# Blueberry Automated Quasi-Pulse Irrigation

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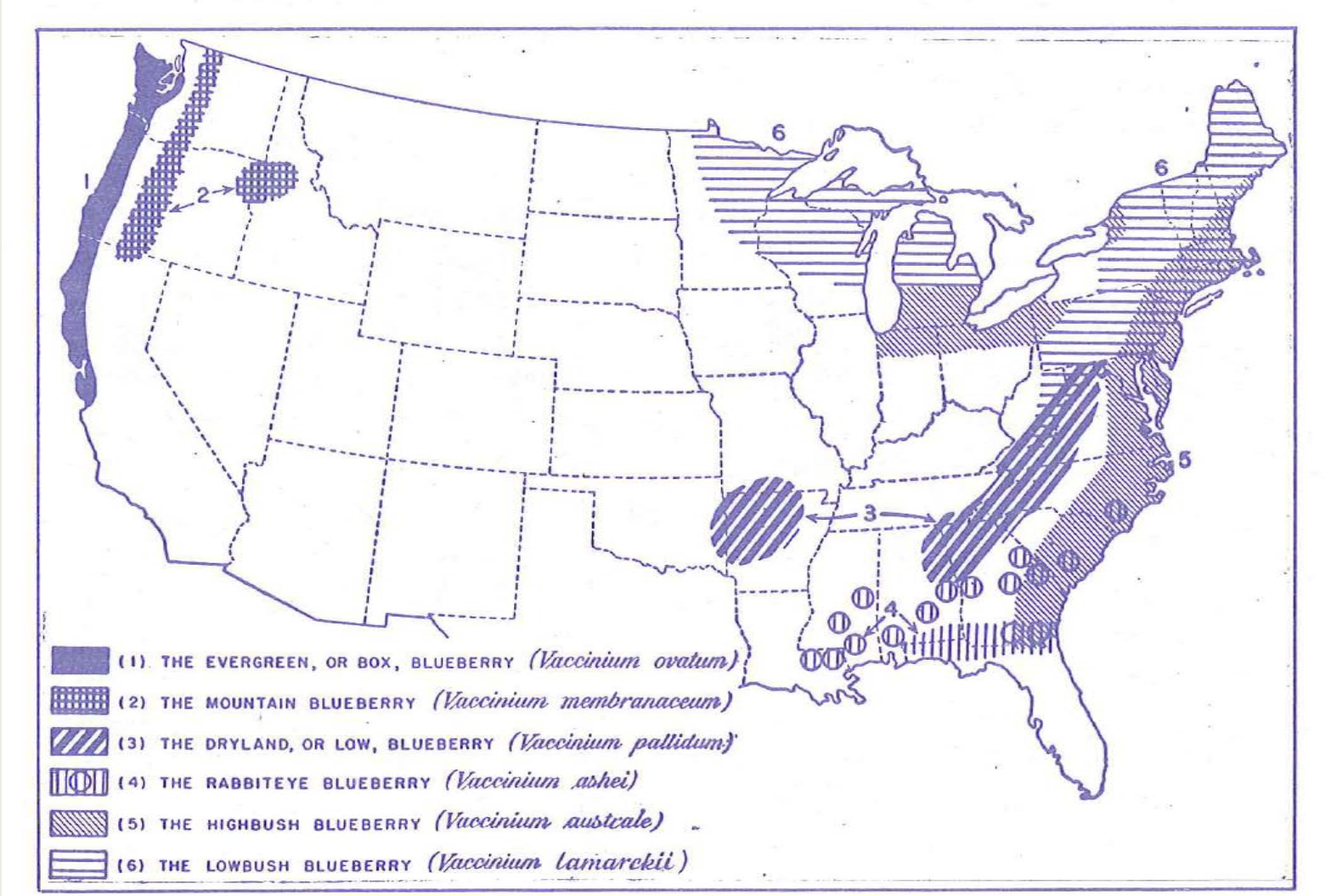
Otto Hoffmann & John Snyder

Funded by a Natural Resources Conservation Service (NRCS) Conservation Innovation Grant

# Blueberries Native to US

## Wild species harvested




1978 USDA Farmers' Bulletin No. 2254, Commercial Blueberry Growing

# Blueberry Native Habitat

Native Americans called them "Starberries" Often dried for stews and pemmican

Blueberry bog
Black Moshannon State Park
Philipsburg, PA
Note: Plants grow on mounds above the water

Wild highbush blueberry

# Raised Beds

Phytophthora Root Rot losses

# Mulching

Sawdust

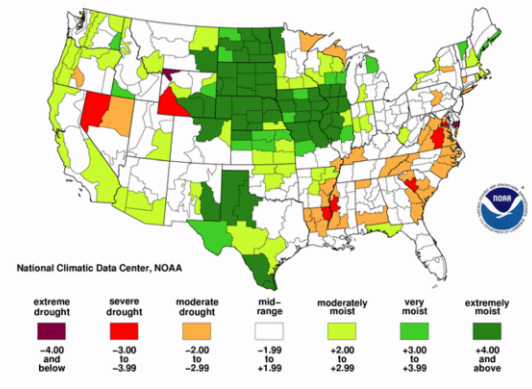
Pine needles

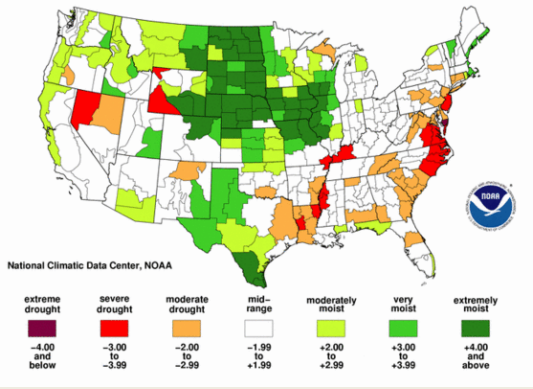
- Suppresses weeds
- Moderates soil temperature
- Conserves moisture
- Releases nutrients

