Where Do Nutrients Go When You Irrigate? Managing Irrigation to Enhance Nutrient Retention in Container Production

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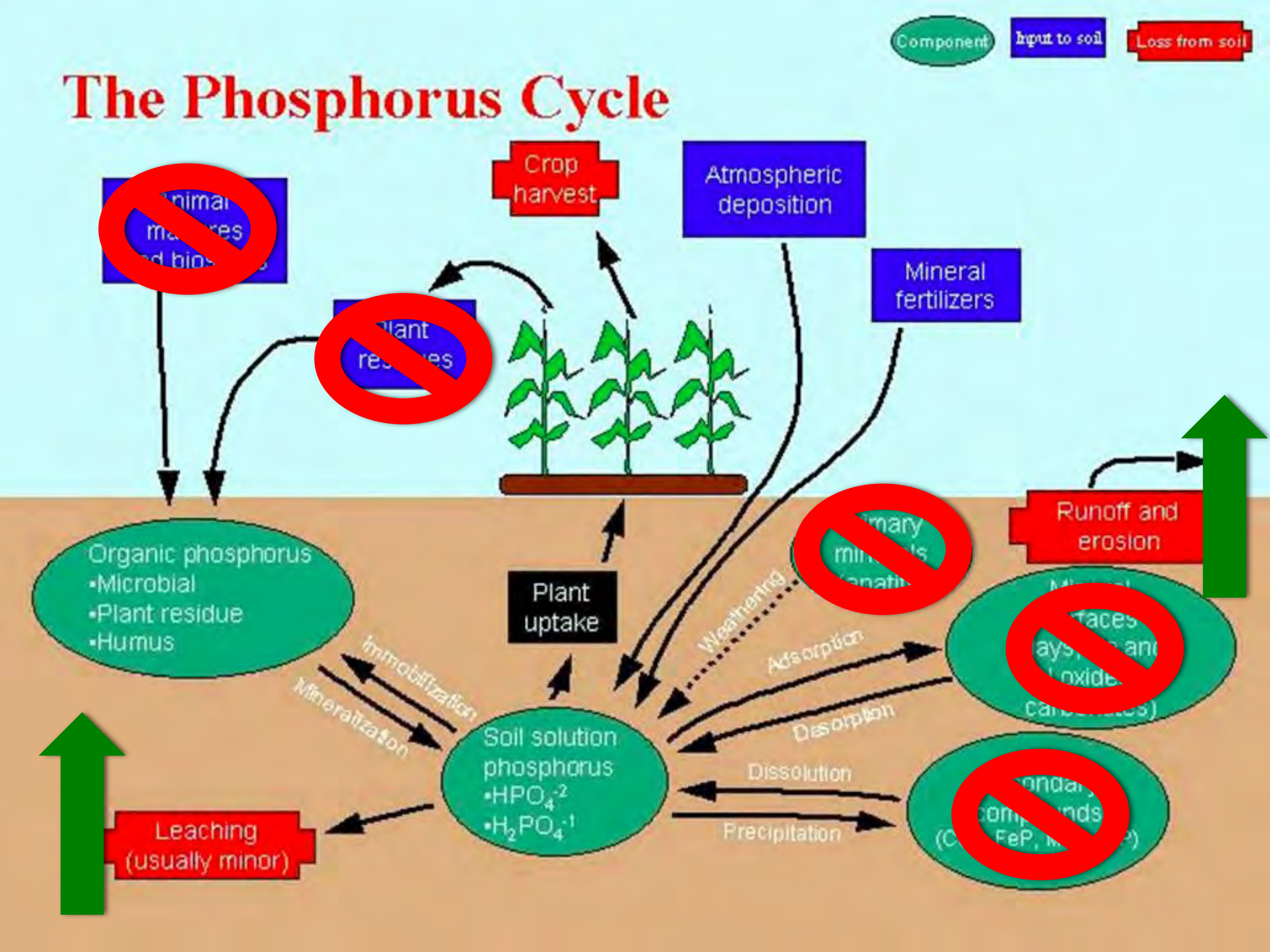
Component
Input to soil
Loss from soil
The Phosphorus Cycle
Crop harvest
Atmospheric deposition
Mineral fertilizers
Runoff and erosion
Organic phosphorus
•Microbial
•Plant residue
•Humus
Plant uptake
Weathering
Adsorption
Desorption
Immobilization
Mineralization
Soil solution phosphorus
•HPO_4^{-2}
•$H_2PO_4^{-1}$
Dissolution
Precipitation
Leaching (usually minor)

Important considerations

- Water quality
  - Soluble salts
  - Alkalinity
- Container substrate physical properties (water availability terminology)
- Determining when to irrigate
  - System size, type and application rate (frequency of irrigation)
  - How much is too much
  - How much is enough
- Nutrient losses
- Cost of water

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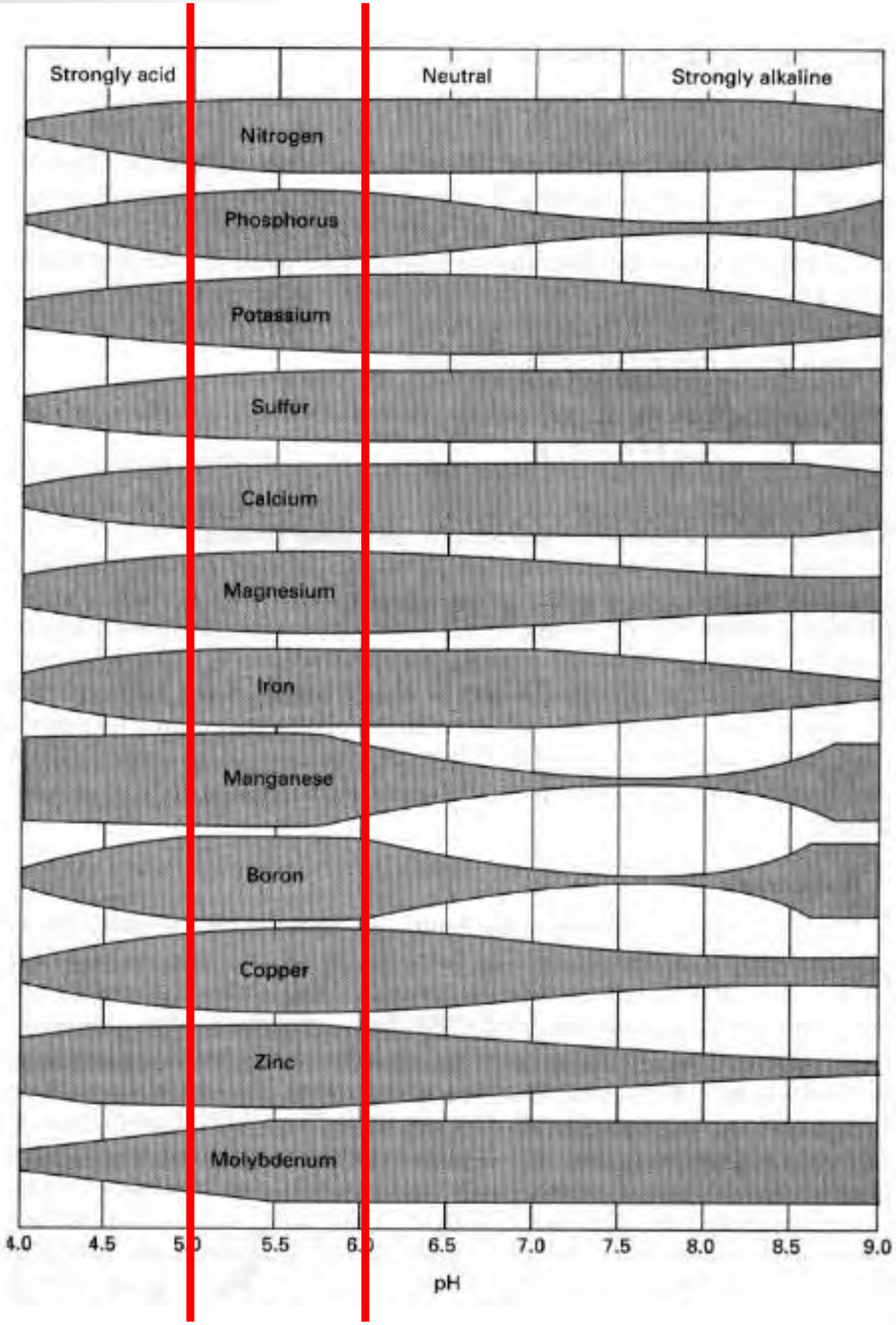

Optimum pH ~ 5 – 6

pH > ~6 will create deficiencies of P, Mn, B, Cu, Zn

pH < ~5 will create deficiencies of many essential elements

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CHOUCROUTE
GRILLADES
SANDWICHS
Ouvert

Out of Readily Available Water

Permanent Wilting Point

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How much is too much?

