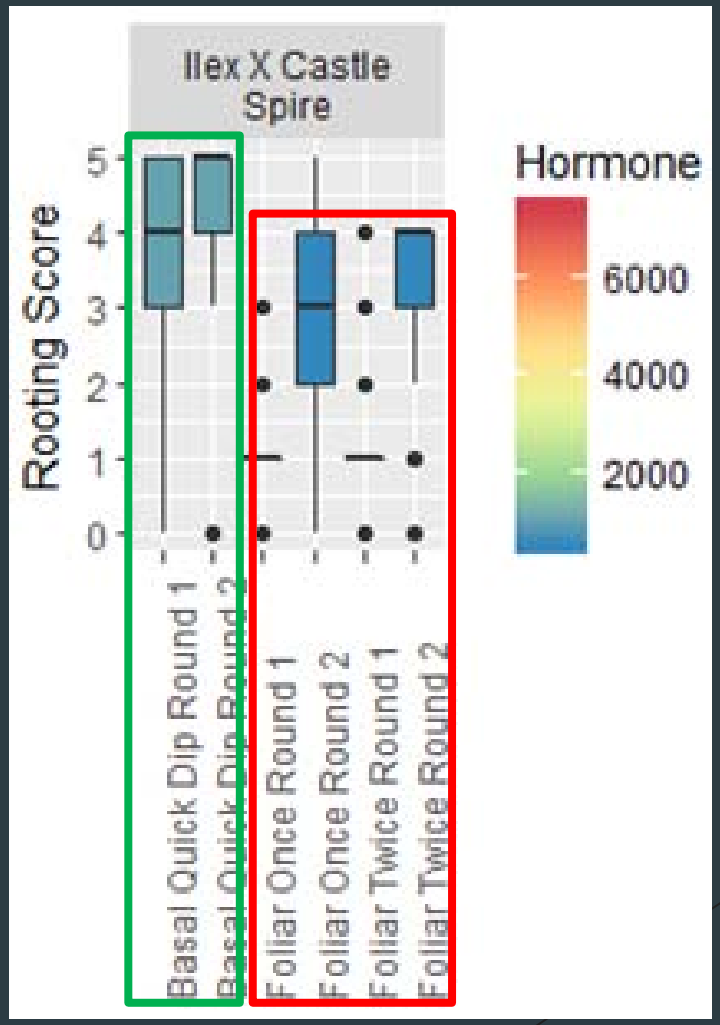
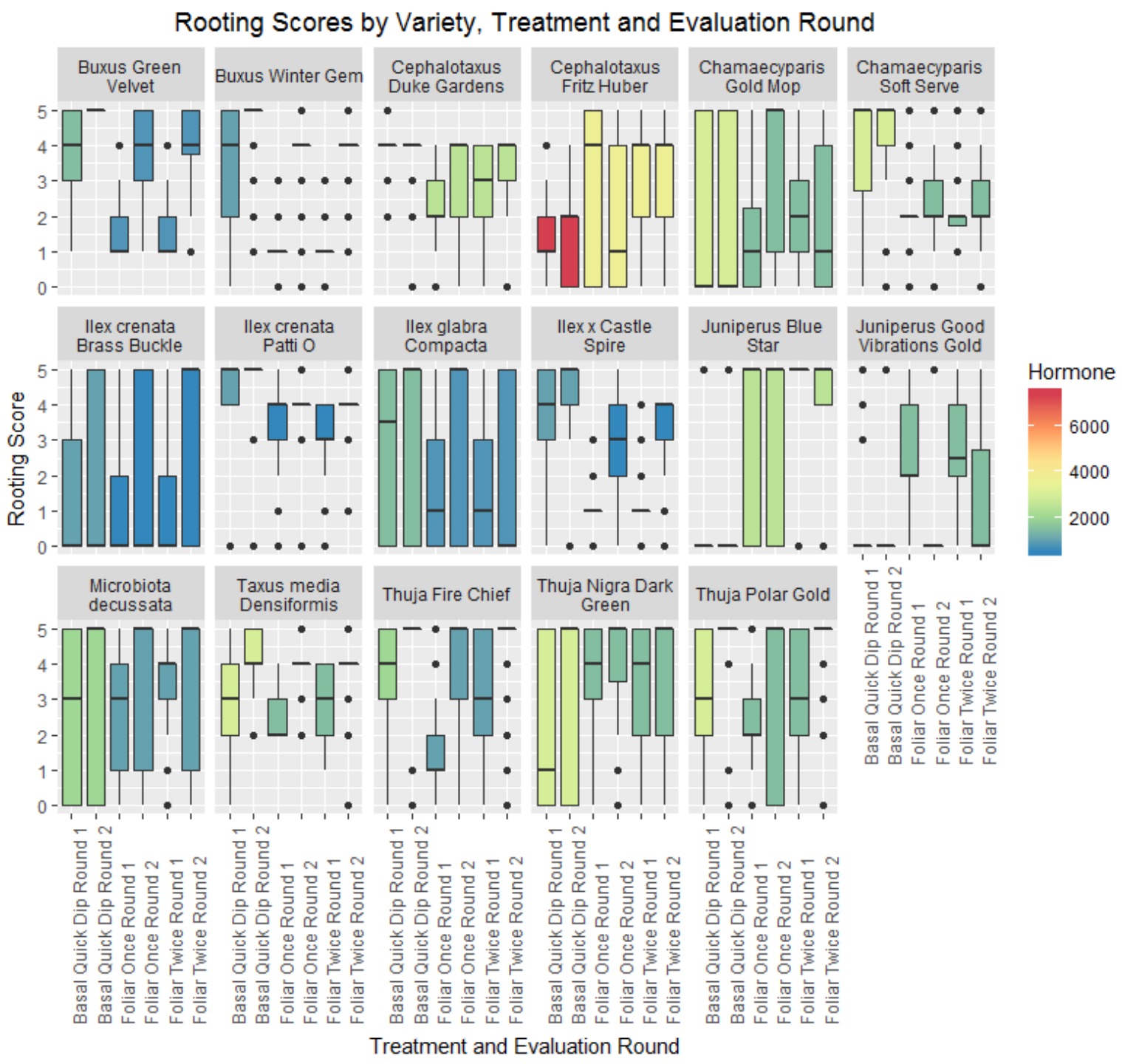
      - (mean 3.8 and 4.2)
    - Foliar rooting scores
      - Foliar once (mean 0.9 and 2.7)
      - Foliar twice (mean 1.1 and 3.3)



Results

- Comparing rooting scores: varieties
- To simplify comparisons, varieties were arranged by leaf type



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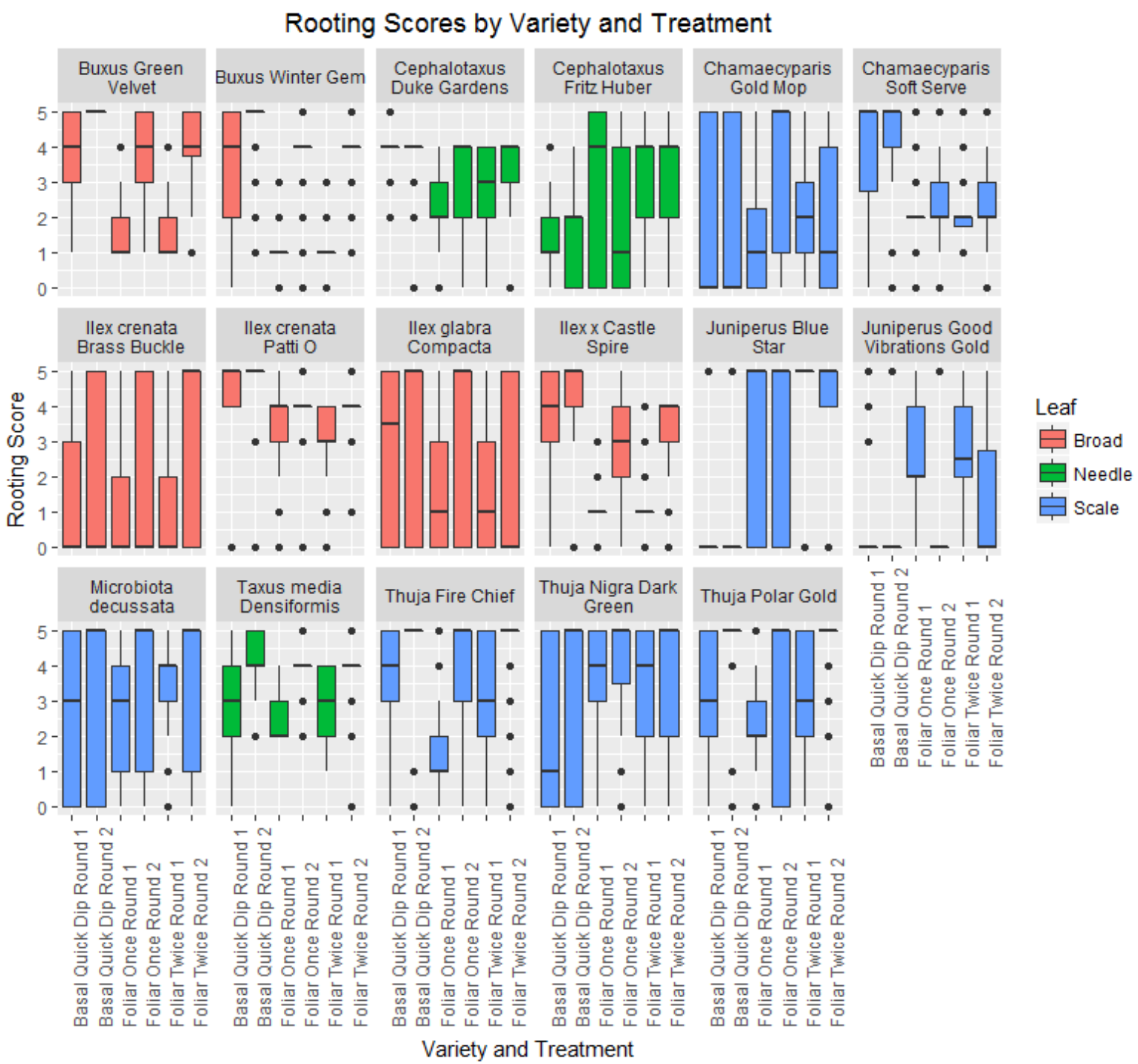
  - Broad:
    - *Buxus*
    - *Ilex*
  - Needle:
    - *Cephalotaxus*
    - *Taxus*
  - Scale:
    - *Chamaecyparis*
    - *Juniperus*
    - *Microbiota*
    - *Thuja*



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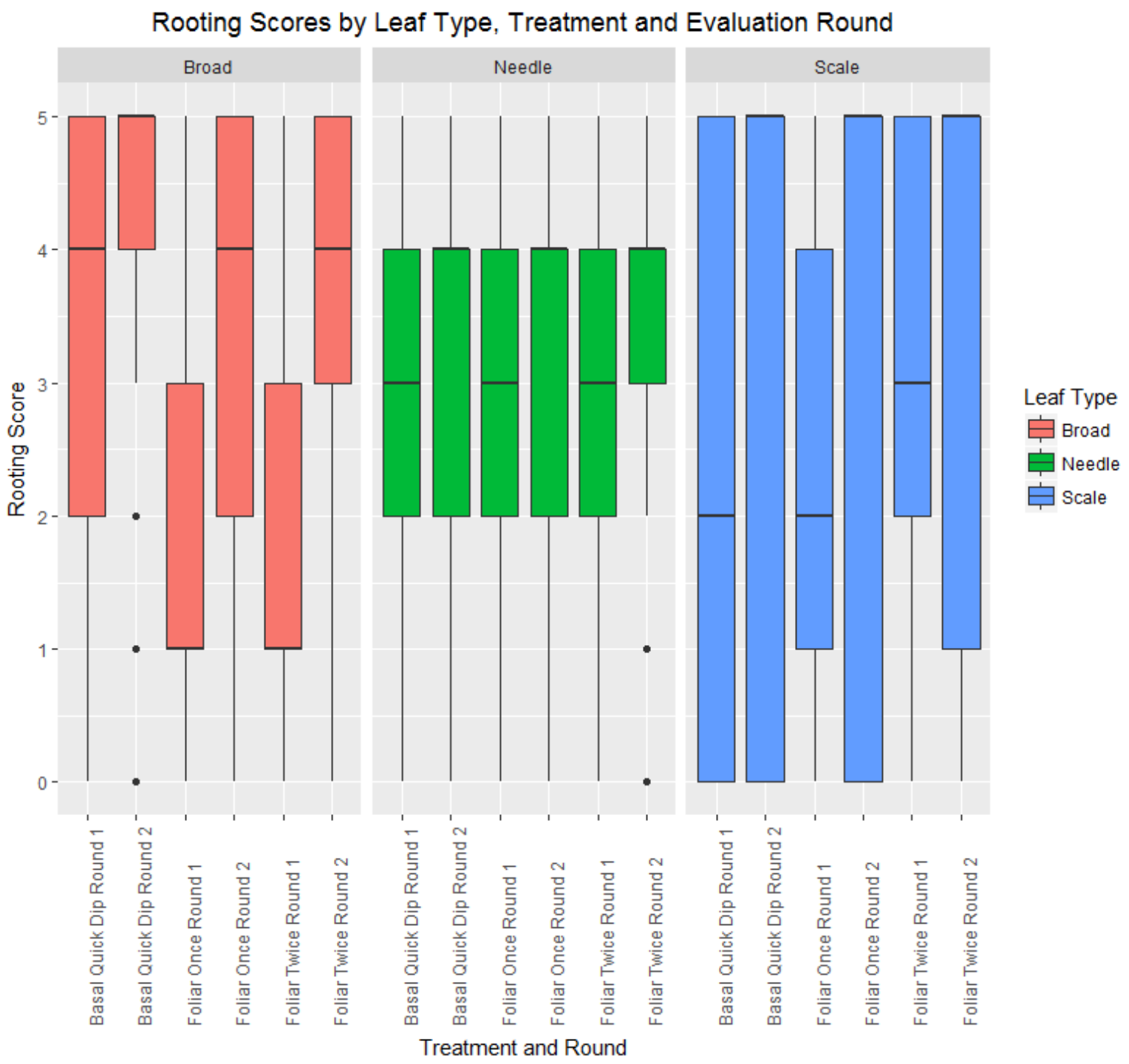