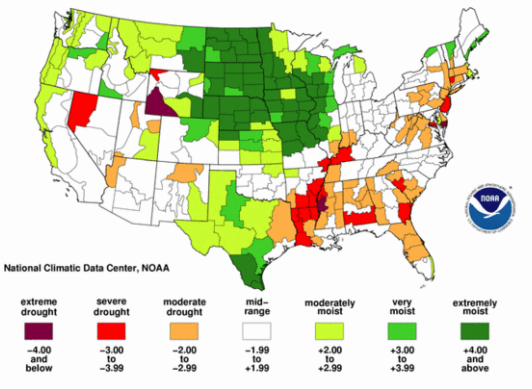
Tree trimmings

2010 - Second driest season on record in 110 Years
2011 – Wettest season on record, Lexington
- Seemed very dry in west KY

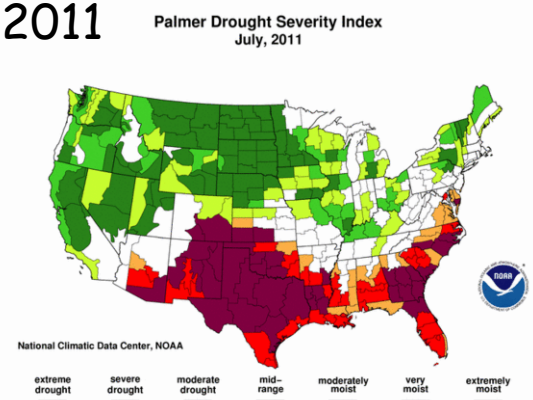
2010

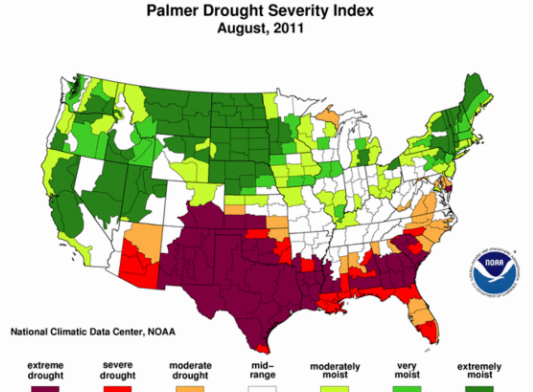


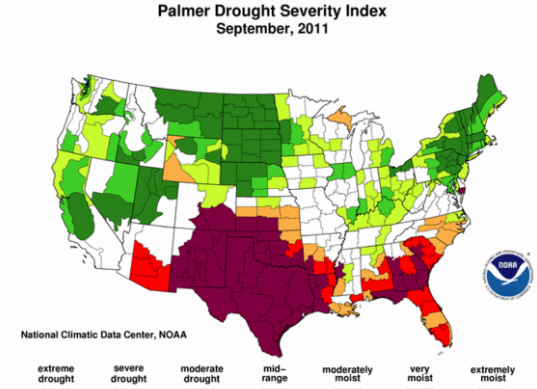




2011



# 2011 – Variable Across the State

## Rainfall

- Jan.
  - 2" below normal
- Feb.-June
  - 12.6" above normal
- Jul-Aug.
  - 1.9" below normal
- Sept.
  - 2" above normal

## Temperature

- Dec.
  - 8.8 °F below normal
- Jan.
  - 2.9 °F below normal
- Feb-June
  - Above normal
- April & July
  - 4 °F above normal
- Sept.
  - 3 °F below normal

# Roots

- Root system is relatively shallow and forms an inverted cone.
- Greatest bulk
  - Top 9" of soil
  - Few larger roots extend down to 30"
- Most roots grow parallel to the soil surface and a few roots extend out from the plant as far as 2 yards,.
  - 50% are within 1'
  - 84% are within 2' of the crown
- Normally found in the decomposing mulch, but not in the upper undecomposed mulch

- The highbush root system is larger than that of the rabbiteye, but is less efficient in nutrient uptake.

- Blueberry roots show little lateral transport of nutrients and water.
  - Fertilizer must be spread in a circle around the plant.
  - Water must also be well distributed around the plant.
  - Thus 2 emitters per plant