Container Capacity (CC) = 60% Substrate Moisture Content (SMC)
Unavailable Water (UW) = 25% SMC

Available Water (AW) = 35% water depletion

Readily Available Water (RAW) = CC * 35% = 21% (occurs at 39% SMC)

But don't really want wilting, say we water to replace 10% below CC (50% SMC)

Trade size	Container volume (gallon)	Volume AW in pot (gallon)	Irrigation to replace RAW (GPA / Acre-Inch)
#1	1.007	0.35	28,119 / 1.04
#3	3	1.05	41,582 / 1.53
#5	3.734	1.31	44,410 / 1.64
#7	7.492	2.62	64,109 / 2.36
#10	10.257	3.59	69,348 / 2.55
#15	13.351	4.67	66,319 / 2.44

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CC = 45% SMC
UW = 25% SMC

AW = 20% water depletion
RAW = 11% water depletion (34% SMC)
But to avoid wilting replace at 6% depletion (39% SMC)

Trade size	Container volume (gallon)	Volume AW in pot (gallon)	Irrigation to replace RAW (GPA / Acre-Inch)	Irrigation to replace 6% RAW (GPA / Acre-Inch)
#1	1.007	0.20	14,729 / 0.54	8,034 / 0.30
#3	3	0.60	21,782 / 0.80	11,881 / 0.44
#5	3.734	0.75	23,263 / 0.86	12,689 / 0.47
#7	7.492	1.50	33,579 / 1.24	18,316 / 0.67
#10	10.257	2.05	36,326 / 1.34	19,814 / 0.73
#15	13.351	2.67	34,738 / 1.28	18,948 / 0.70

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Replace 6% RAW with Distribution Uniformity = 80%

Trade size	Container volume (gallon)	0% Leaching Fraction (GPA / Acre-inch)	10% Leaching Fraction (GPA / Acre-inch)	20% Leaching Fraction (GPA / Acre-inch)
#1	1.007	10,042 / 0.35	11,047 / 0.41	12,051 / 0.44
#3	3	14,851 / 0.55	16,336 / 0.60	17,821 / 0.66
#5	3.734	15,861 / 0.58	17,446 / 0.64	19 033 / 0.70
#7	7.492	22,896 / 0.84	25,186 / 0.93	27,475 / 1.01
#10	10.257	24,767 / 0.91	27,244 / 1.00	29,721 / 1.09
#15	13.351	23,685 / 0.87	26,054 / 0.96	28,422 / 1.05

How much is enough?

- Experience
  - Weather/evapotranspiration
  - Feel/weight
- Leaching Fraction
- Moisture sensors

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Leaching Fraction (LF) =

(amt of water leached with plant / amt without plant) * 100

Courtesy Ted Bilderback, NCSU

Determining Leaching Fraction

Container	1	2	3	4	5	Avg
Plant Container (ml)	250	225	160	275	210	224
Empty Container (ml)	775	770	740	870	760	783
Leaching Fraction (%)	32	30	21	31	28	29

Older recommendations are for LF ≤ 20 %, based on greenhouse studies

LF = 0 should be considered for nurseries. YOU MUST Monitor container EC if go to 0 LF

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Leachate pH and EC

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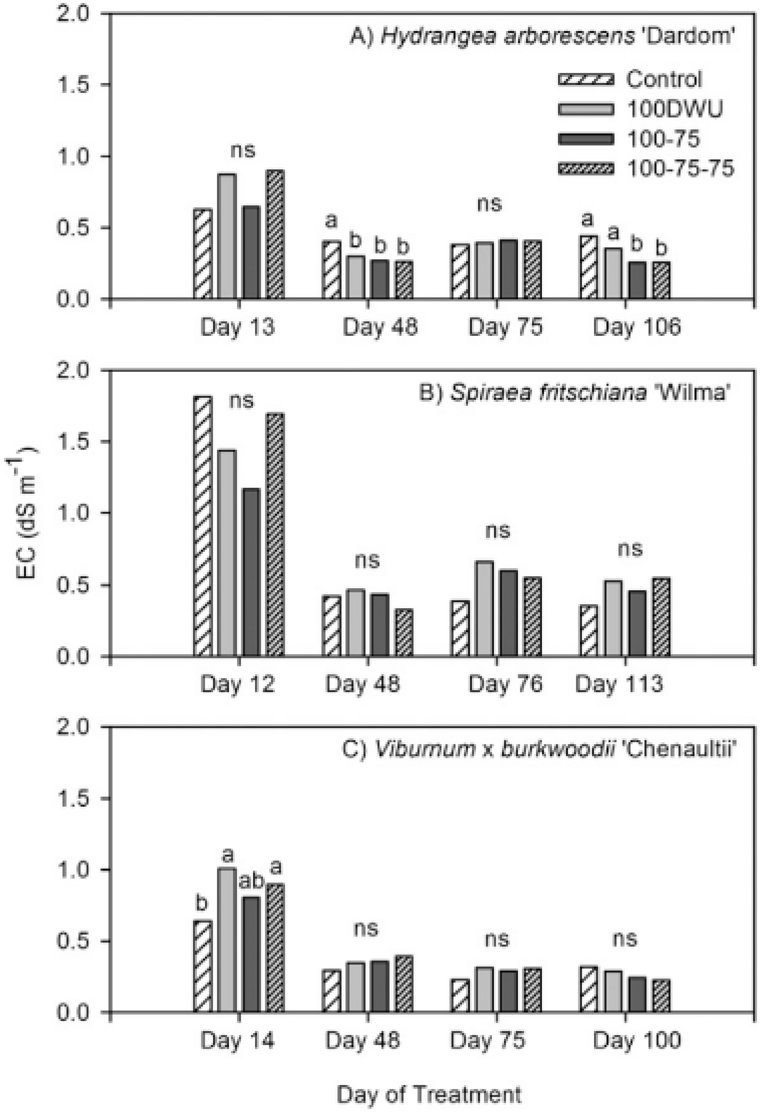
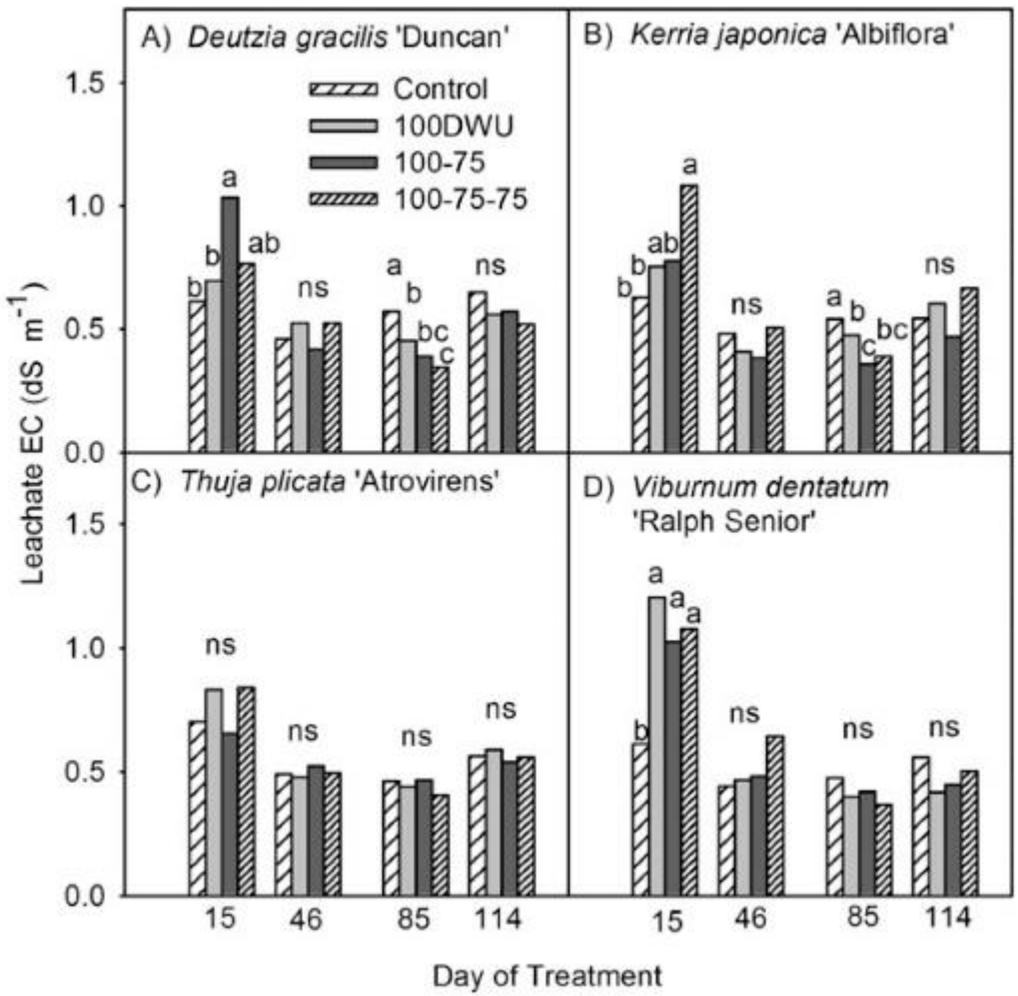
Soluble Salts (EC)