Results

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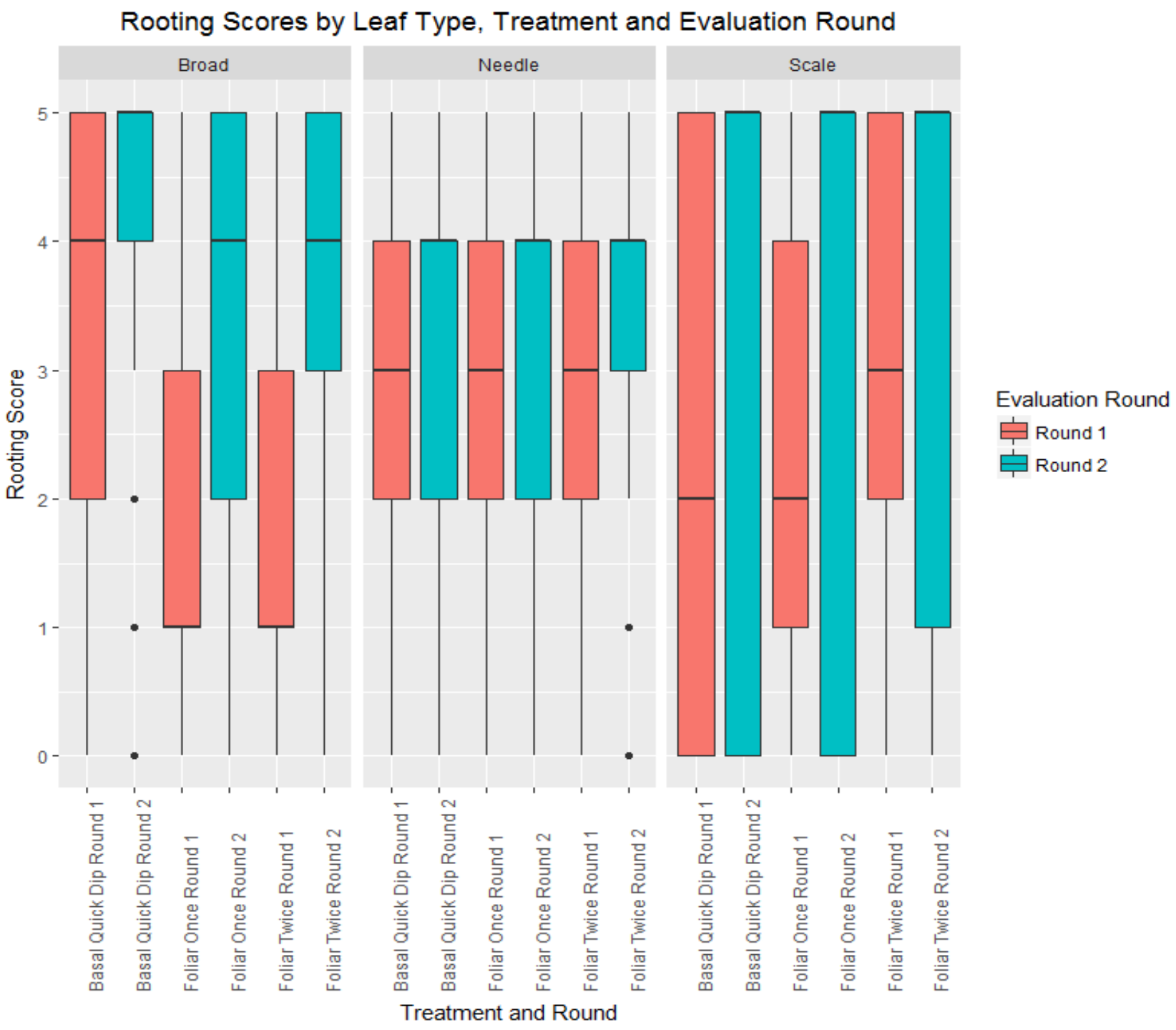
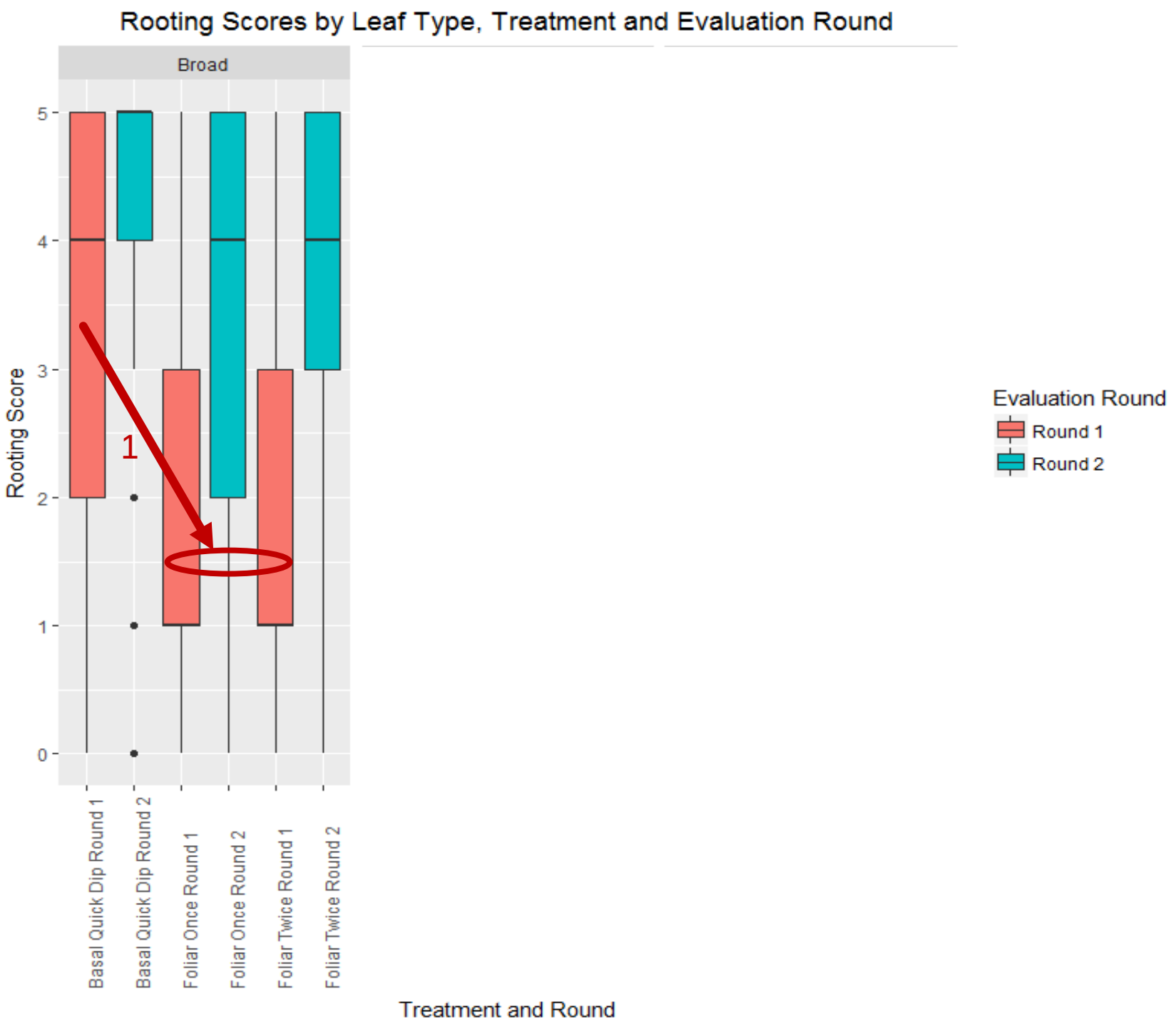
- To simplify comparisons, varieties were arranged by leaf type
- Leaf types were grouped together by treatment and round
- Treatments and evaluation rounds were compared



Results

- Comparing rooting scores: Broad leaves
- Both foliar treatment rooting scores were significantly less than the basal quick dip treatment
- Round 1
  - BQD (mean 3.3)
  - F1 & F2 (mean 1.6)