# Roots

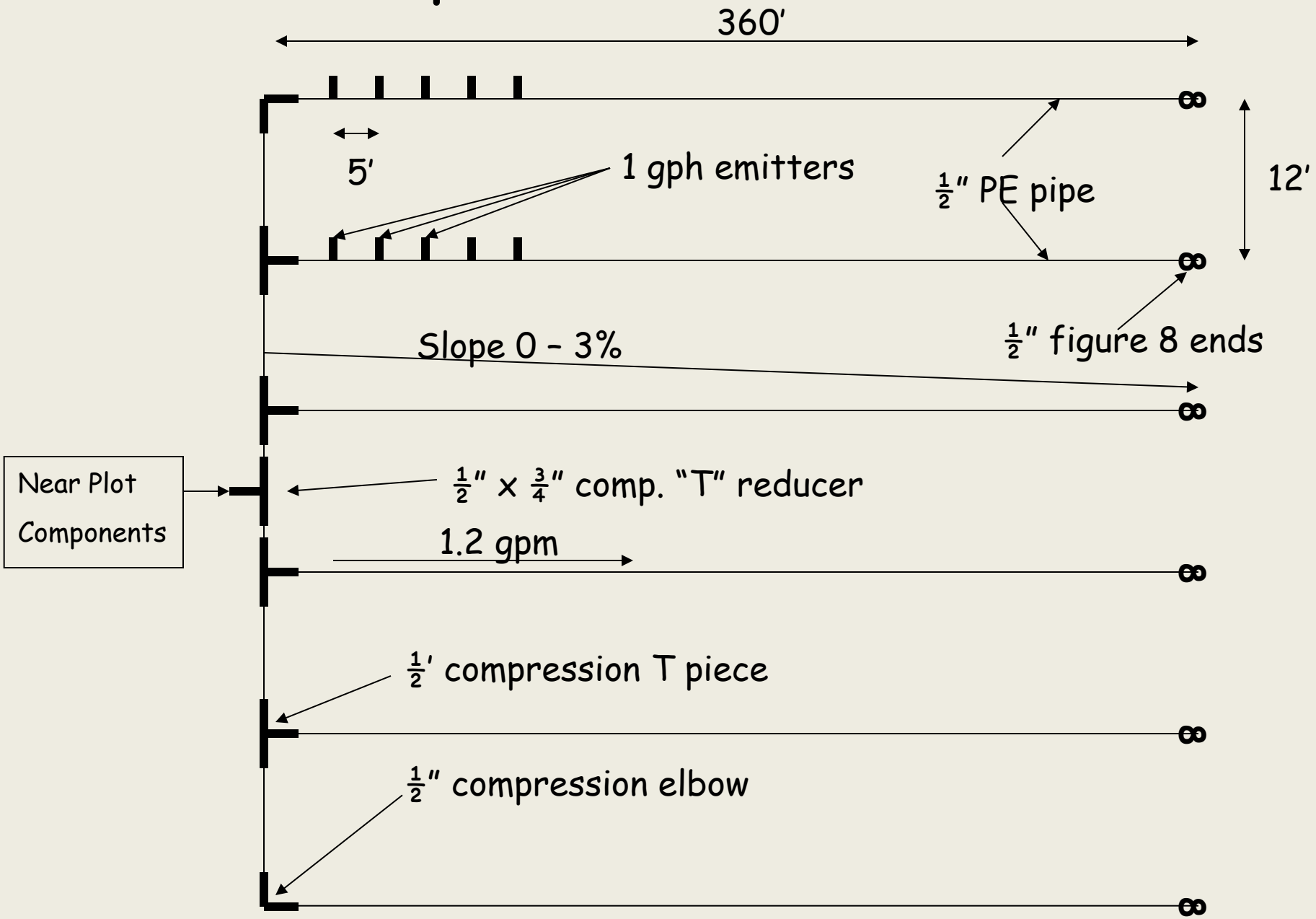
- Roots remain active below ground up to midwinter
- As temperatures drop below 45°F winter roots become brown
  - Secondary thickening
  - Formation of lignin
  - Occurs first in shallow roots
  - Root tips remain white and capable of absorbing water

# Irrigating to saturate soil

- An ideal loam soil will be:
  - 45% "soil" ie. minerals
  - 25% micropores (small air spaces between soil particles-hold water)
  - 25% macropores (root and worm holes, etc-hold air and water)
  - 5% organic material

Photo Courtesy: Tim Coolong

# Drip Lines for ½ acre



# Traditional Drip System Operation

- Grower assesses soil water content
  - Visual/soil feel
  - Tensiometer measurement
- Manually turns water system on and shuts off when plants are sufficiently wet

# Solid-state Controller


# Operating Time

- ¼" water/day (***maximum ~1,300 gal/day)***
- 3 gal/day/plant (5 ft plant spacing)
- 1 gal/hr emitter – 3 hours
- Options
  - 2 times per day for 1 ½ hour
  - ***3 times per day for 1 hour***
  - ***6 times per day for ½ hour***
- *Note these are expected to be the maximum irrigation rates during critical growing conditions

# Irrigation Scheduling

- Traditionally, ½ hours to 3 hours per zone
- Problem
  - Field observations show some of the irrigation water infiltrates below root depth if watering lasts more than 20 minutes
  - Due to macropores (cracks in soil from decayed roots, worm holes, etc.)
  - Macropores enable water to quickly infiltrate to depths of 1 ft to 3 ft (or greater)

# Study Purpose

- Reduce irrigation water loss by eliminating water movement below the plant root system.
- Reduce water use by pulsing the water on.
- Automate the trickle irrigation process.
- Provide an affordable low cost system useful for growers.

- Don't kill the plants!
  - Blueberries do not have root hairs and it is more difficult for them to take up water.