Warsaw et al., 2009

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Types of Moisture Sensors

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2010 - 2015

Substrate volumetric moisture content determined with Theta probes or Decagon 10HS sensors via a Campbell datalogger programmed to calculate DWU and apply irrigation by controlling solenoid valves. Irrigation applied based on the highest plant DWU.

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Wireless sensor networks

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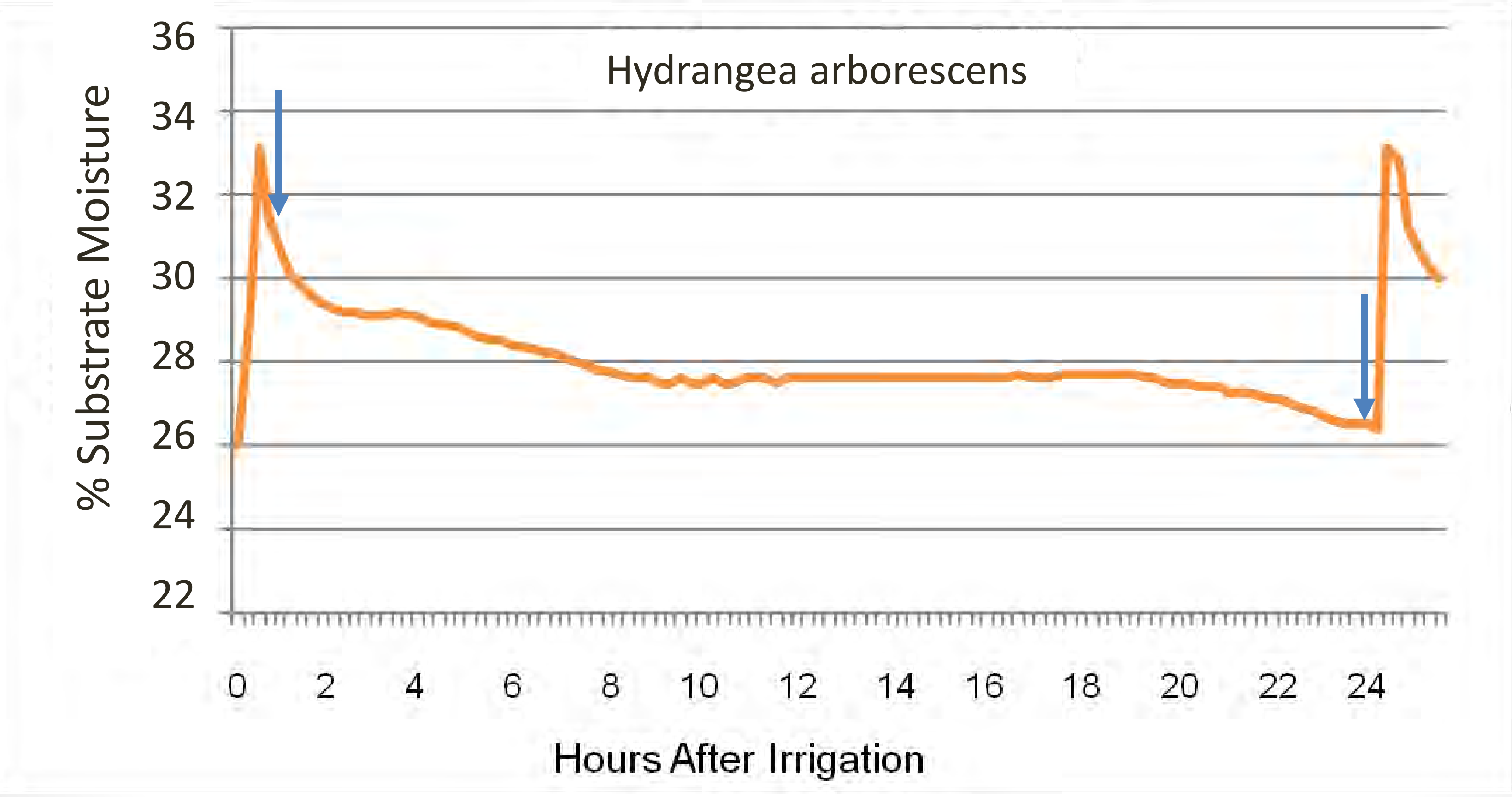
Calculating Daily Water Use (DWU)



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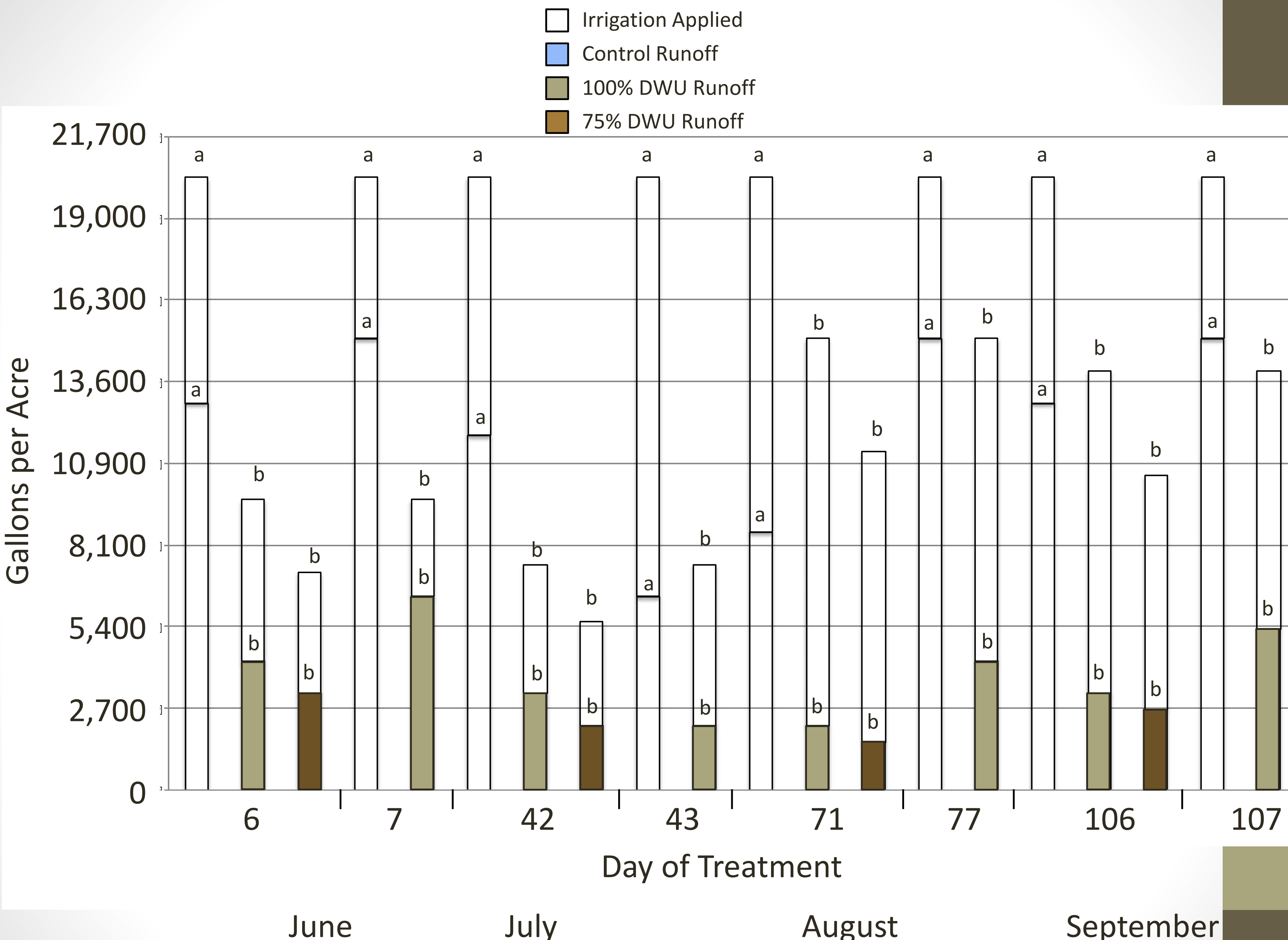
Overhead Irrigation Typical Treatments