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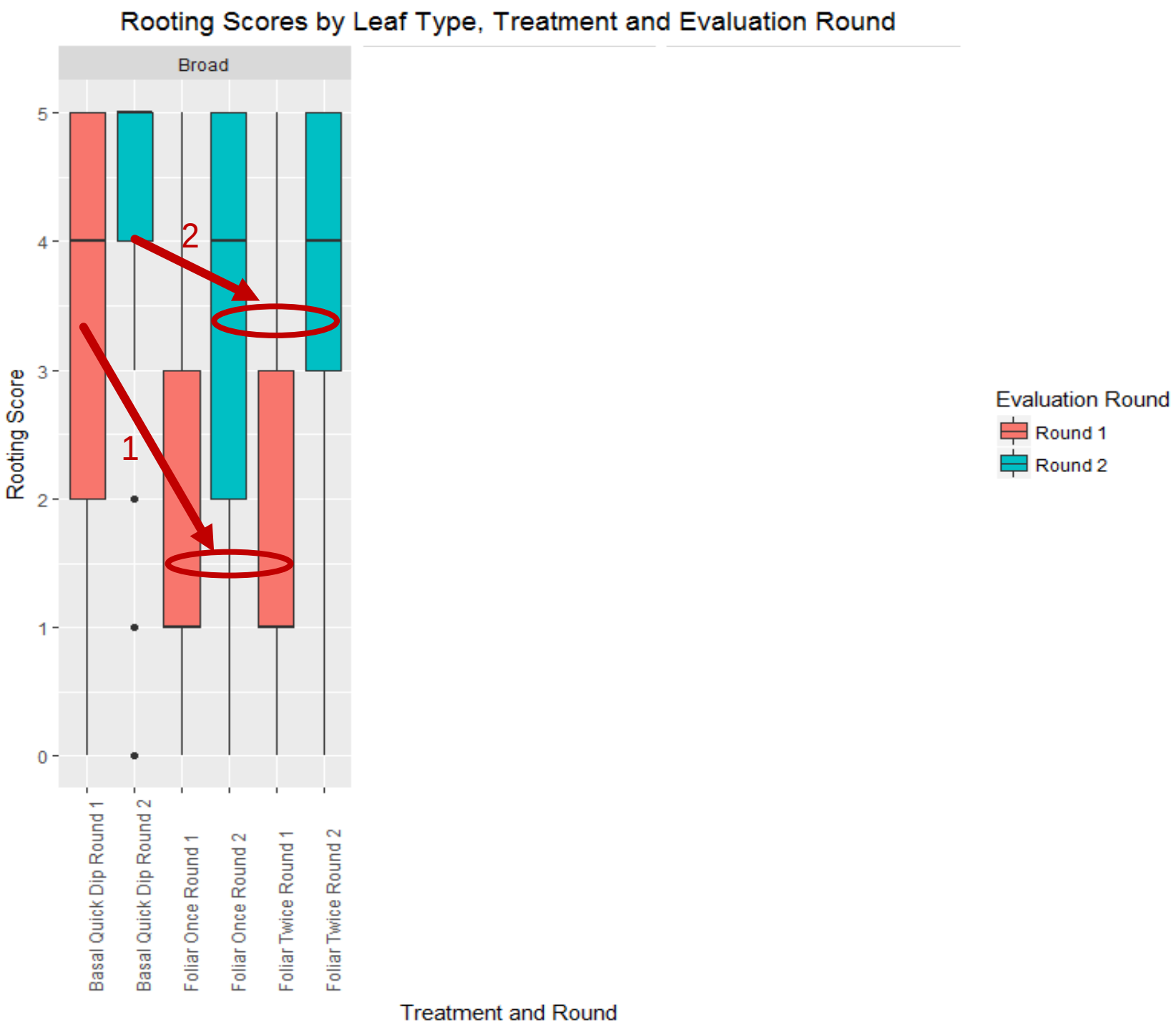
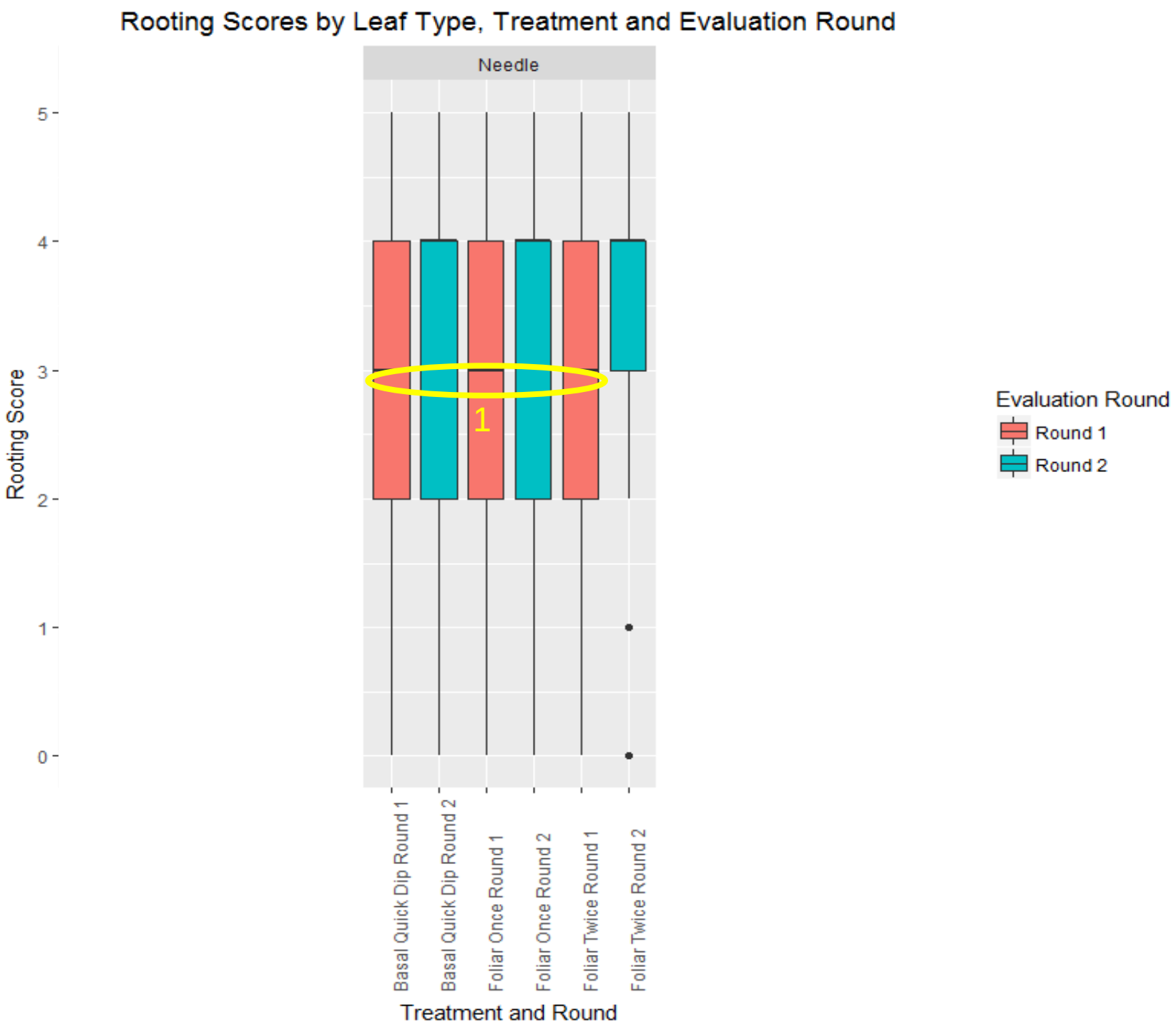
  - F1 & F2 (mean 1.6)
- Round 2
  - BQD (mean 4.0)
  - F1 & F2 (mean 3.2-3.5)



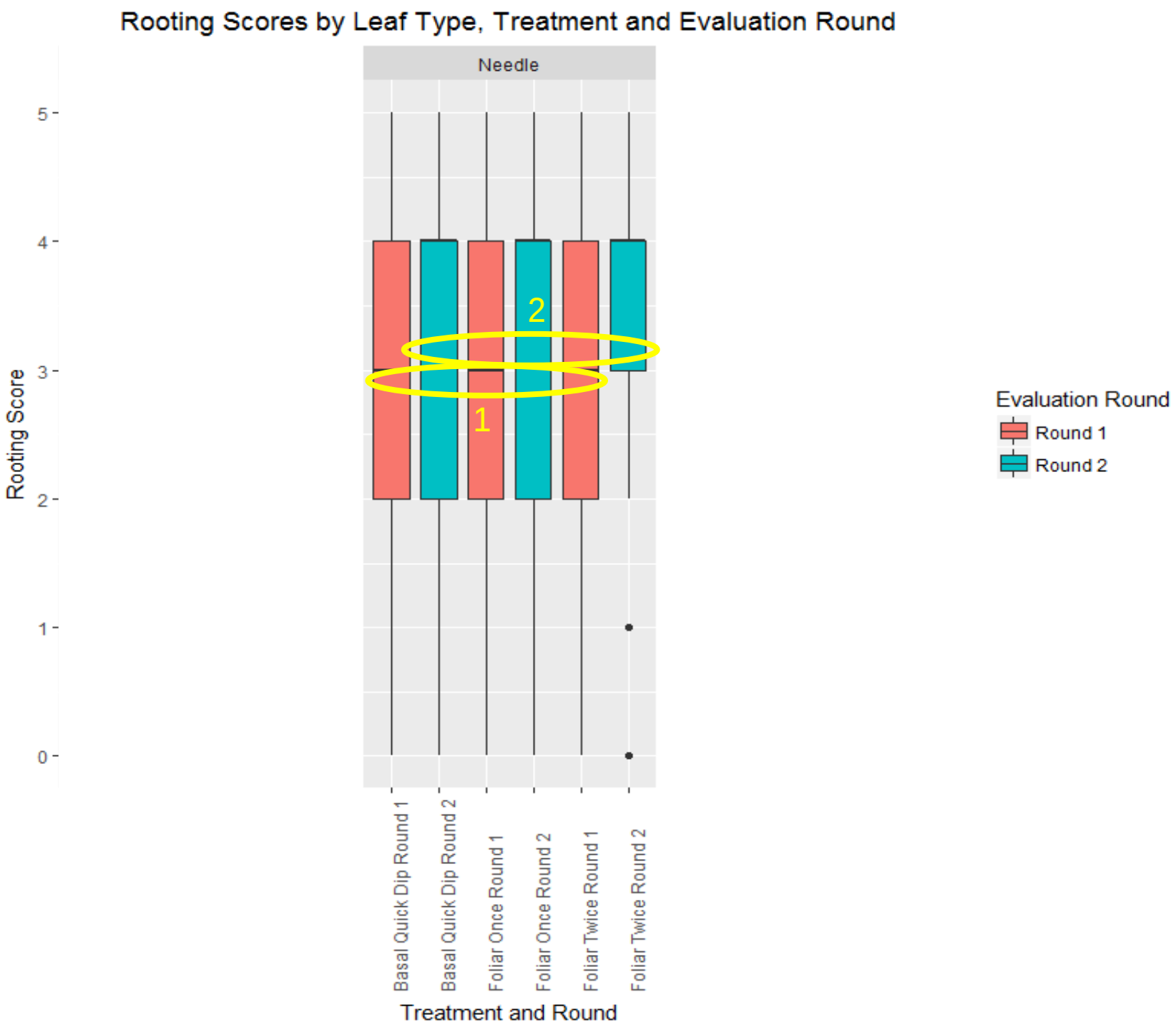
Results

- Comparing rooting scores: Needle leaves
- There was no significant difference in rooting scores for round 1
- Round 1
  - BQD, F1 and F2 (means 2.7-3.1)



Results

- Comparing rooting scores: Needle leaves
- Foliar twice was significantly higher than foliar once in round 2, but not significantly different than BQD
- Round 2
  - BQD, F1 (means 3.2 and 2.9)
  - F2 (mean 3.5)



Results

- Comparing rooting scores: Scale leaves
- The foliar twice rooting scores were higher than the basal quick dip and the foliar once for both rounds
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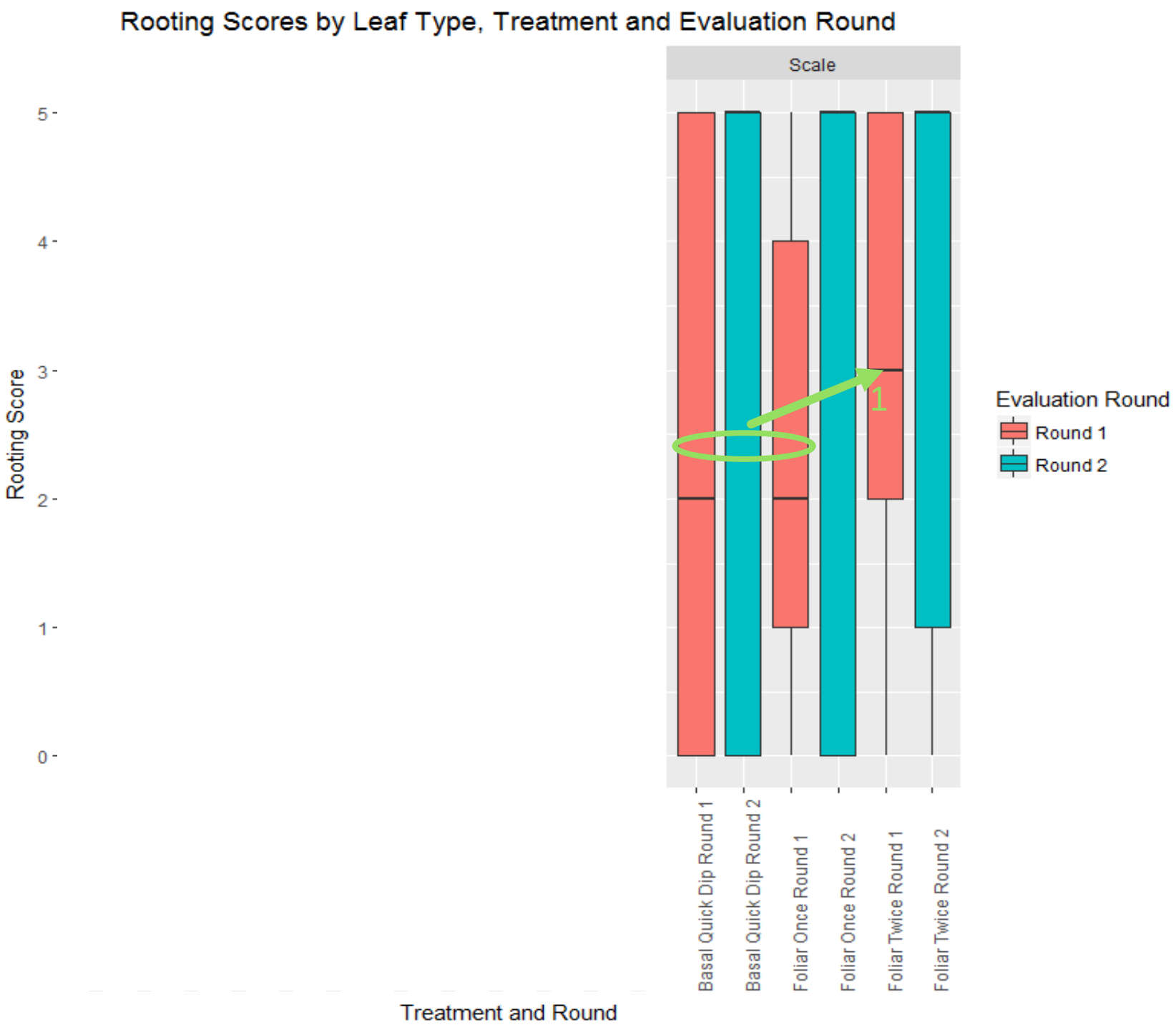
  - BQD, F1 (means 2.3-2.6)
  - F2 (mean 3.0)