# Soil Water Content

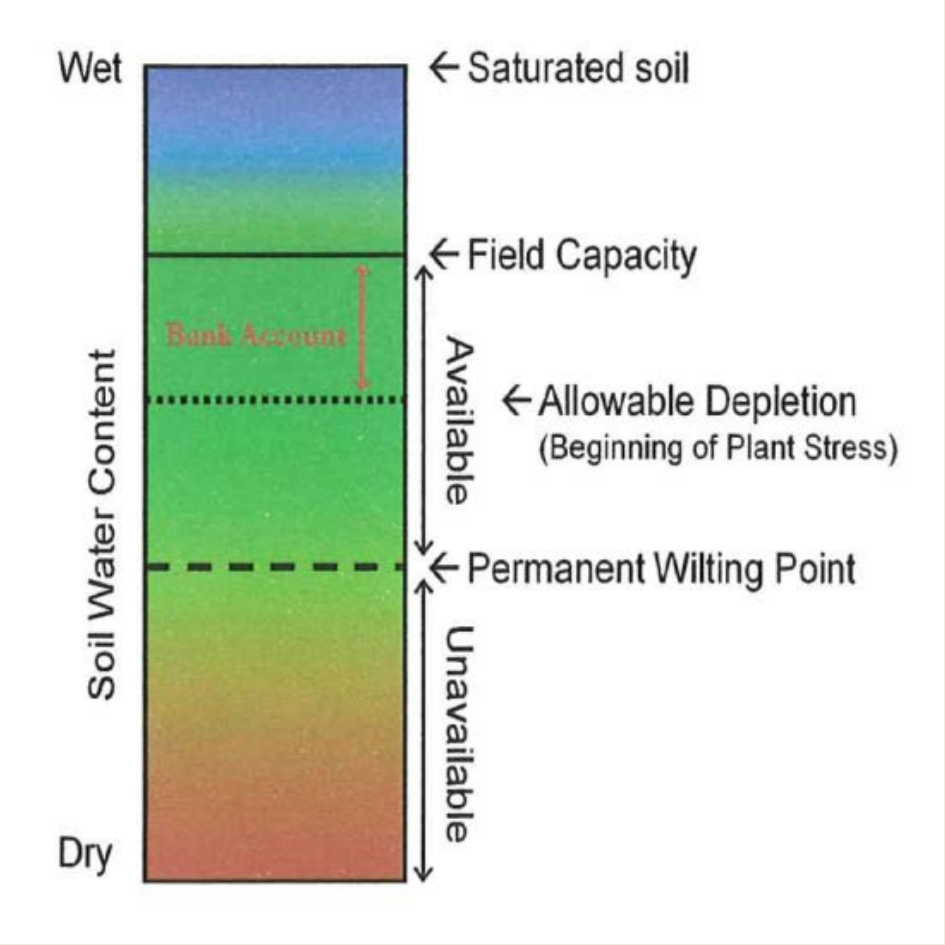
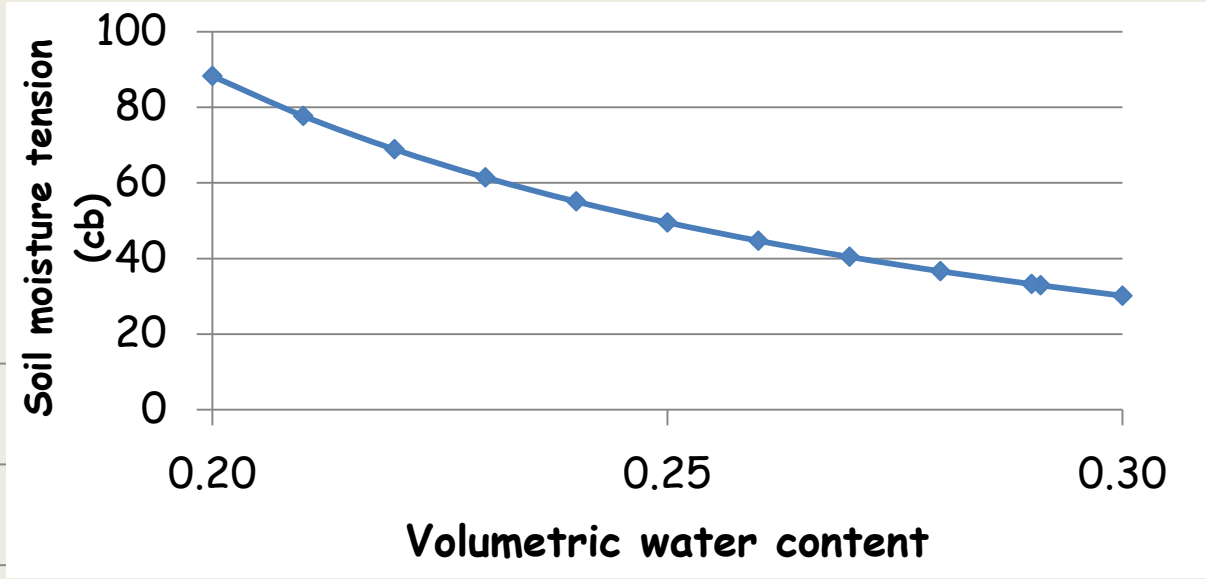



Figure courtesy: Utah State Univ., Brent Black

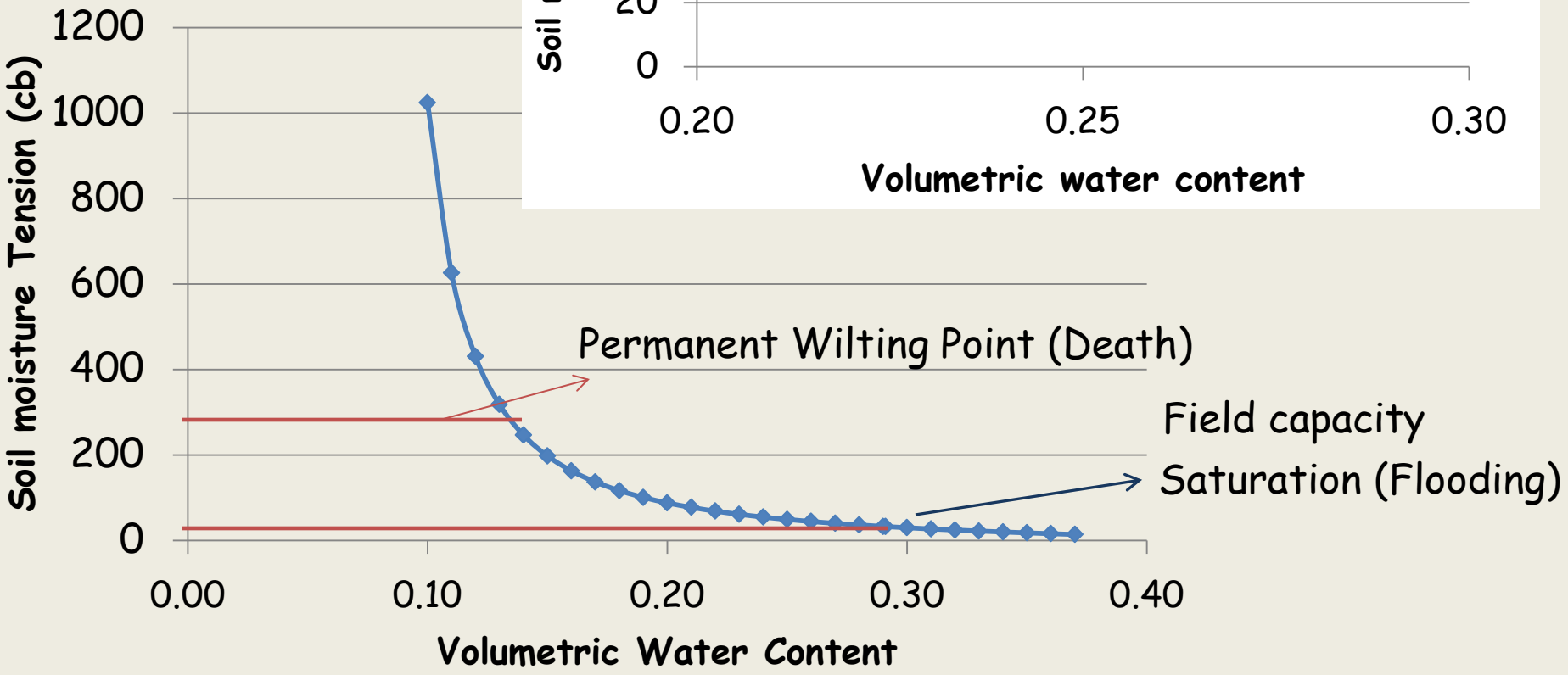
- Ideally soil moisture is maintained between field capacity and the allowable depletion point