- Control = ¾ acre-inch per day
- 100 DWU = 100% of plant daily water use (ET) replaced
- 100-75 DWU = alternating 100% DWU with 75% DWU
- 100-75-75 DWU = alternating 1 day at 100 % DWU with 2 days of 75% DWU



Warsaw et al., 2009 HortScience

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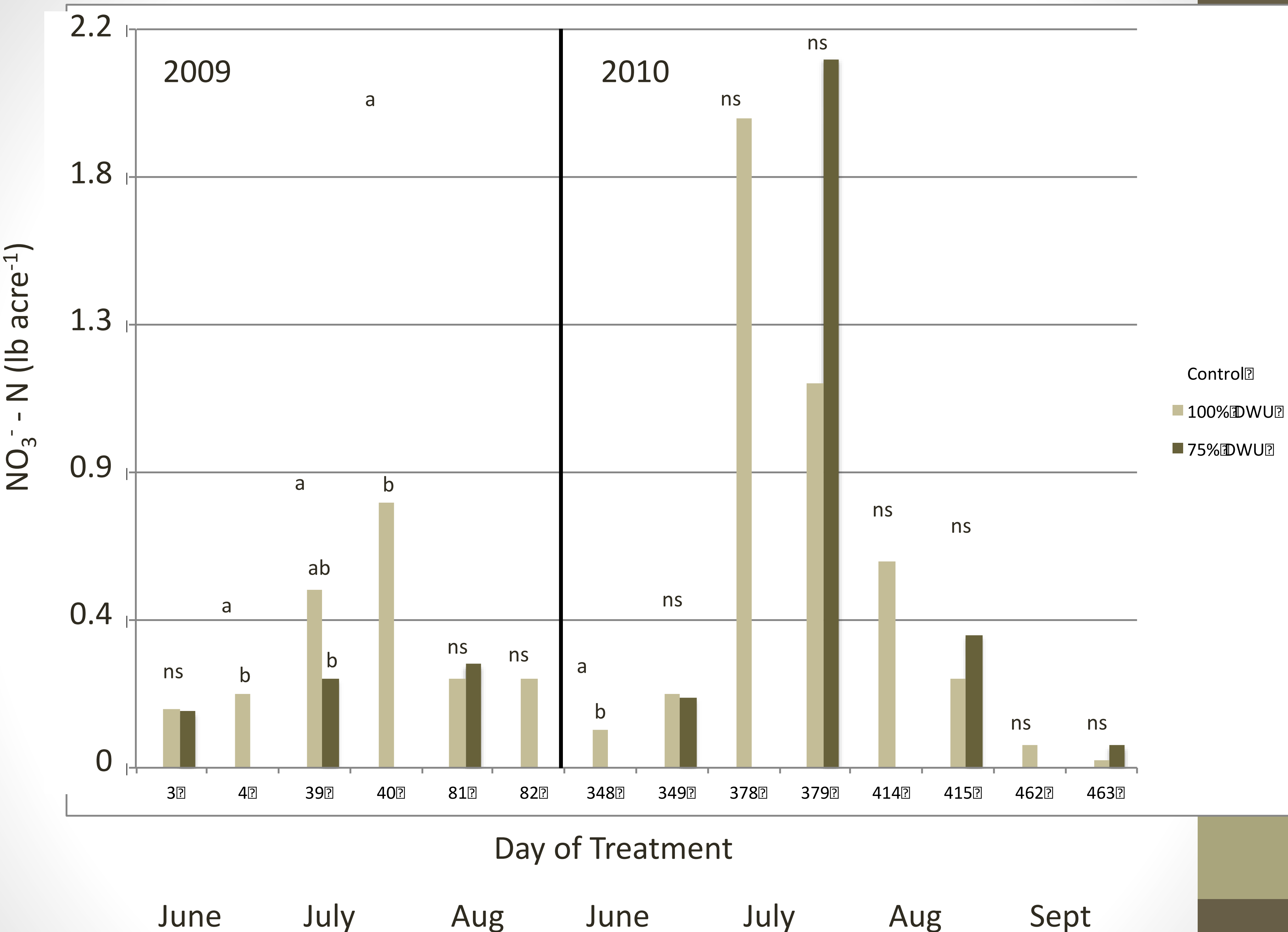

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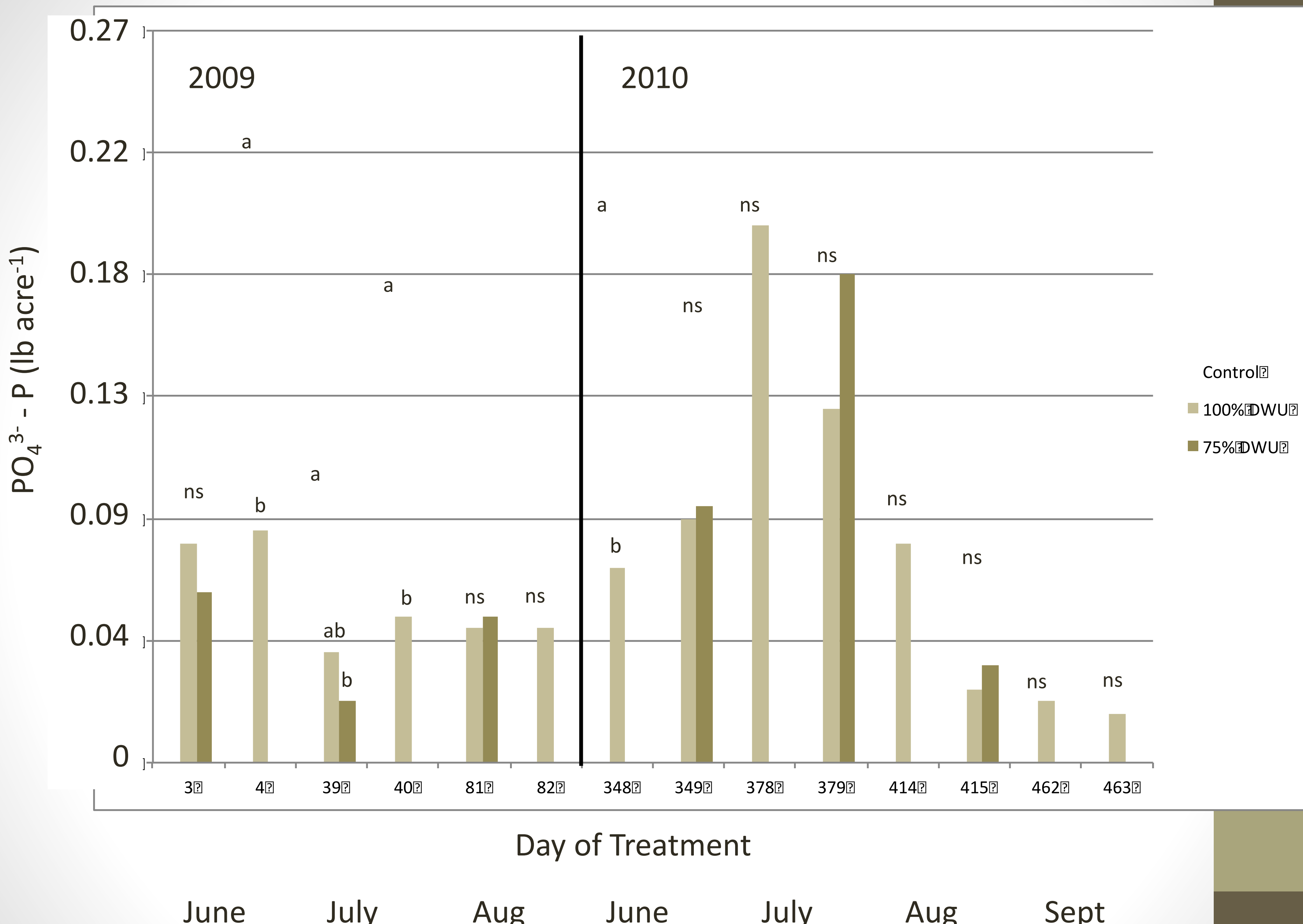