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  - F2 (mean 3.0)
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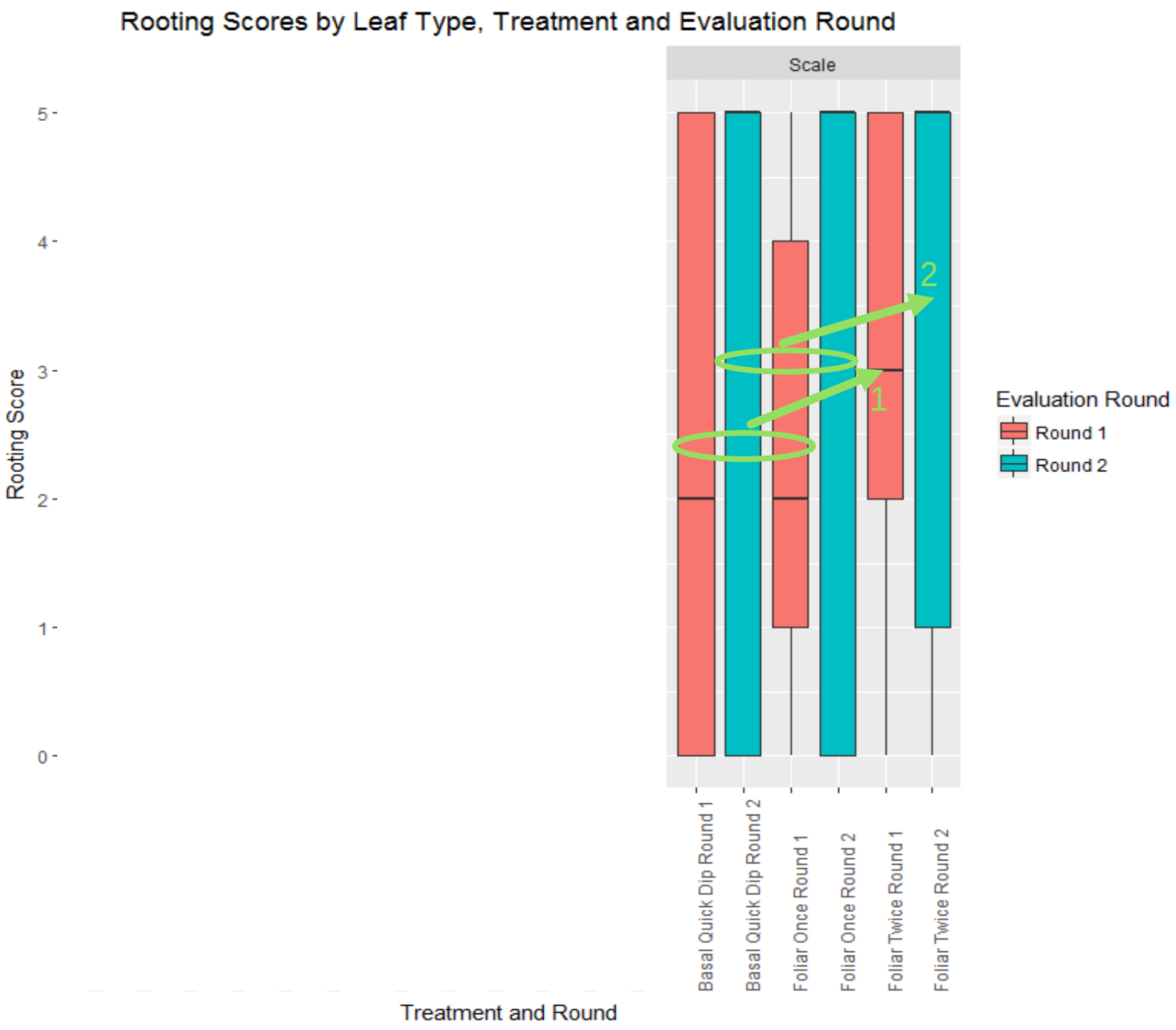
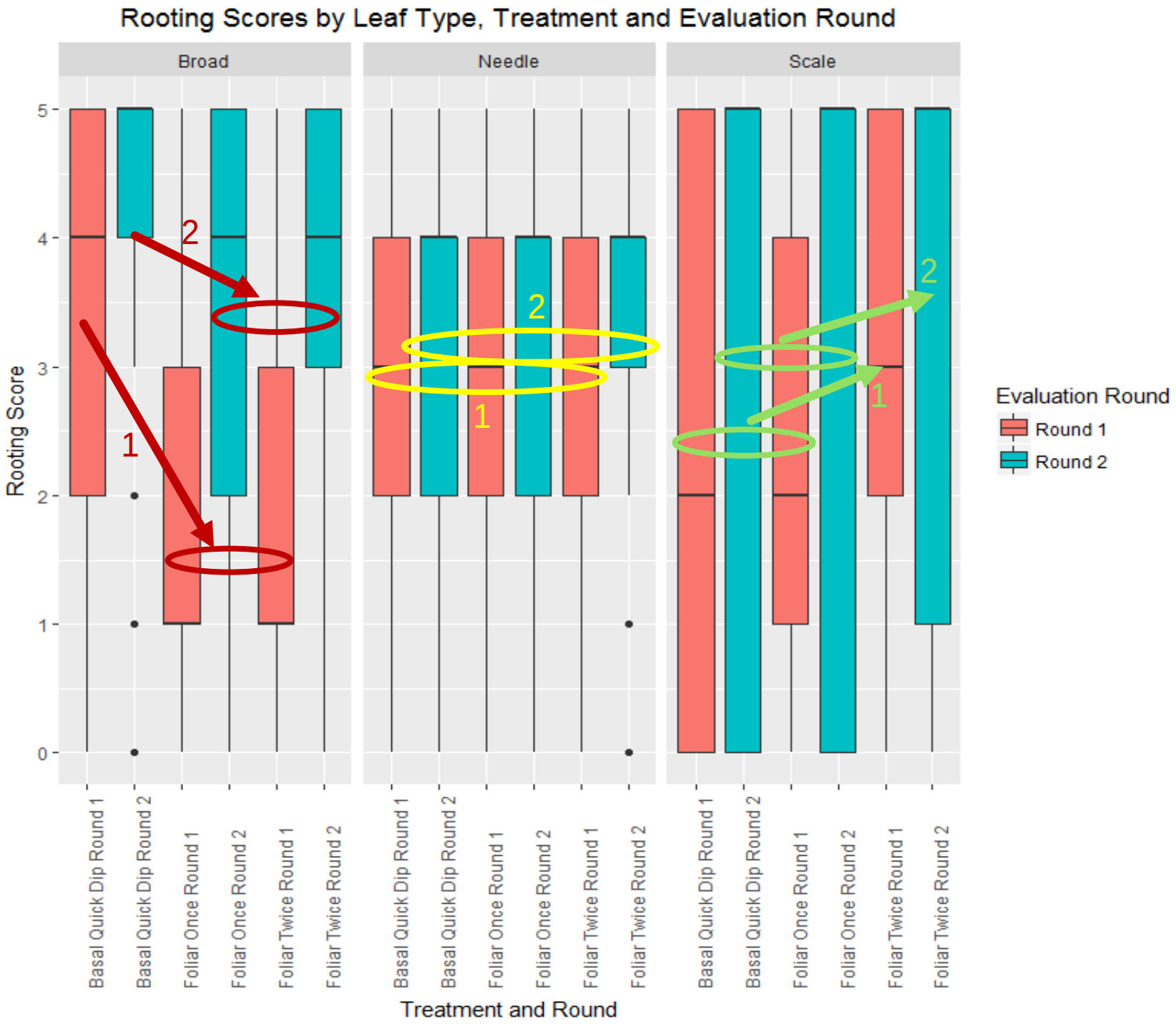


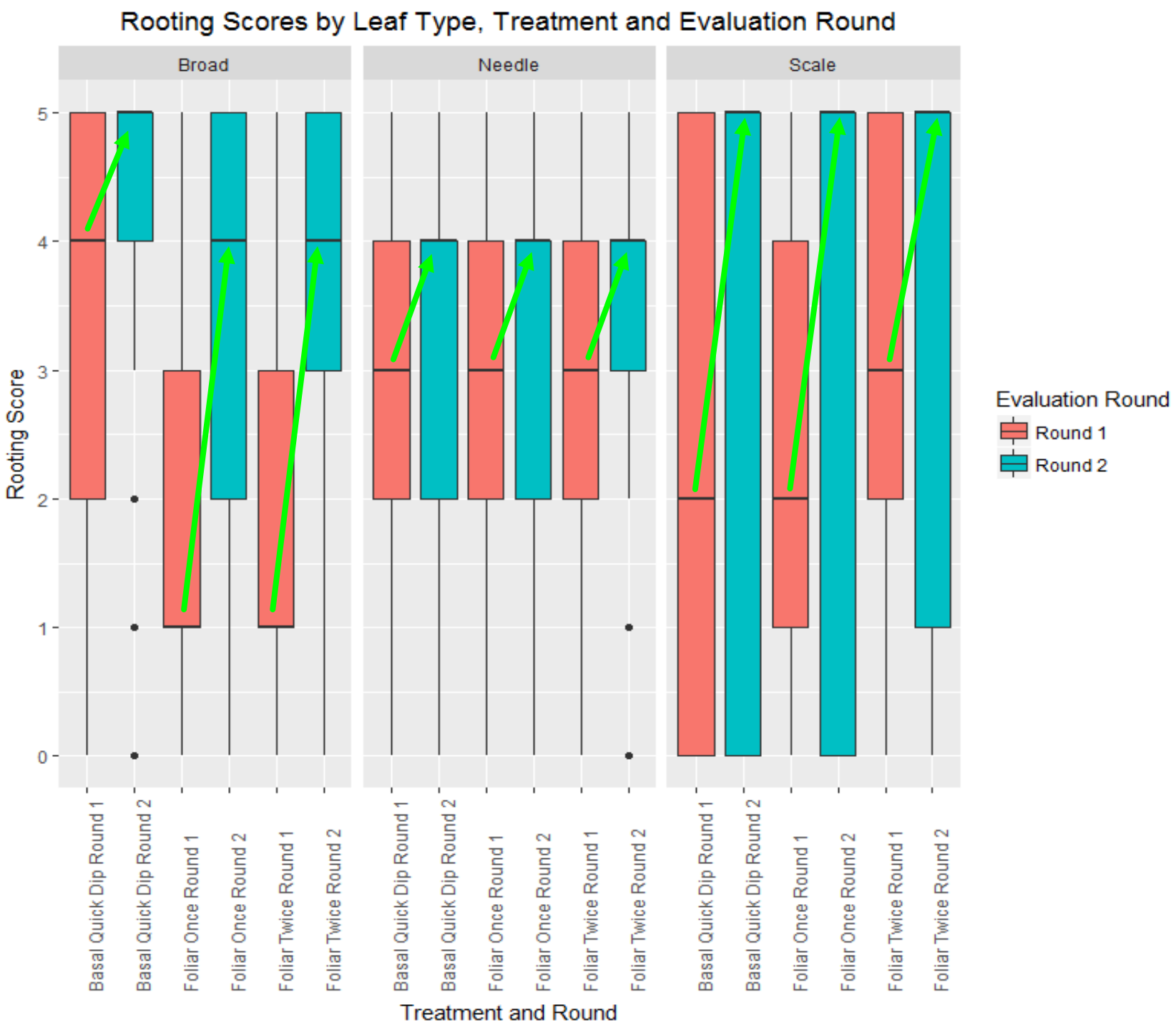
Results

- Comparing rooting scores: leaf types
- Broad leaves showed a general decrease
- Needle leaves were not significantly different
- Scale leaves showed a general increase