$$\text{Volumetric water content} = \frac{\text{Volume of water}}{\text{Soil volume + Water volume + Air space}}$$

**Moisture release curve for silt loam**




The drier the soil the lower the volumetric water content



# Previous Systems
## (2008-2009 Blueberries & Blackberries)

- Based on automatic tensiometers
  - On = 30 cb & off = 10 cb
  - Soil moisture varied widely in short distance
  - Difficult to place tensiometers to represent area
  - Tensiometers loose contact with soil when too dry and cease functioning
- Required electricity
  - Wire is expensive
- Blackberries removed the water as fast as it was pulsed in for short intervals when it was hot and used even more water

# System Characteristics for Blueberries

- Automated
- Quasi-Pulsed
- Function at low soil moisture levels
- Low cost

# Sensors Located Next to One Plant at Each Site

Manual Treatment

Manually irrigated by grower based on experience and tensiometer(s)

Automated Treatment

Automatically irrigated based on buried Watermark sensor

# System Components for Quasi-Pulse Irrigation

Watermark sensors
from Irrometer Co., Inc

- Solid state electrical resistance devices
- Buried permanently?
- Range 0-200 centabars
- Irrigates based on average between 2 sensors

Sensors 12" from plant and emitter

# System Components for Quasi-pulse Irrigation


Set desired soil moisture level on dial

WEM allows irrigation if soil moisture is above set level

System set to irrigate 8 times in 24 hrs at 3 hour intervals.

Battery powered Hunter Controller for irrigation timing


# Quasi-pulse System Cost

| Item | Quasi- pulse Cost Estimate |
|---|---|
| Hunter controller | $90 |
| Water meter[1] | $105 |
| Hunter PGV valve[2] | $15 |
| Watermark system[3] | $200 |
| Watermark meter[4] | $330 |
| Total | $740.00 |


[1]Optional to track water consumption
[2]Based on 1" PVC valve
[3]Two sensor system with battery controller (Type WEM-B)
[4]Optional - to acquire moisture levels from Watermark sensors

**Table 2. Recommended Watermark™ sensor values at which to irrigate.**

| Soil Type | Irrigation Needed (*centibars*) |
|---|---|
| Loamy sand | 40 – 50 |
| Sandy loam | 50 - 70 |
| Loam | 60 - 90 |
| Silt loam, silt | 70 - 90 |
| Clay loam or clay | 90 – 120 |

™Watermark is a registered trademark of Irrometer, Co., Riverside, CA.

# Early Season Adjustment


- 2010
  - Adjusted Watermark Module from 5 to 7 in late July for all sites.
- 2011
  - Watermark Modules set to 7 for season.

# Solenoid & Water Meter

# Rainfall Measurement

Tipping bucket
Measures 1/100" rainfall
McCormick & Reed sites

Mesonet Station
at Hort. Res.
Farm Lexington
Cal Blake site

# Additional Components for Research that A Grower Would Not Need

- Data loggers
  - Rainfall
    - Logged each 1/100" rainfall
  - Manual system operation
  - Quasi-pulsed system operation
  - Logged each second of each irrigation system operation

# Additional Components for Research – (Decagon Soil Moisture Sensors)


Sensor depth 6" & 12"
2 for manual irrigated bush
2 for quasi-pulsed irrigated bush