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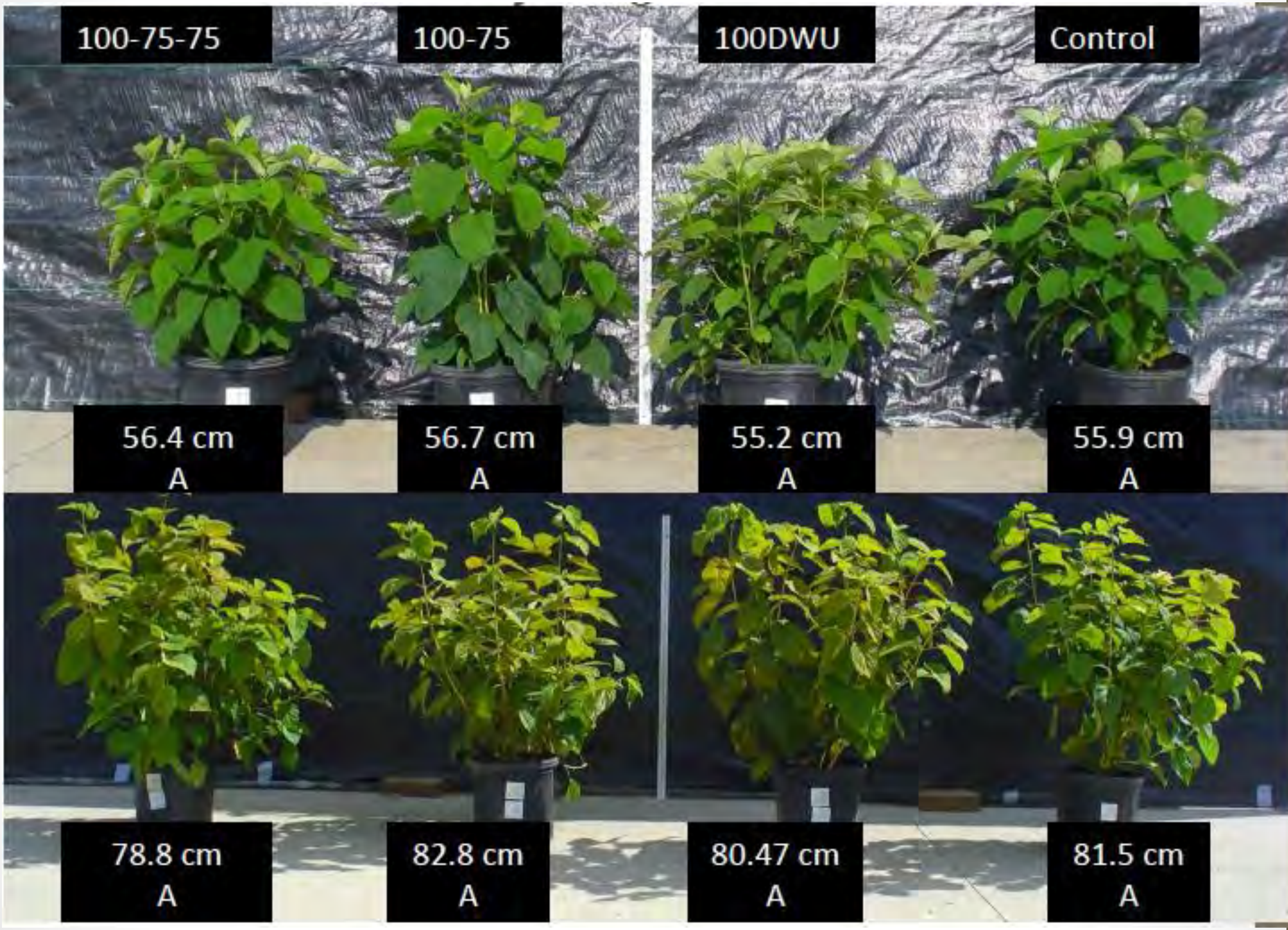
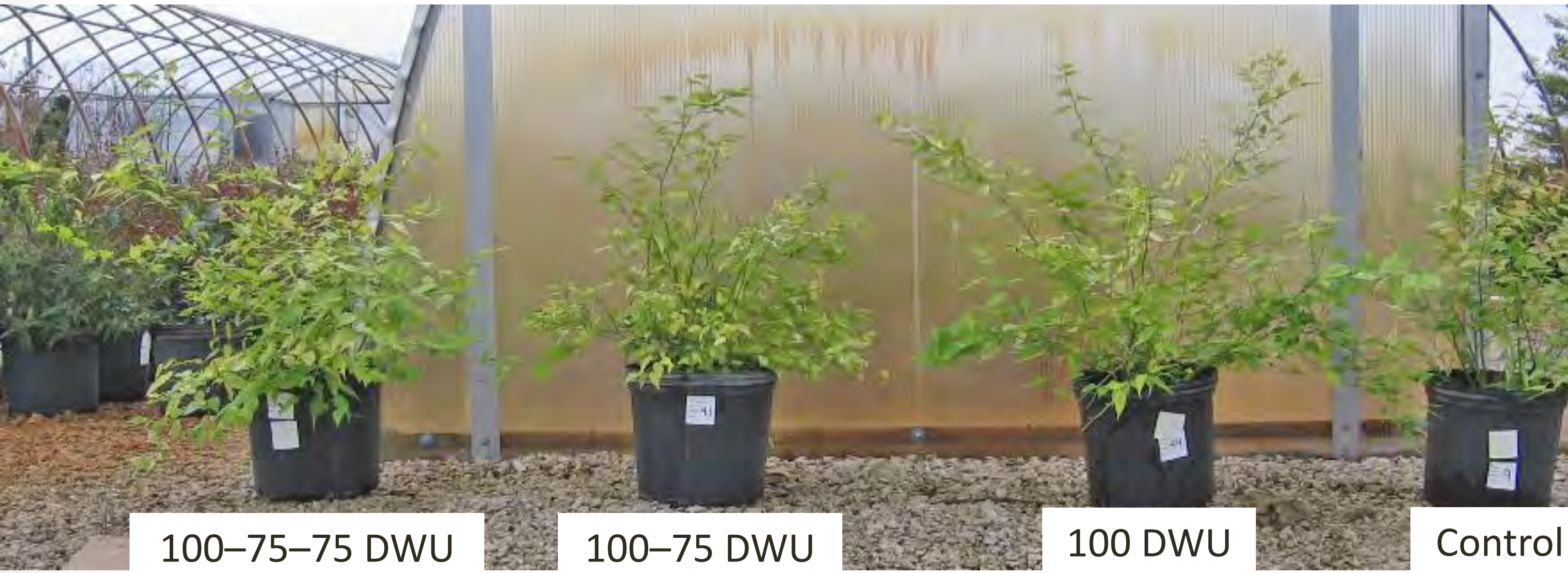
Hydrangea arborescens 'Abetwo'



Kerria japonica 'Albiflora'