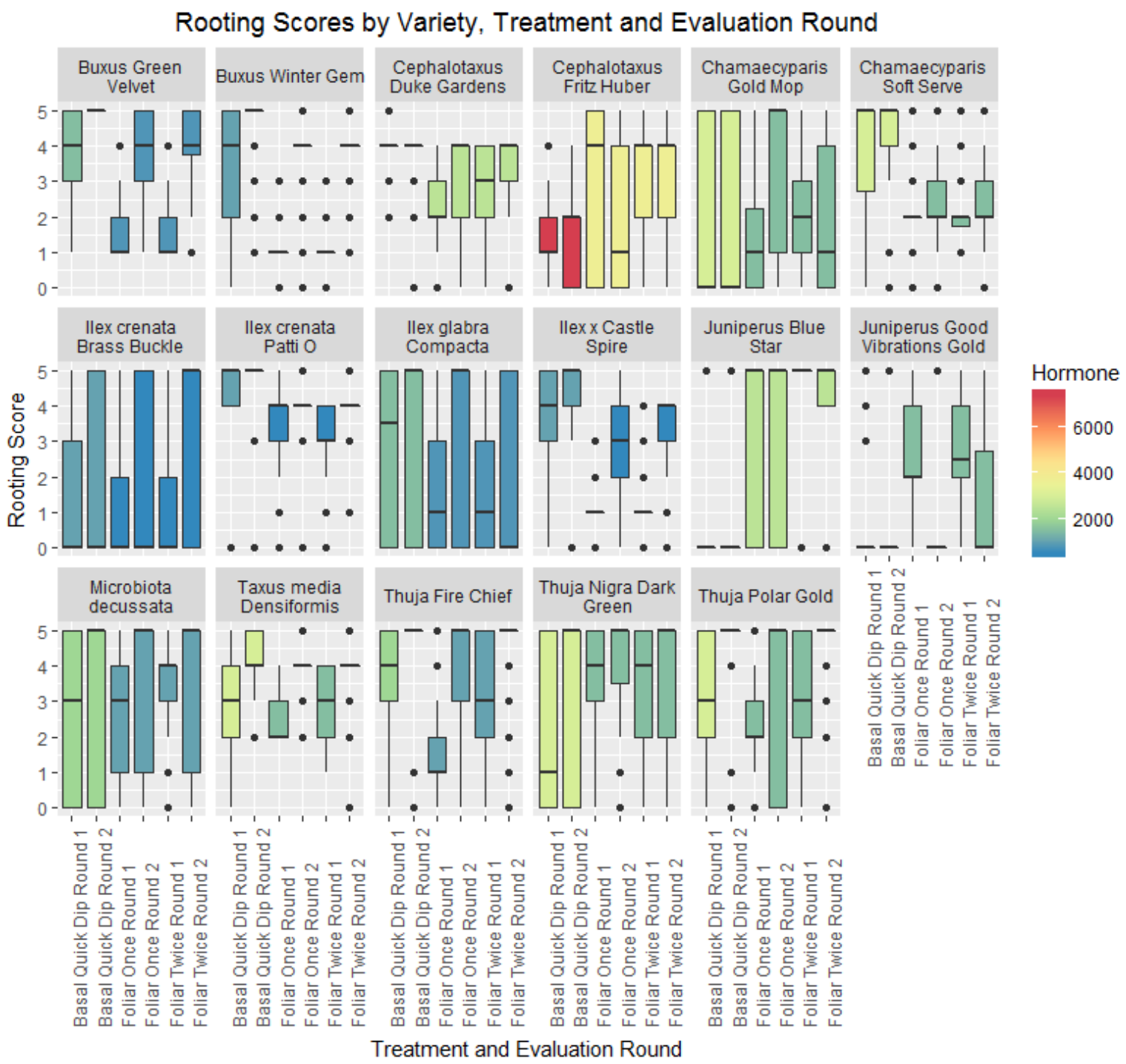
Results

- Comparing rooting scores: leaf types
- Rooting scores for all treatments and for all leaf types significantly improved over time between round 1 and round 2



Results

- Comparing rooting percentage:
- Rooting scores were converted to rooting percentages:
  - 0-3 = unrooted
  - 4-5 = rooted



Results

- Comparing rooting percentage:
- Rooting scores were converted to rooting percentages:
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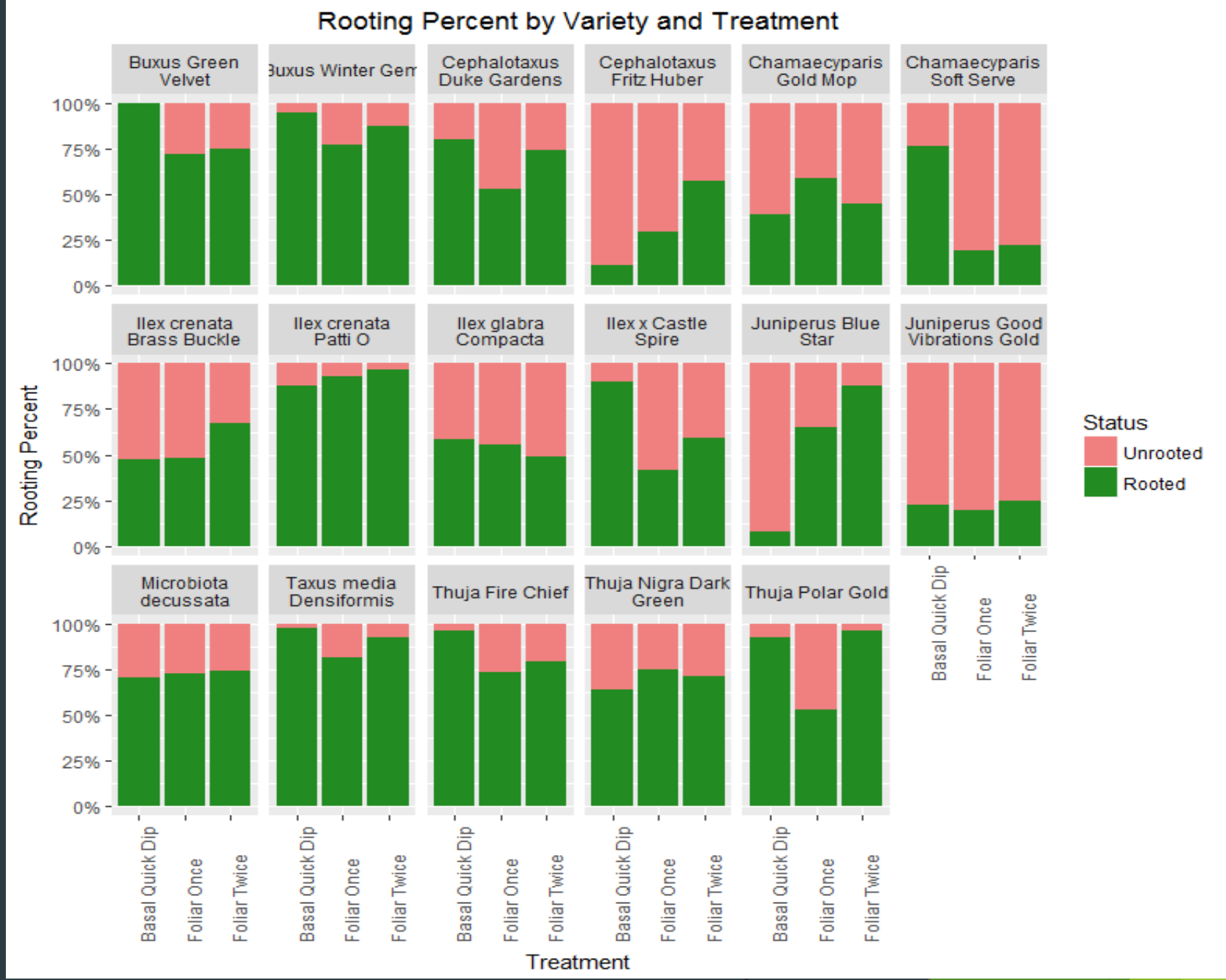
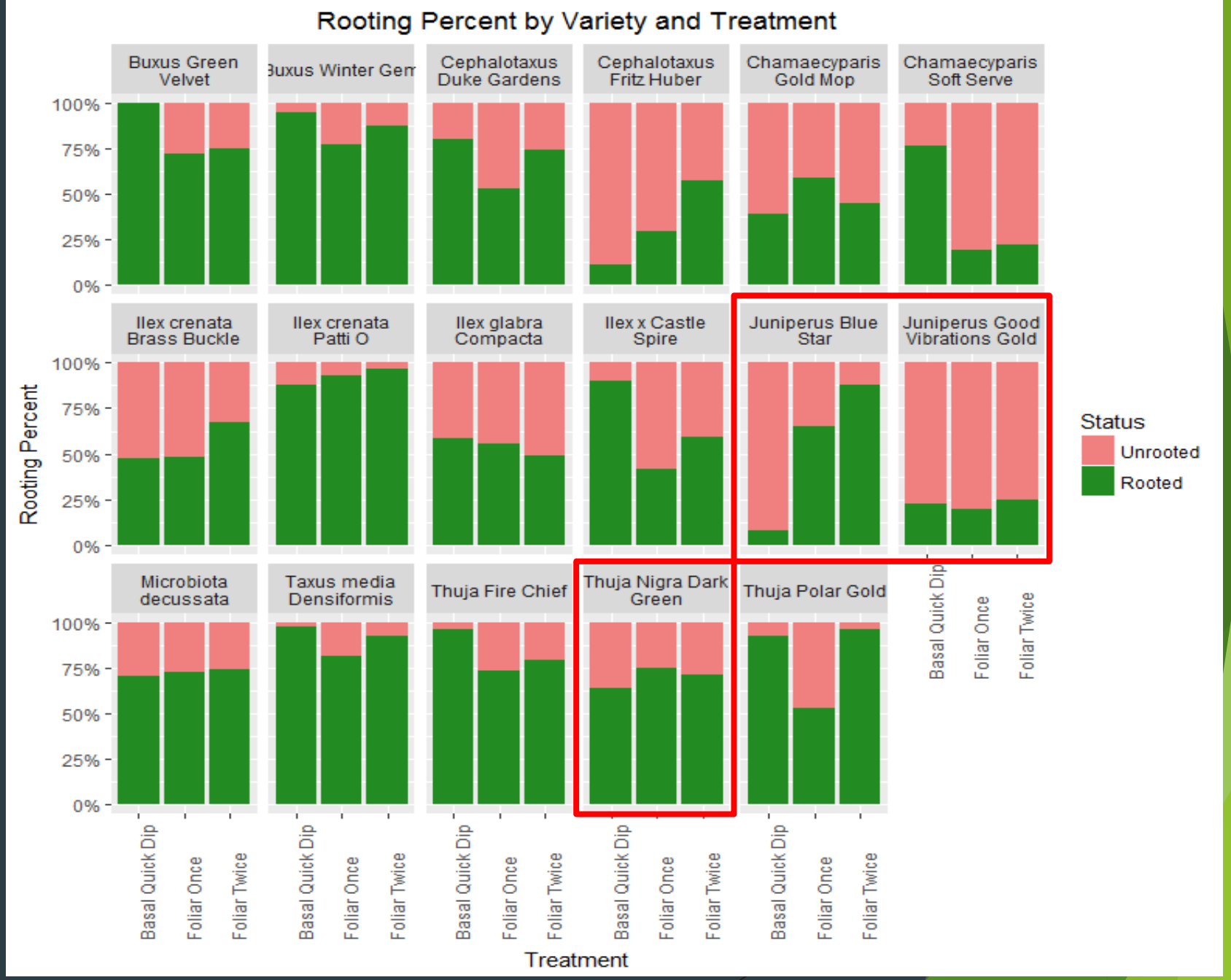
Results

- Comparing rooting percentage: varieties Round 2
- Round 2 is when transplanting took place



Results

- Comparing rooting percentage: varieties Round 2
- Round 2 is when transplanting took place
- Noticeable foliar responses