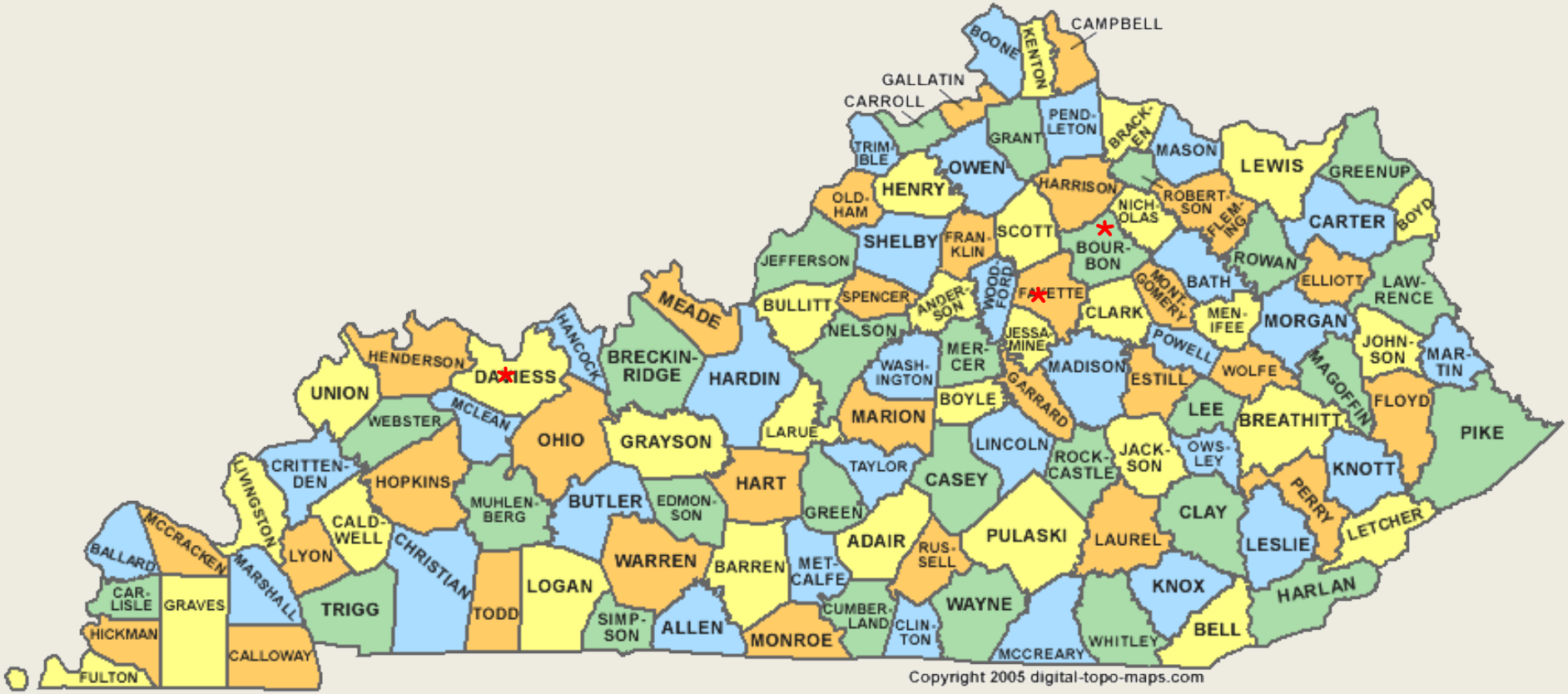

Soil moisture recorded every 2 hours, 24 hrs/day

Burl & Otto

Chris

Patrick

# Grower Demonstration Plot Locations



# Nancy & Royce McCormick

## Owensboro,KY


Photos courtesy:
Stephen Patton

- 2010
  - Plants spaced 4' X 14'
  - Emitters spaced 1' apart
  - Jun. 7, 2010 Installed
  - Jul. 23, 2010 Watermark sensor switched from 5 to 7
  - Oct. 16, 2010 Shut down
- 2011
  - Jun. 7, 2011 Started
  - Oct. 24, 2011 Shut down

# McCormick Blueberries

Raised mulched beds
Silt clay soil

"Darrow" blueberry

# Dana & Trudie Reed

## Paris, KY

Photo courtesy: Stephen Patton

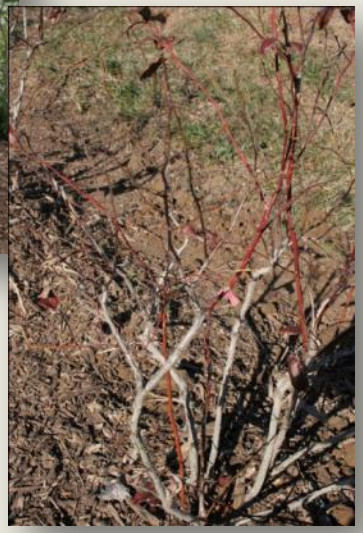

5 year-old "Spartan" blueberries
Left row pulsed, right row manually irrigated

Slightly raised mulched beds
Silt clay soil

# Reed Blueberries

Quasi-pulse Irrigated

Manually Irrigated



- 2010
  - Plants spaced 4' X 14'
  - Inline emitters spaced 3' apart
  - Jun. 2, 2010 Installed
  - Jul. 28, 2010 Watermark sensor switched from 5 to 7
  - Oct. 28, 2010 Shut down
- 2011
  - Jun. 9, 2011 Started
  - Oct. 3, 2011 Shut down