100–75–75 DWU
66.00 ab

100–75 DWU
58.52 ab

100 DWU
67.87 a

Control
55.74 b

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Thuja plicata 'Atrovirens'

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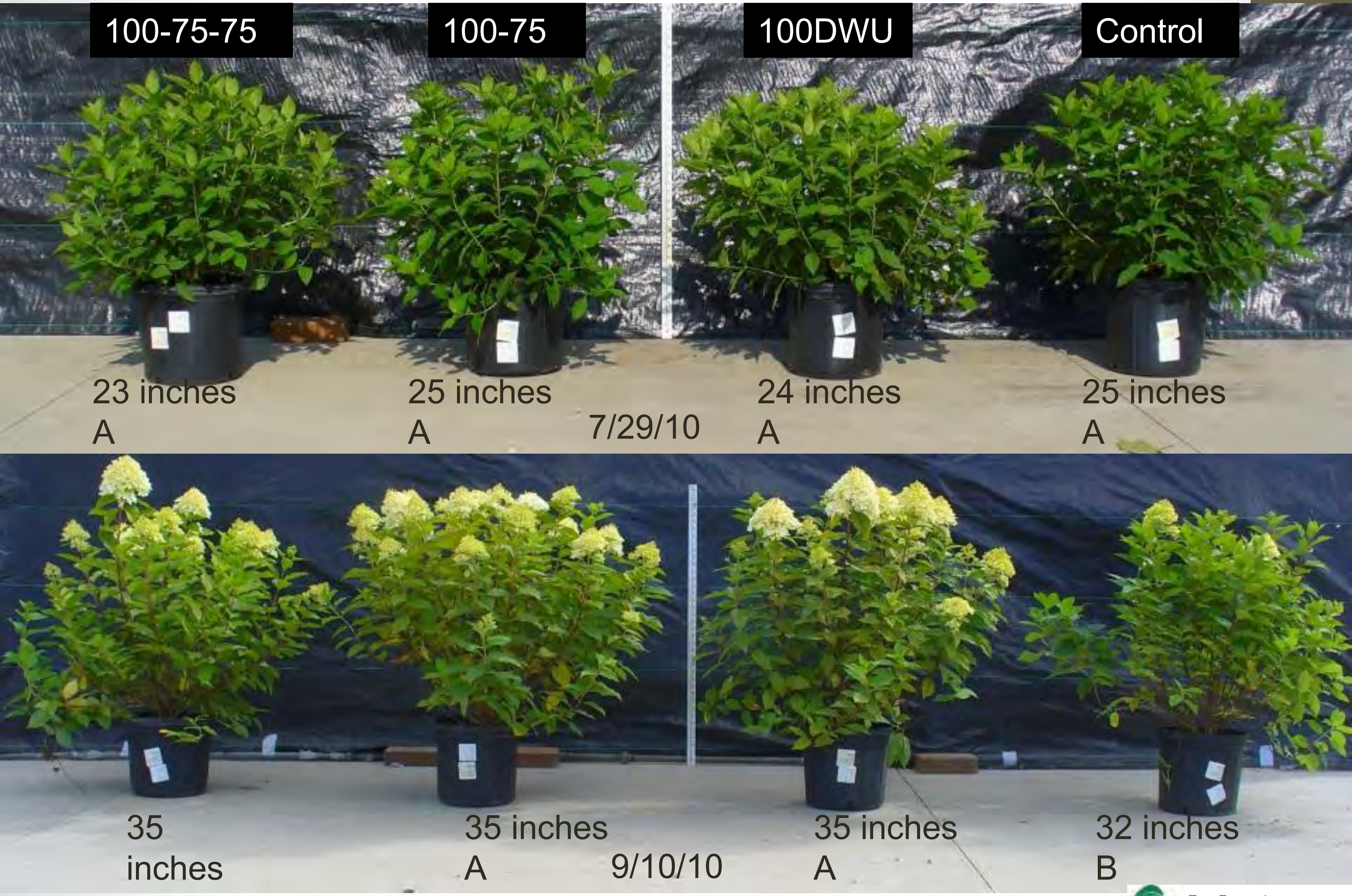
Growth Index-Hydrangea paniculata ‘Limelight’



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Viburnum dentatum Autumn Jazz

100–75–75 DWU	100–75 DWU	100 DWU	Control
13.69 a	13.13 a	13.43 a	9.72 a

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	Foliar Nutrient Content			
	Control[z]	100DWU	100-75	100-75-75
	Hydrangea paniculata 'Limelight'			
Day 63				
N (%)	2.87 A[y]	2.88 A	2.99 A	2.96 A
P (%)	0.24 A	0.29 A	0.30 A	0.29 A
K (%)	1.65 A	2.23 A	2.07 A	2.07 A
Day 90				
N (%)	2.24 A	2.35 A	2.38 A	2.31 A
P (%)	0.14 B	0.17 AB	0.18 A	0.17 AB
K (%)	0.41 B	0.65 A	0.61 AB	0.67 A
	Itea virginica 'Morton'			
Day 63				
N (%)	2.50 A	2.69 A	2.46 A	2.65 A
P (%)	0.22 A	0.22 A	0.22 A	0.24 A
K (%)	0.65 A	0.55 A	0.58 A	0.66 A
Day 90				
N (%)	2.37 A	2.74 A	2.59 A	2.55 A
P (%)	0.16 B	0.20 AB	0.20 AB	0.21 A
K (%)	0.48 A	0.53 A	0.54 A	0.55 A
	Physocarpus opulifolius 'Seward'			
Day 63				
N (%)	3.19 A	3.19 A	3.19 A	3.33 A
P (%)	0.31 B	0.37 A	0.37 A	0.39 A
K (%)	1.09 B	1.46 A	1.59 A	1.66 A
Day 90				
N (%)	2.15 A	2.20 A	2.28 A	2.28 A
P (%)	0.21 B	0.23 AB	0.25 A	0.24 A
K (%)	0.38 B	0.41 A	0.45 A	0.42 A
	Spiraea media 'Darsnorm'			
Day 63				
N (%)	2.27 A	2.38 A	2.23 A	2.42 A
P (%)	0.63 A	0.67 A	0.66 A	0.66 A
K (%)	1.26 A	1.63 A	1.66 A	1.64 A
Day 90				
N (%)	2.50 A	2.70 A	2.63 A	2.74 A
P (%)	0.72 B	0.81 AB	0.87 A	0.81 AB
K (%)	1.14 B	1.39 AB	1.52 A	1.32 AB

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Irrigation and Runoff

Application Rates: N = 123 lb/ac, P = 15 lb/ac (35 lb P2O5)

Amount recovered based on 100% land use with #3 containers spaced 1.5 ft on-center over 4 months.

Treatment	Irrigation Applied gal/acre	Runoff volume gal/acre (% Applied, % of Control Applied)	Nitrate recovered lb/acre (% Applied)	Phosphate recovered lb/acre (% Applied)
Control	2.4 million	1.04 million (43%)	12 (10%)	3.1 (21%)
100% DWU	1.6 million	0.48 million (31%, 20%)	7.2 (6%)	1.7 (11%)
100-75% DWU	1.4 million	0.29 million (21%, 12%)	5.9 (5%)	1.2 (8%)
100-75-75% DWU	1.3 million	0.37 million (29%, 15%)	5.7 (5%)	1.2 (8%)