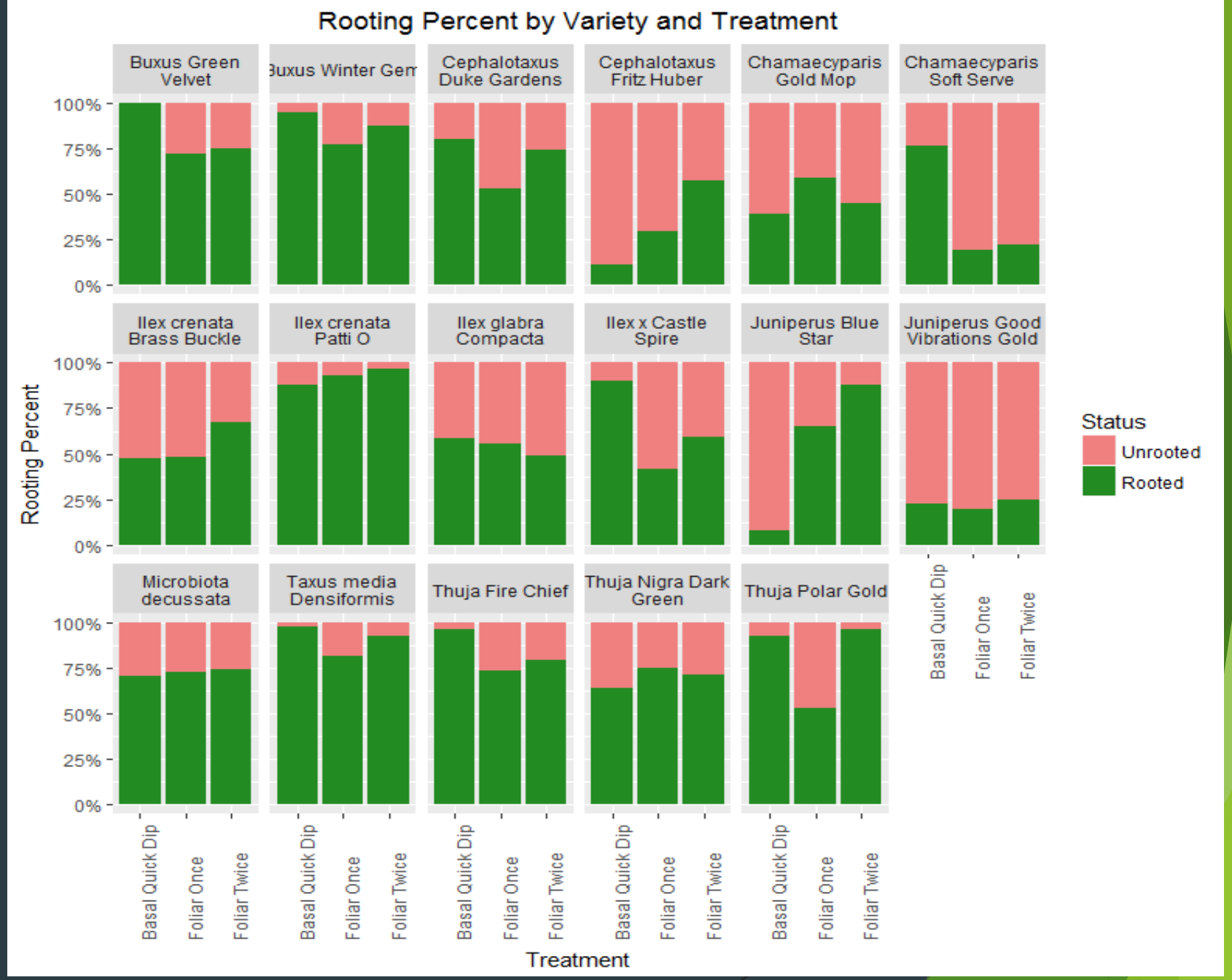


Results

- Comparing rooting percentage: varieties Round 2
- Examples
  - *Thuja* ‘Nigra Dark Green’
  - *Juniperus* ‘Blue Star’
  - *Juniperus* Good Vibrations® Gold

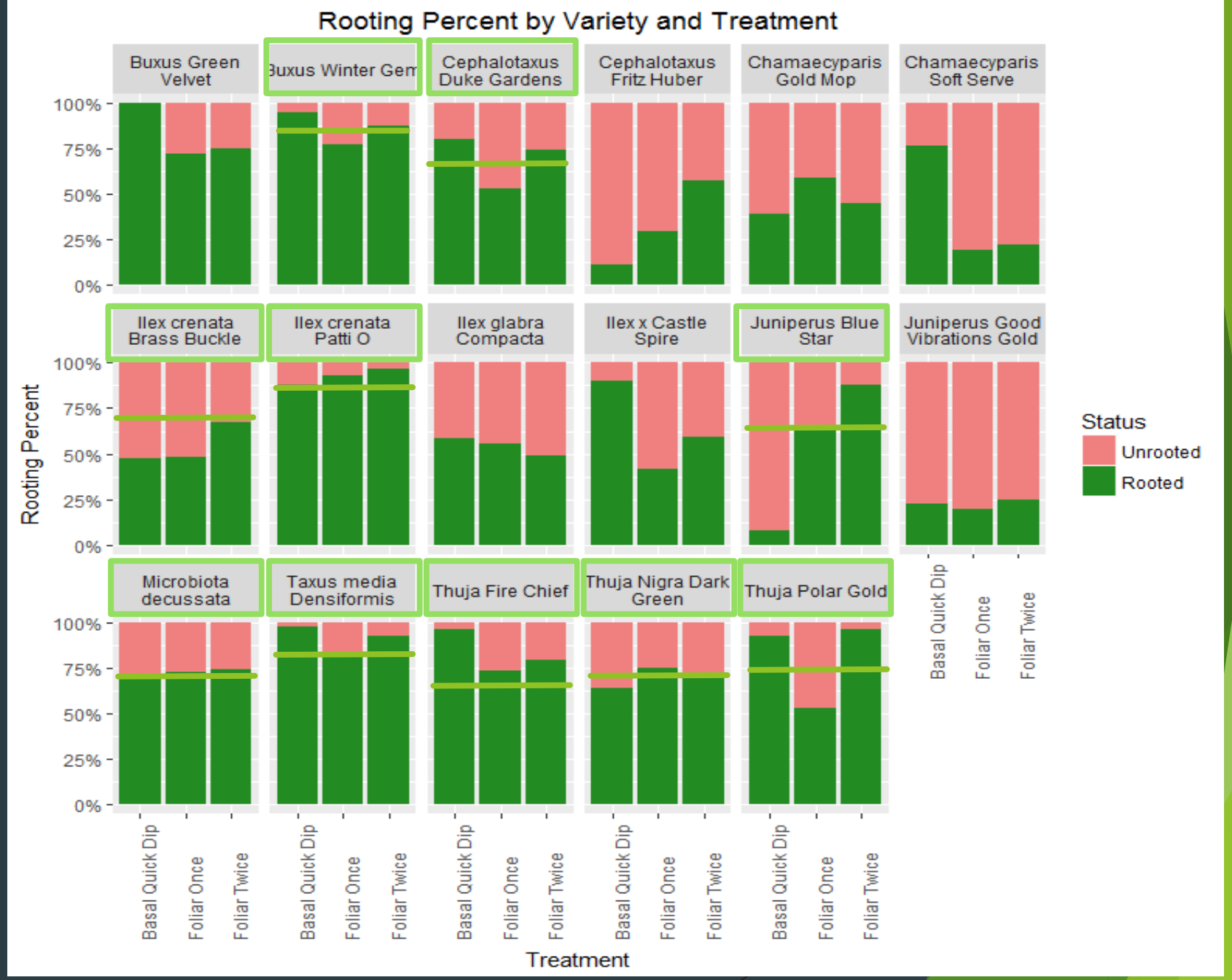
Results

- Comparing rooting percentage: varieties Round 2
- Rooting percentages of foliar treatments were compared to historical



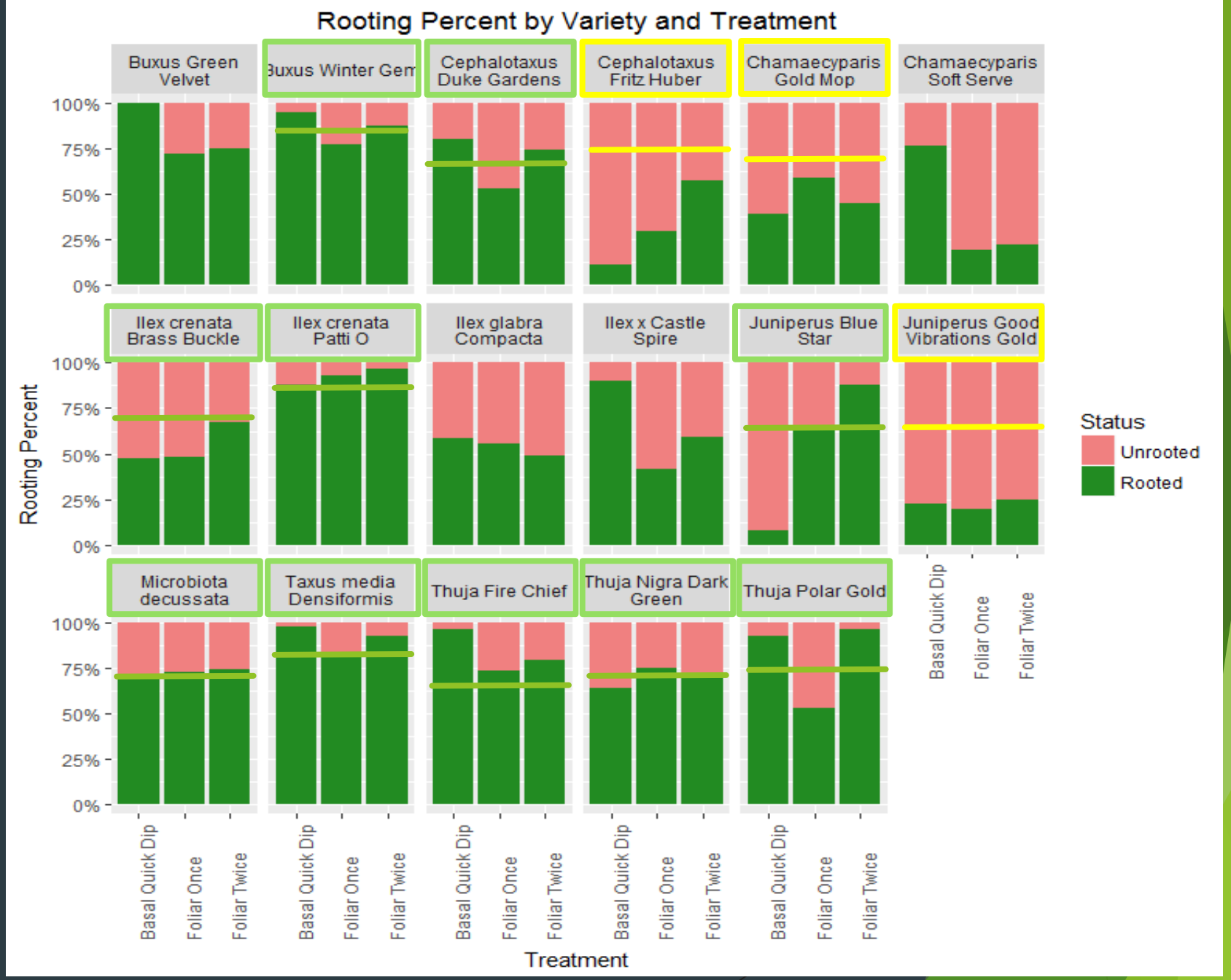
Results

- Comparing rooting percentage: varieties Round 2
- Rooting percentages of foliar treatments were compared to historical
  - within 5% of historical



Results

- Comparing rooting percentage: varieties Round 2
- Rooting percentages of foliar treatments were compared to historical
  - within 5% of historical
  - Less than historical, but better than the basal quick dip experiment