# Cal, Judi & Kit Blake

## Lexington, KY


Photo courtesy: Stephen Patton

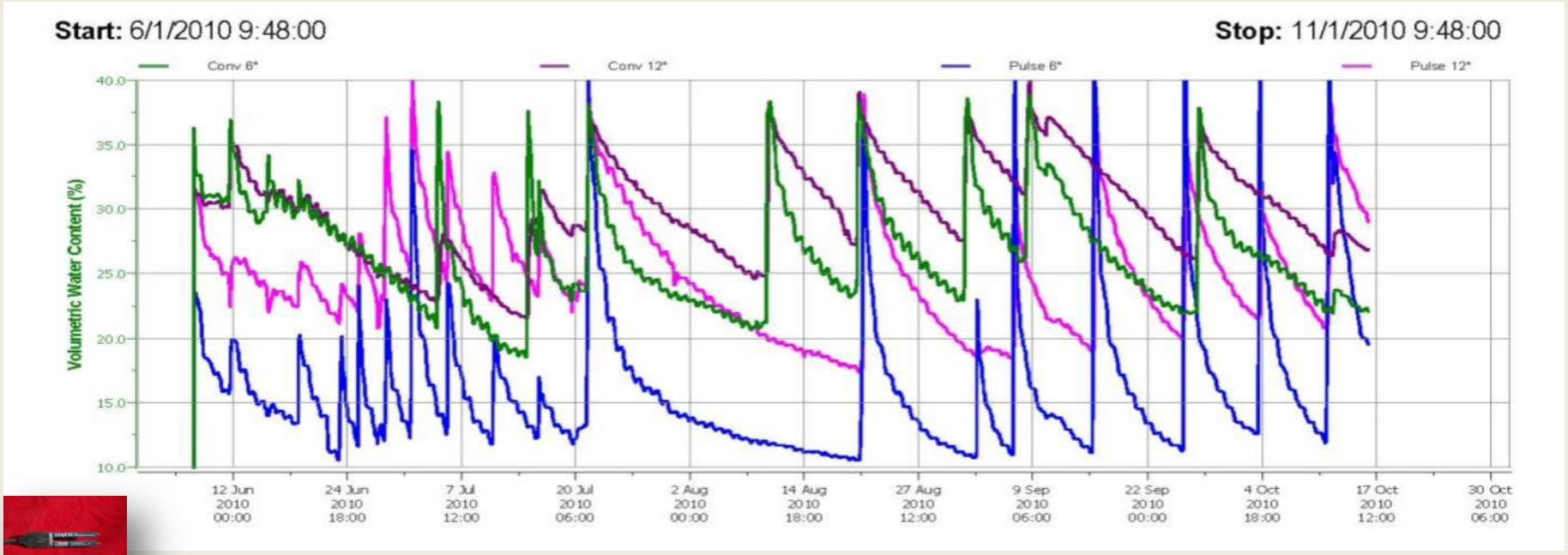
'Nelson' & 'Jersey' blueberries planted in 2002 RBD

Flat unmulched beds
Maury silt loam soil

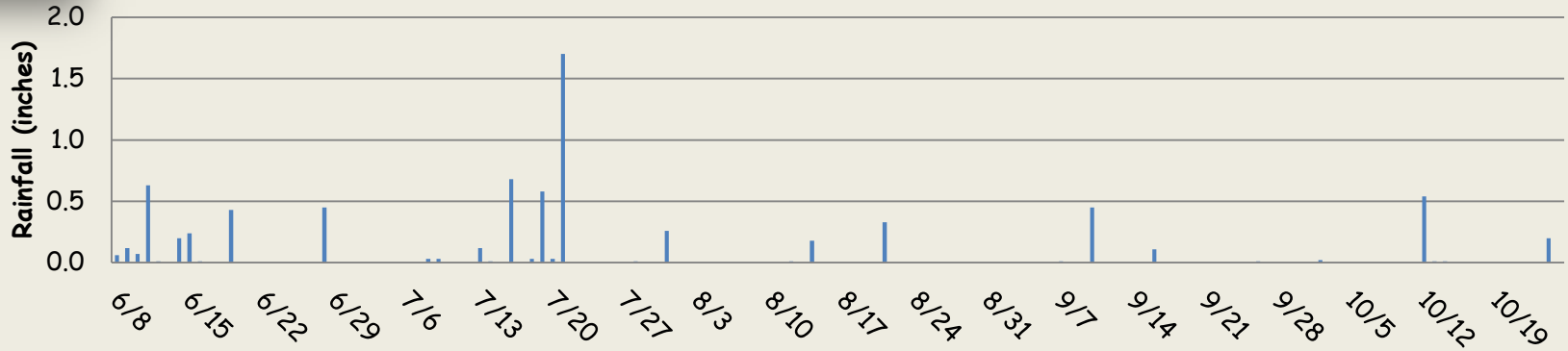
# Blake Blueberries

- 2010
  - Plants spaced 5.7' X 14'
  - 2 Emitters per plant
  - Jun. 7, 2010  Installed
  - Jul. 17, 2010 Watermark sensor switched from 5 to 7
  - Oct. 26, 2010 shut down
  - Designed with pulsed and manual drip tubes in each row
- 2011
  - Jun. 8, 2011 Started
  - Sept. 29, 2011 Shut down