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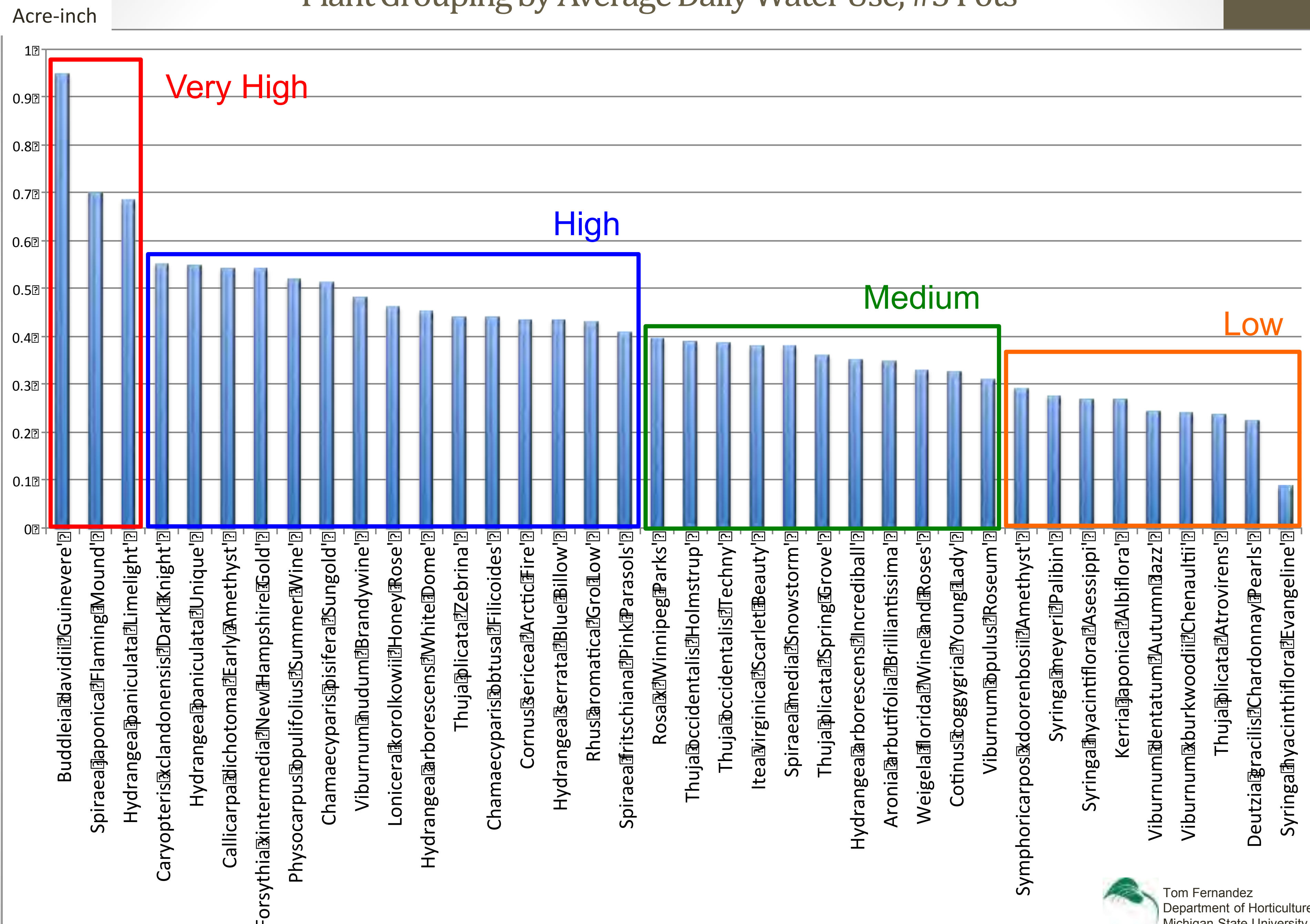
Plant Grouping by Average Daily Water Use, #3 Pots



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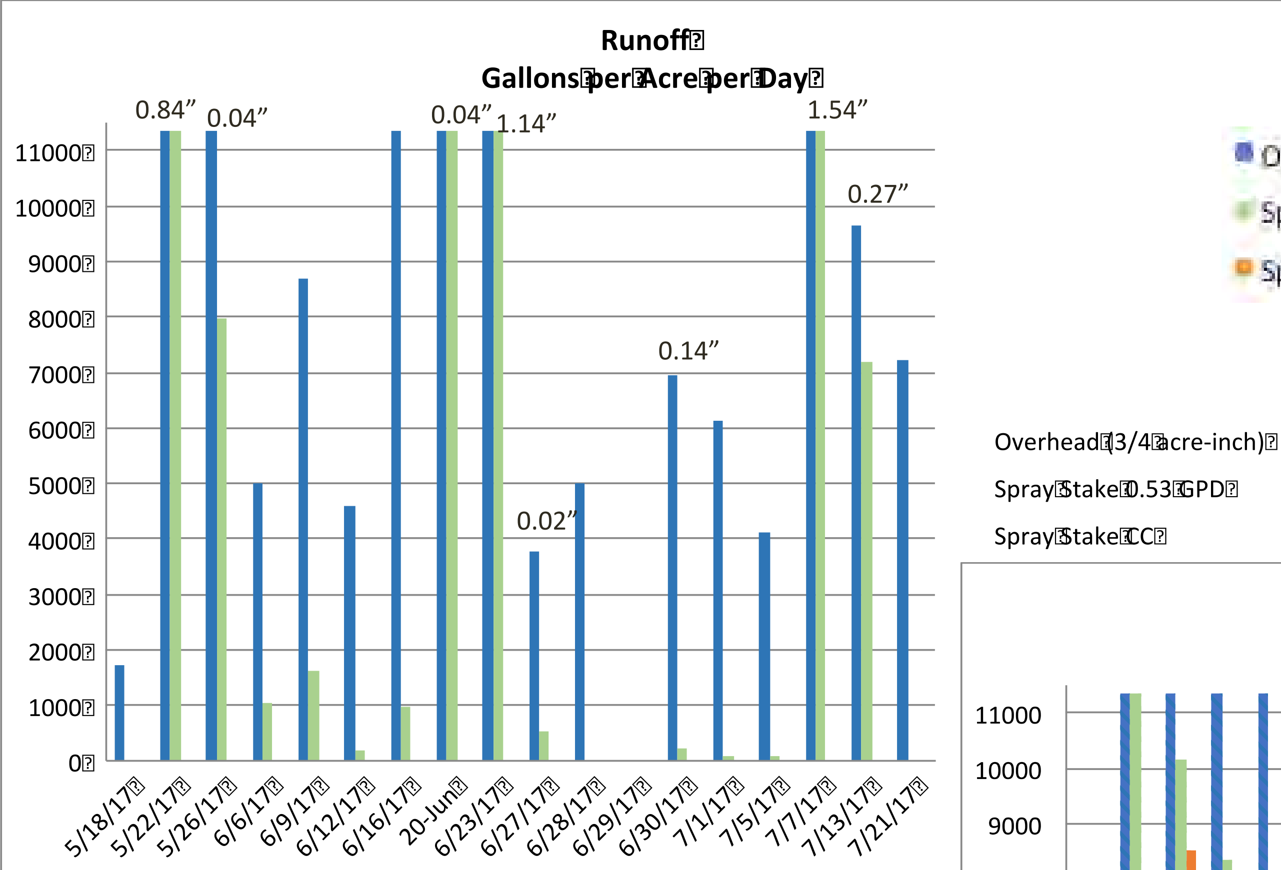
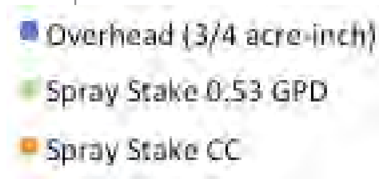
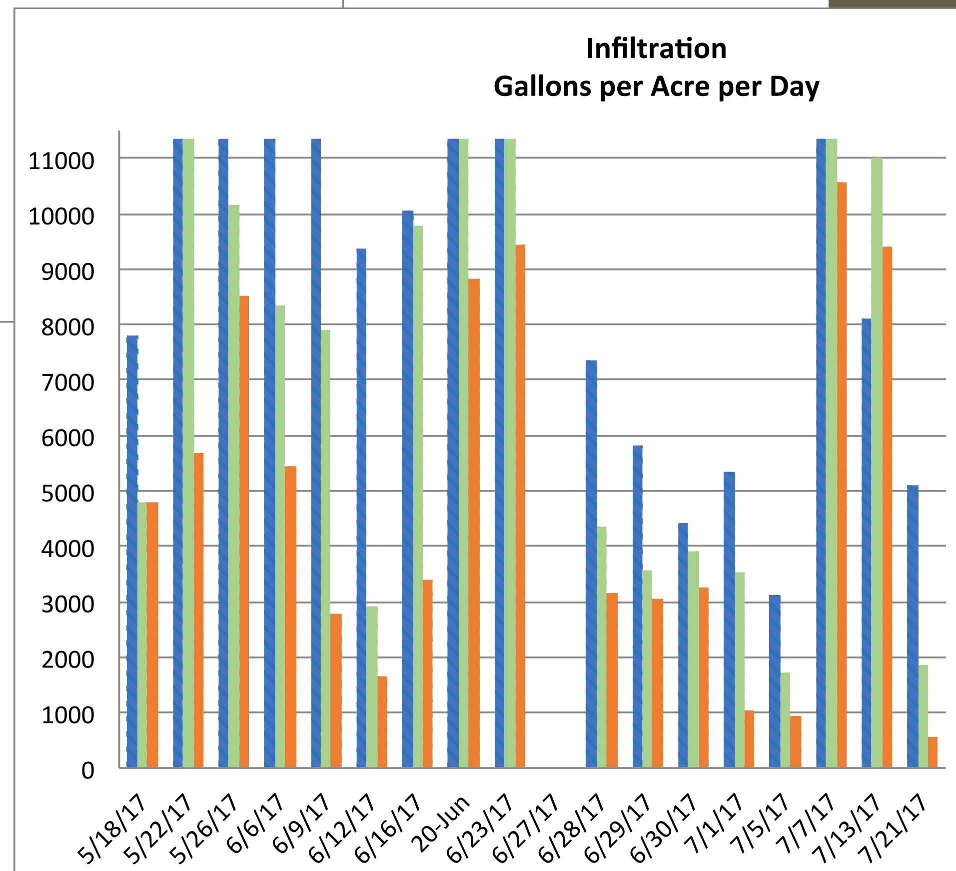
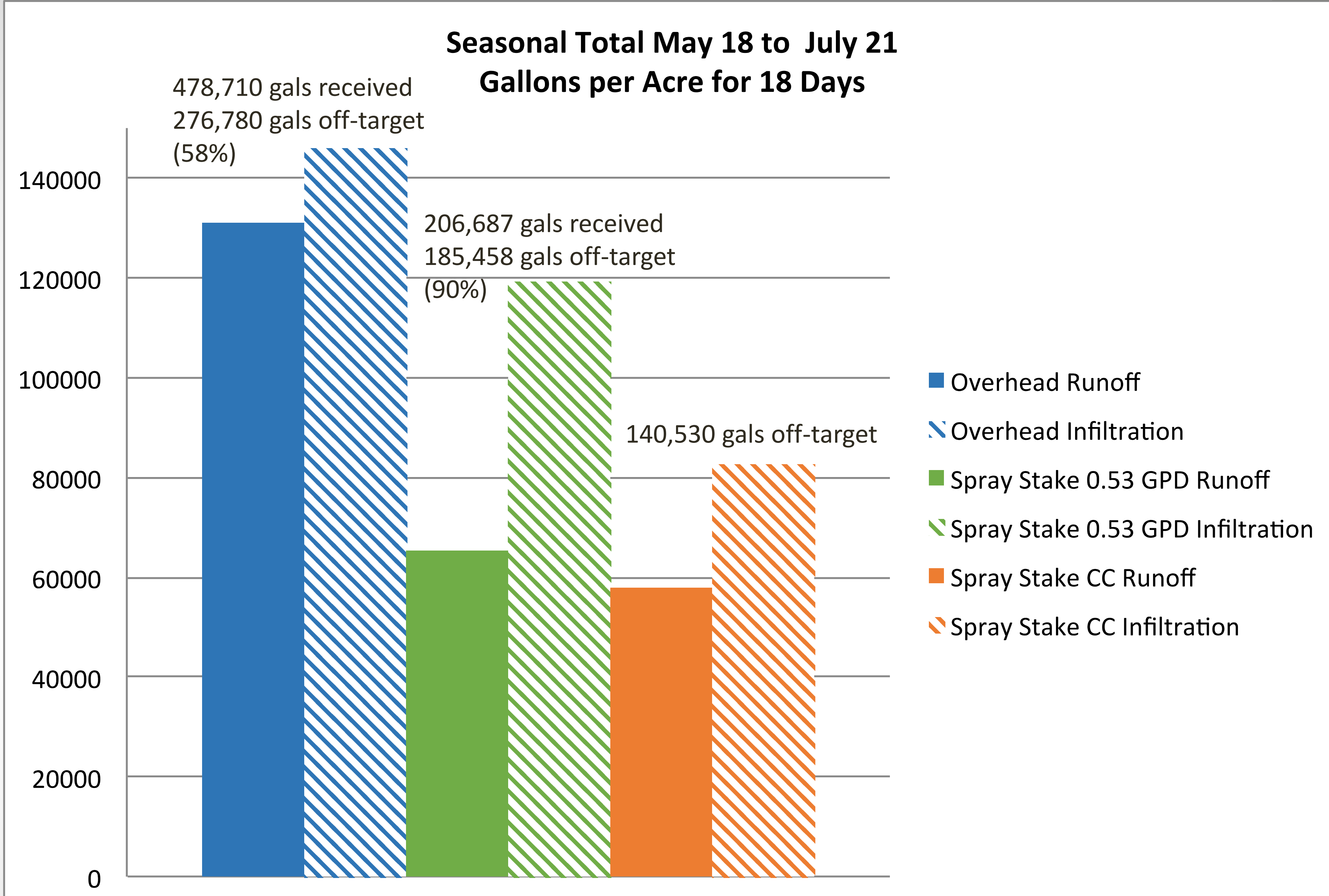
Treatments 2017
Overhead at ¾ inch per day
Spray stake at 0.53 GPD
Spray stake at 9% reduction from CC