Results

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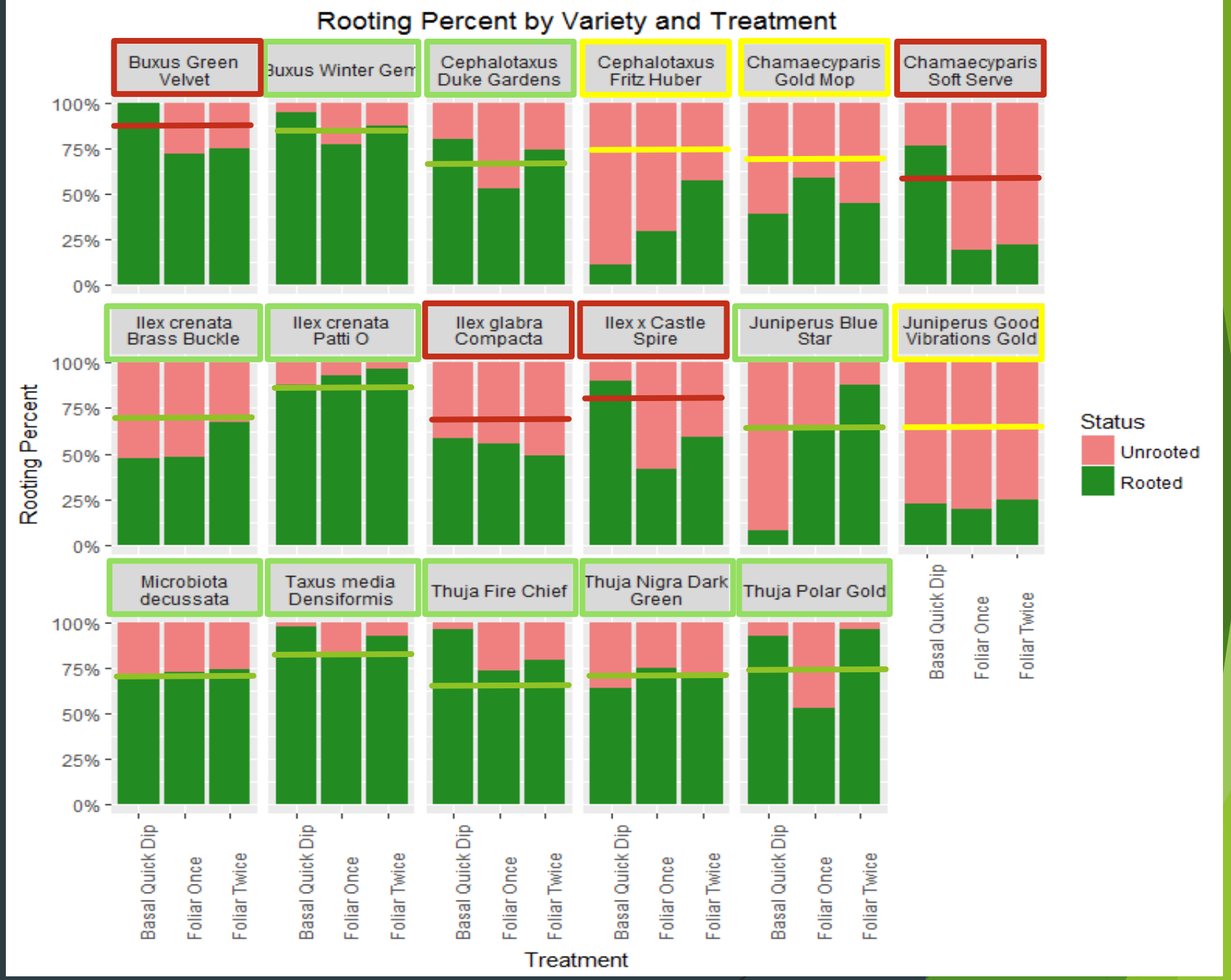

Outline

- Background
- Evergreen Hardwood Experiment
  - Materials and Methods
  - Results
- Deciduous Softwood Experiment
  - Materials and Methods
  - Results
- Discussion

Methods and Materials: Deciduous

- Materials
  - Cuttings were taken and treated on site between June and August, 2017
    - All cuttings were taken from stock plants
  - Four varieties stuck by the ISO line were included in the study:
    - *Buddleia x* 'Miss Molly'
    - *Hydrangea paniculata* FIRE LIGHT®
    - *Physocarpus opulifolius* TINY WINE®
    - *Weigela florida* SONIC BLOOM® RED

Methods and Materials: Deciduous

- Methods
  - Control was stuck by hand
  - Basal quick dip was applied and stuck by hand
  - Foliar application was stuck using the ISO production line, applied with a back pack sprayer

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Weigela SONIC BLOOM® RED - 2 weeks after sticking

Buddleia 'Miss Molly' - 2 weeks after sticking

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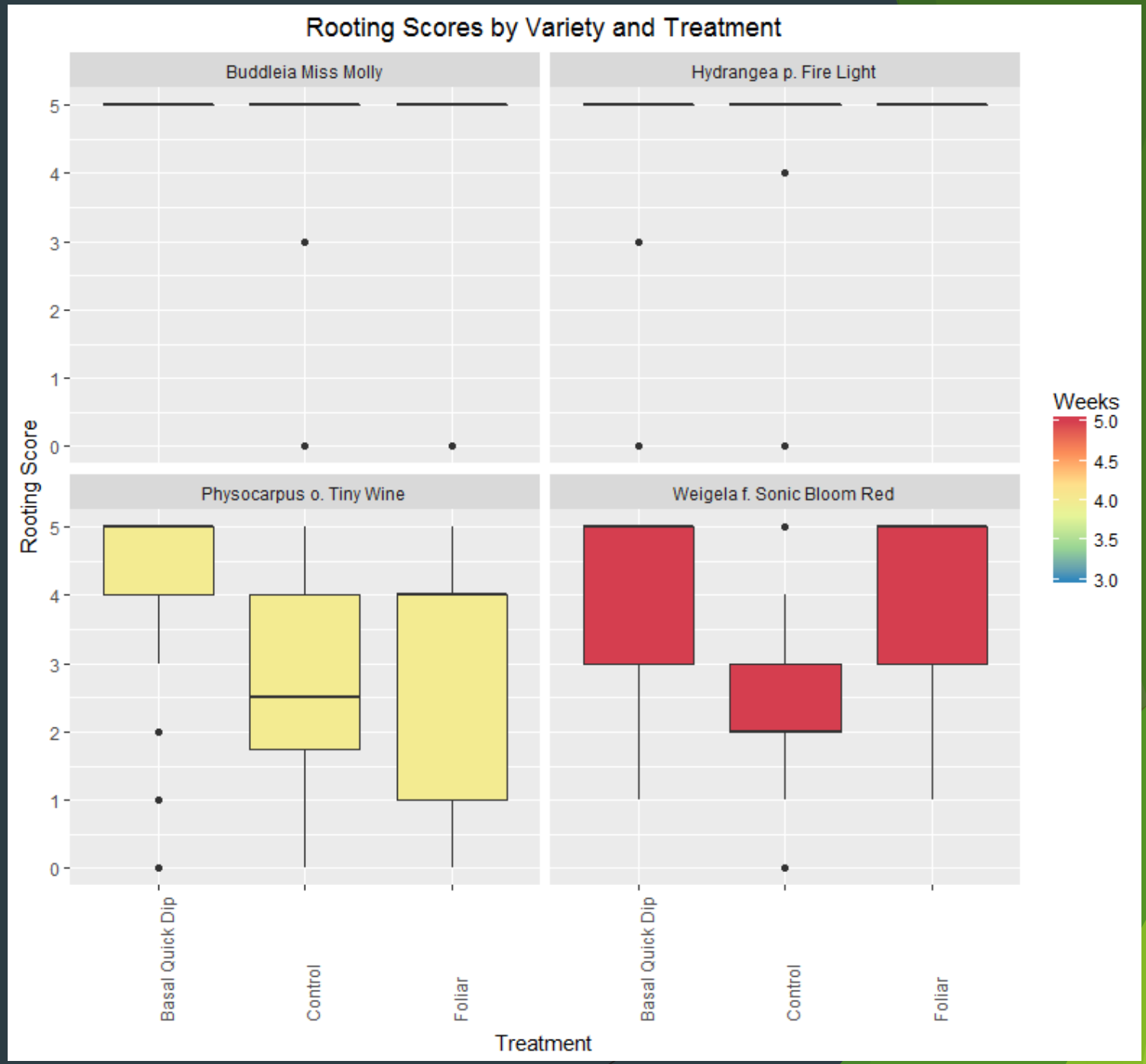
Weigela SONIC BLOOM® RED - 2 weeks after sticking

Buddleia 'Miss Molly' - 2 weeks after sticking

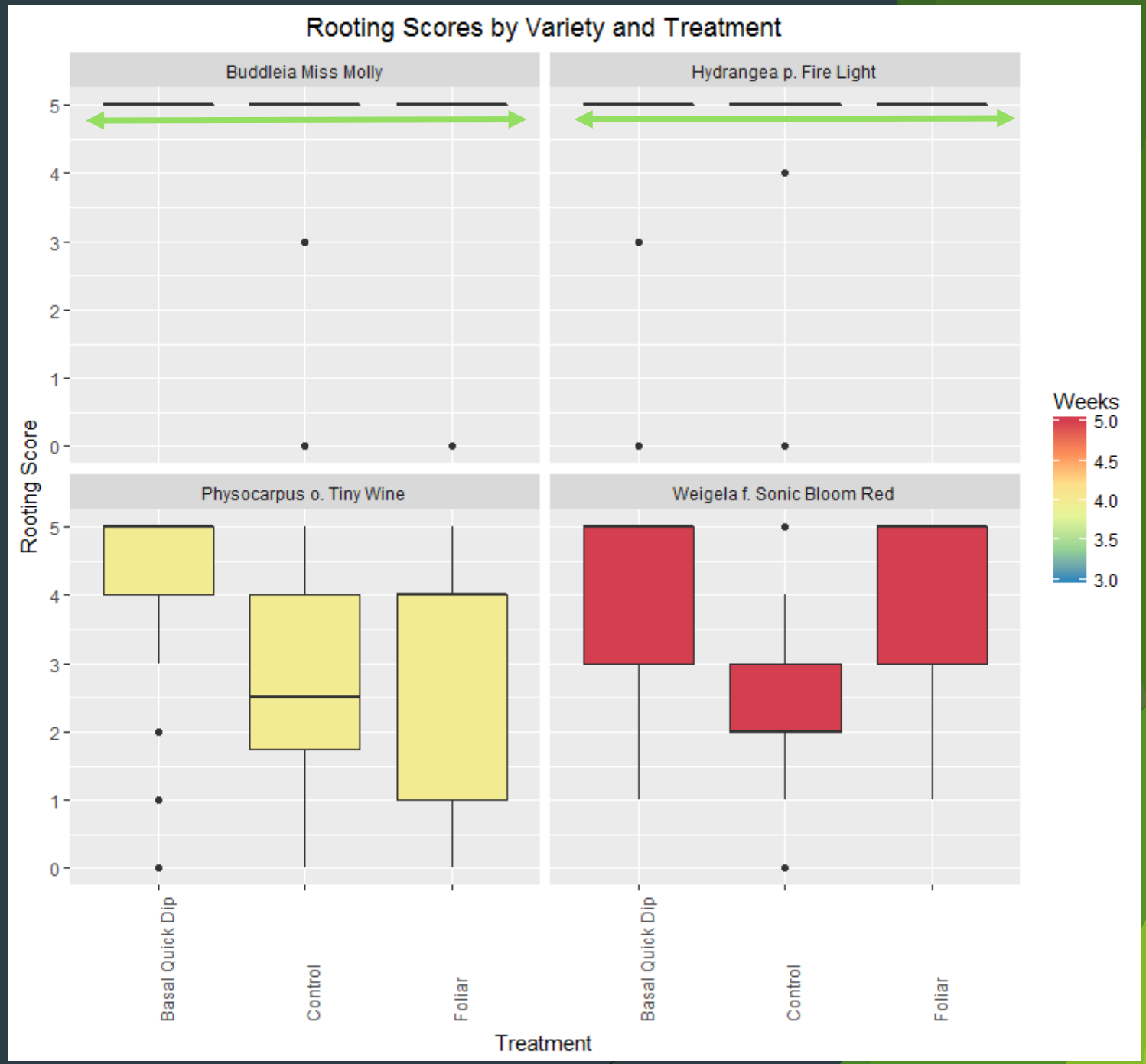
Results

- Comparing rooting scores: varieties



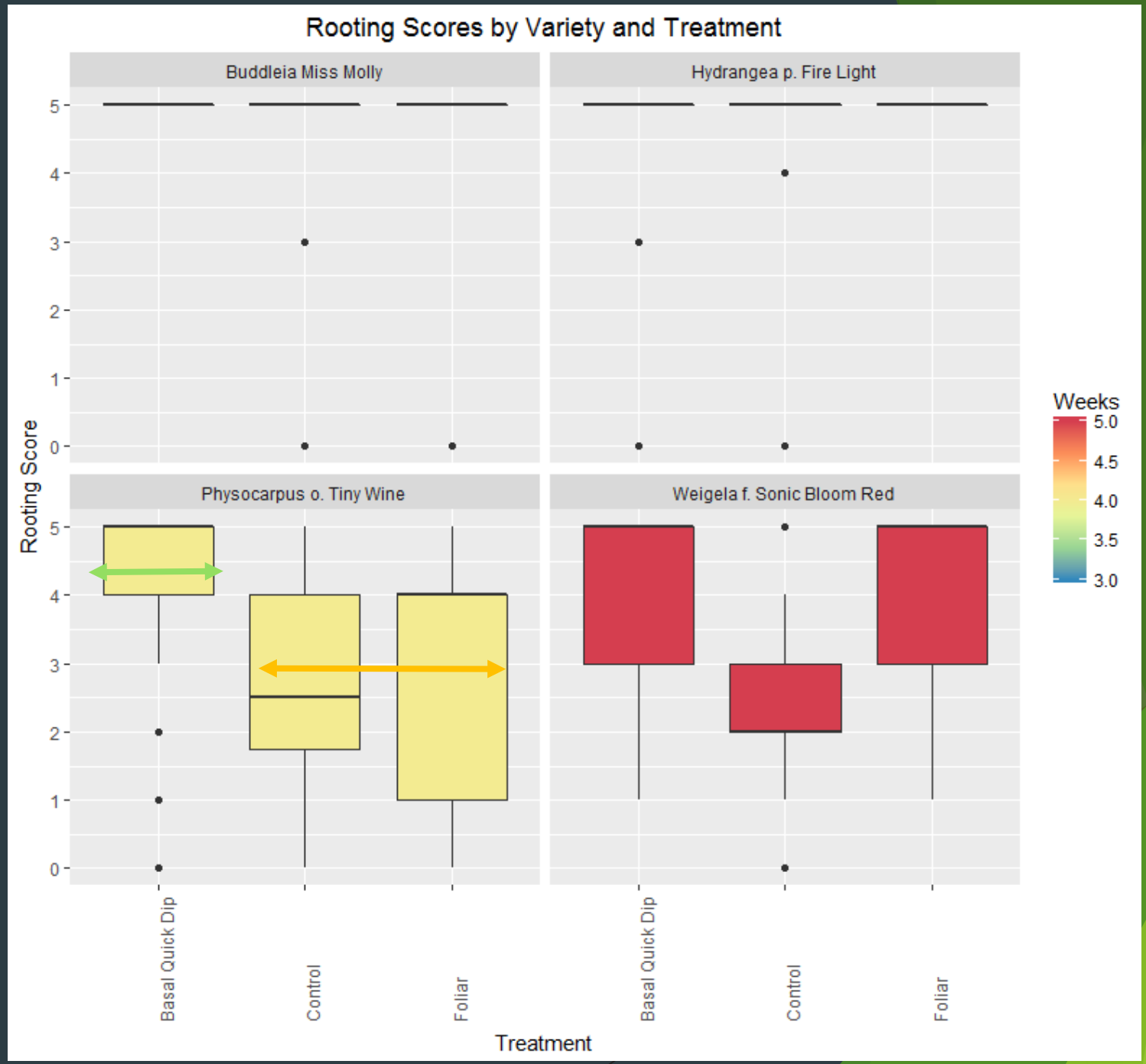
Results

- Comparing rooting scores: varieties
- All treatments for *Buddleia* ‘Miss Molly’ and *Hydrangea paniculata* FIRE LIGHT® were not significantly different
  - *Buddleia* ‘Miss Molly’ (means 4.8-5)
  - *Hydrangea paniculata* FIRE LIGHT® (means 4.7-5)



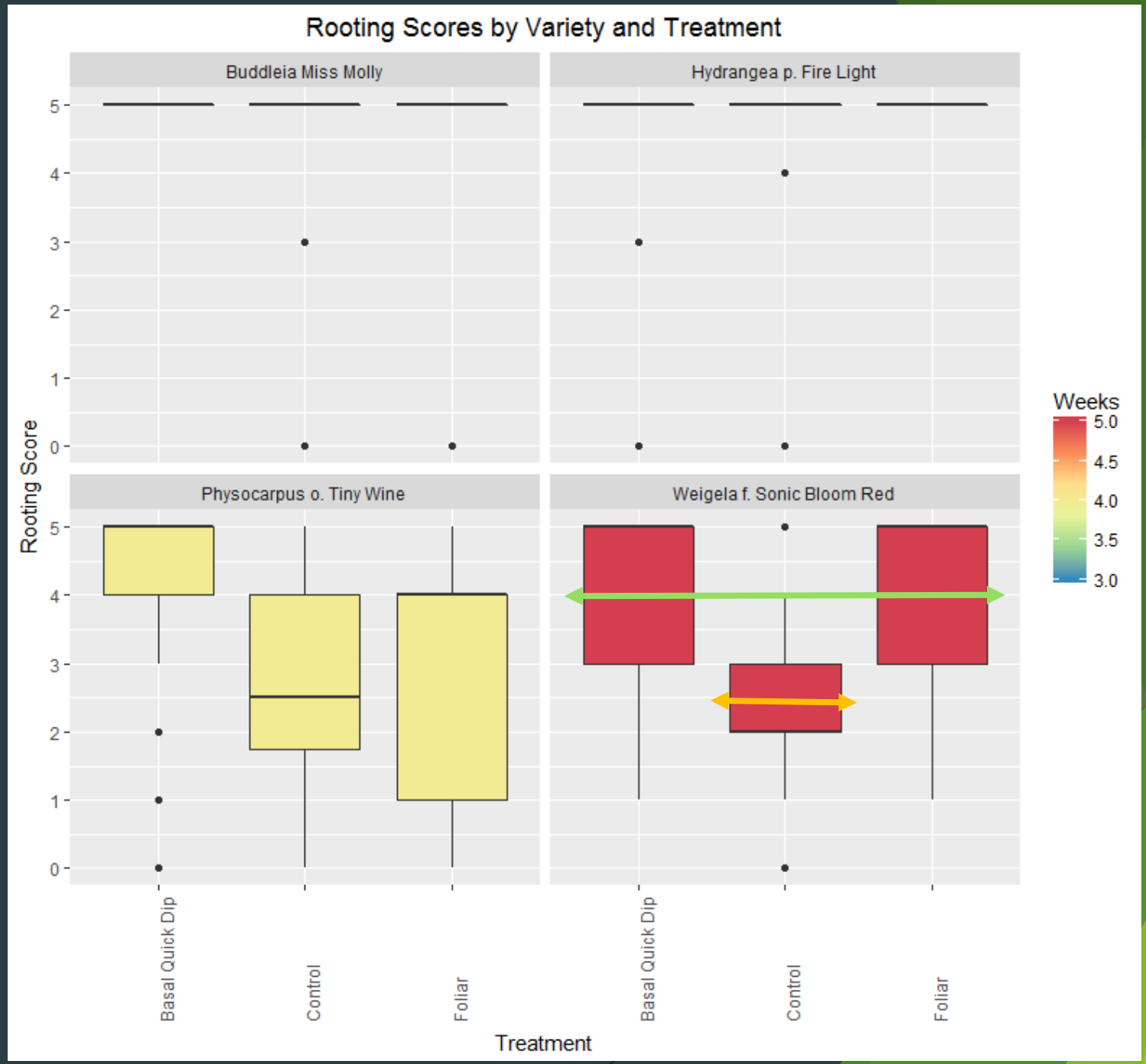
Results

- Comparing rooting scores: varieties
- *Physocarpus opulifolius* TINY WINE®
  - the foliar treatment was not significantly different than the control (means 2.8-3.1), but
  - The basal quick dip was significantly higher (mean 4.4)



Results

- Comparing rooting scores: varieties
- *Weigela florida* SONIC BLOOM® RED
  - the foliar treatment was not significantly different than the basal quick dip (means 3.9-4), but
  - The control was significantly lower (mean 2.5)



Outline

- Background
- Evergreen Hardwood Experiment
  - Materials and Methods
  - Results
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Discussion

- Main question:
  - “Can a foliar treatment of rooting hormone replace a basal quick dip treatment without a loss of plant quality or rooting percentage?”

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  - For evergreen hardwood cuttings, generally:
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    - Needle leaved evergreen foliar treatments were not different than the basal quick dip
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Discussion

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  - For evergreen hardwood cuttings, generally:
    - Broad leaved evergreen foliar treatments were worse than basal quick dip
    - Needle leaved evergreen foliar treatments were not different than the basal quick dip
    - Scale leaved evergreen foliar treatments were better than the basal quick dip
  - For deciduous softwood cuttings, generally:
    - There was no difference between a basal quick dip and a foliar treatment

Discussion

- Possible explanations: Evergreen
  - Broad leaved evergreen foliar treatments were worse than basal quick dip

Discussion

- Possible explanations: Evergreen
  - Broad leaved evergreen foliar treatments were worse than basal quick dip
    - Foliar hormone concentration was half that of the basal quick dip, although there was no difference between foliar once and twice
    - Application temperature was below the recommended 60 degrees (40-50 degrees F), but this was standard production protocol for hardwood cuttings at Spring Meadow
    - Less leaf surface area when compared to needle or scale leaved evergreens
    - Fewer stomata when compared to needle or scale leaved evergreens

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    - Less leaf surface area when compared to needle or scale leaved evergreens
    - Fewer stomata when compared to needle or scale leaved evergreens

- Possible explanations: Deciduous
  - There was no difference between a basal quick dip and the foliar treatment
    - Most rooting percentages were 95% or above, it is not possible to be significantly higher
    - The only variety that did not have a positive response was *Physocarpus* TINY WINE®, which is a dwarf variety

Discussion

- Future studies:
  - Evergreen
    - Similar studies will continue with new varieties, including a full rate foliar treatment at the time of sticking and a control with no treatment
    - foliar treatment studies will be expanded with varieties that responded positively or with no difference

Discussion

- Future studies:
  - Evergreen
    - Similar studies will continue with new varieties, including a full rate foliar treatment at the time of sticking and a control with no treatment
    - foliar treatment studies will be expanded with varieties that responded positively or with no difference
  - Deciduous
    - Large commercial groups of the same genera as the study were tested with a foliar treatment
      - All rooting percentages were within 5% of the historical rooting percentage
    - Other genera are stuck by the ISO line and could be tested in the future

Acknowledgements

- Gail Berner, Propagation Manager, Spring Meadow Nursery
  - Experimental design
- Megan Mathey, Ornamental Plant Breeder, Spring Meadow Nursery
  - editing
- Adriana Robinson, Videographer, Spring Meadow Nursery
  - ISO video and pictures
- Paul Fisher, PhD, Professor and Extension Specialist, Environmental Horticulture Department, University of Florida
  - Rooting scale

Research

- Blythe, Eugene, et al. "Rooting of Rose Cuttings in Response to Foliar Applications of Auxin and Surfactant" *HortTechnology,* vol. 14 no. 4, October-December 2004, pp. 479-483. *HortTechnology,* http://horttech.ashspublications.org/content/14/4/479.abstract . Accessed 4 October 2016.
- Drahn, Samuel. "Auxin Application via Foliar Sprays" *Combined Proceedings International Plant Propagator's Society,* vol. 57, 2007, pp. 274-277. *IPPS Combined Proceedings*, http://www.ipps.org/proceedings-volume/auxin-application-via-foliar-sprays-sup-copy-_sup/28. Accessed 27 September 2017.
- Kroin, Joel. "Propagate Plants from Cuttings Using Dry-Dip Rooting Powders and Water-Based Rooting Solutions" *Combined Proceedings International Plant Propagator's Society,* vol. 58, 2008, pp. 360-372. *IPPS Combined Proceedings,* http://www.ipps.org/proceedings-volume/propagate-plants-from-cuttings-using-dry-dip-rooting-powders-and-water-based-rooting-solutions-sup-copy-_sup/27. Accessed 25 September 2017
- Kroin, Joel. "How to Improve Cuttings Propagation Using Water-Based Indole-3-Butyric Acid Rooting Solutions" *Combined Proceedings International Plant Propagator's Society*, vol. 61, 2011, pp. 381-391. *IPPS Combined Proceedings*, http://www.ipps.org/proceedings-volume/how-to-improve-cuttings-propagation-using-water-based-indole-3-butyric-acid-rooting-solutions-sup-copy-_sup/24. Accessed 4 October 2016.
- McGuire, J., and Sorensen D. "Effect of Terminal Applications of IBA on Rooting of Woody Ornamental Plants" *Combined Proceedings International Plant Propagator's Society,* vol. 16, 1966, pp. 257-260. *IPPS Combined Proceedings,* http://www.ipps.org/proceedings-volume/effect-of-terminal-applications-of-iba-on-rooting-of-woody-ornamental-plants-sup-1-_sup/69 Accessed 25 September 2017. Accessed 25 September 2017.
- White, P.S. "Evidence that Temperate East North American Evergreen Woody Plants Follow Corner's Rules" *New Phytologist*, vol. 95 no. 1, September 1983, pp.139-145. *JSTOR,* http://labs.bio.unc.edu/White/Reprints/White_1983_NewPhyt.pdf Accessed 2 October 2017.
- Woodward, F, Kelly, C. "The Influence of CO2 Concentration on Stomatal Density" *New Phytologist*, vol. 131, no. 3, 1995, pp. 311-327. *Wiley Online Library*, http://onlinelibrary.wiley.com/doi/10.1111/j.1469-8137.1995.tb03067.x/pdf Accessed 2 October 2017.