Daily Irrigation Rate
0.75 acre-inch = 20,365 gallons per acre
0.53 GPD = 5,252 gallons per acre
CC = need to calculate



Total irrigation applied for the 18 days
Overhead = 366,563 gallons per acre
Spray Stake 0.53 GPD = 94,540 gallons per acre

Plus
112,147 gallons per acre in precipitation

Summary

- Irrigating based on plant water use
  - No difference in growth
  - Possible reduction in production period
  - Better plant nutrition
- Spray-stake irrigation
  - Decreases water used
  - Even larger decrease in water used when set-point irrigation used
  - Greatly reduces runoff and infiltration losses
  - Fertilizer and pesticide movement
- Better monitoring needed as move toward more conservative irrigation practices

Funding partners

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Cost of Water at the Michigan State Research Nursery

- For 160 irrigation events per year = $0.032 cost per 3 gallon plant
- Reduce water use by 30% = $0.022 cost per plant
- Reduce water use by 70% = $0.009 cost per plant
- Reduce fertilizer leaching by 6% = save $0.005 per plant
- Saving **$0.015-$0.023** per plant, Whoopee!!
- Additional revenue of **$158-$242** per acre
- Water is cheap!

…..at least east of the Mississippi

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McCorkle Nursery, GA

- Gardenia crop: 20,000 sq ft area with 23,400 plants (50,965 plants per acre)
- Gardenia was a “problem” crop for them
- Reduced production time from 11-22 to 8-11 months
- Improved survival from 10% loss to zero loss

Van Iersel, Chappell, Ruter, Lichtenberg, Majsztrik, U’s of GA and MD

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Economic Impact

Costs	
Control node	$675
Sensors (4 @ $90)	$360
Rain gauge	$300
Base station, computer & software	$1,000
Installation	$1,500
Total Cost	**$3,835**
Savings/Profit	
Fewer plant losses	$13,000 ($6.50 per plant)
Time/interest (avg 6 months shorter production cycle @ 8%)	$500
Less fertilizer, pesticides, maintenance, labor	$7,700
Total Savings/Profit	**$21,200 ($0.90 per plant)**
Net	**$17,365**

Van Iersel, Lea-Cox,Chappell, Ruter, Lichtenberg, Majsztrik, Belayneh; U's of GA and MD

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Cost of Water

- Cheap! But not the consequences of over-irrigation
- For 160 irrigation events per year = **$0.032** cost per plant
- Save **$0.005** to **0.018** per plant!
- Less shrinkage, shorter production cycle, less fertilizer applied, less fertilizer lost, less labor, less pesticides used = up to **$0.90** more revenue per plant (remember this example is with a "problem" crop)
- Less off-site movement of water and contaminants

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If scheduling done properly

- Use water more efficiently
- Retains fertilizer where it's needed
- Reduces certain problems with low quality water (alkalinity)
- Reduces plant losses
- Improves plant growth/quality
- Shortens production cycle (greatest cost benefit)
- Reduces runoff volume
- Reduces nutrient loss in runoff

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