# Soil Moisture at 6 & 12 Inch Depth for Quasi-Pulse & Manual Irr., 2010 – McCormick Blueberry



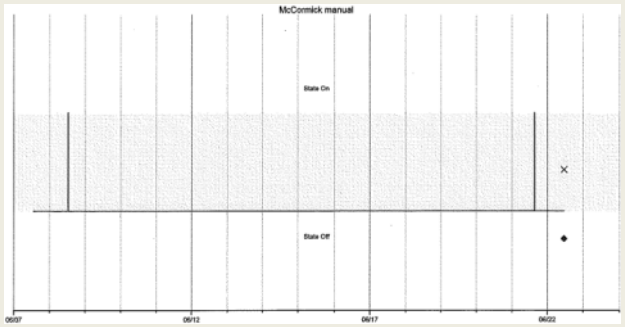


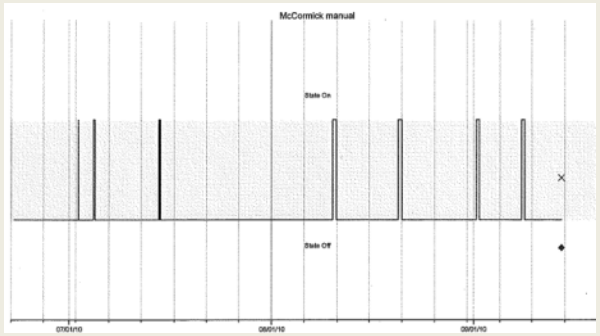



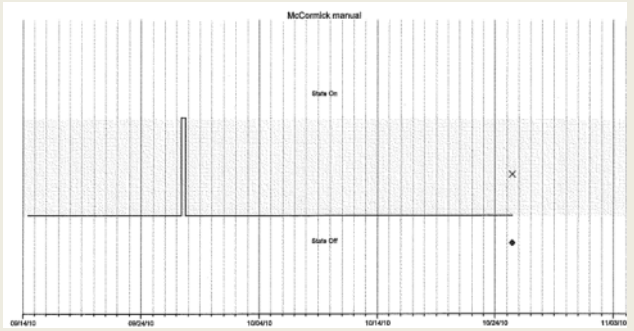

Total Rainfall 7.10" 2010

# McCormick Blueberries – 2010 System Operation

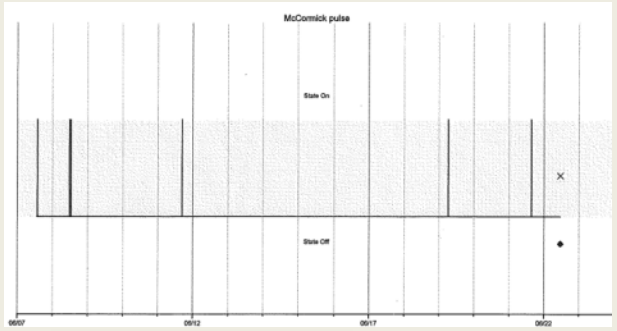
## Manual

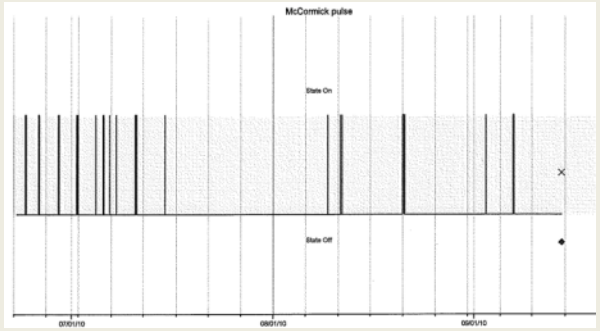


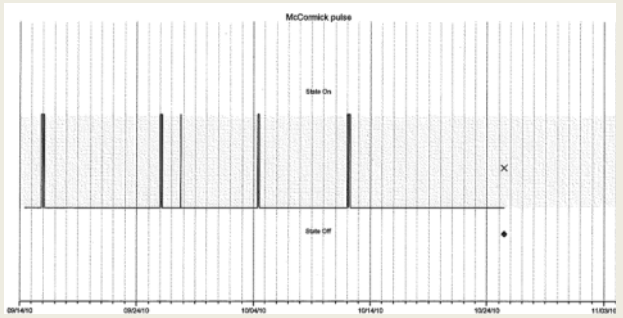




## Quasi-Pulse



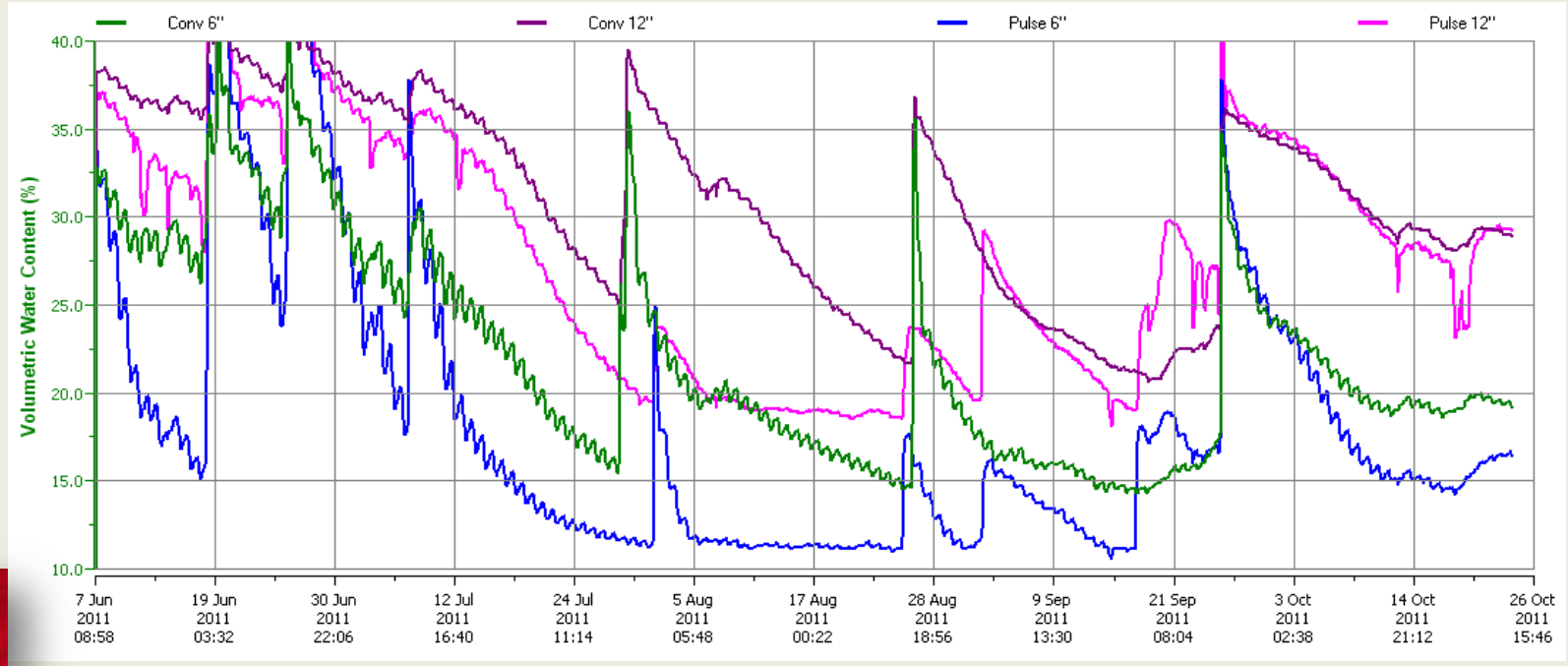



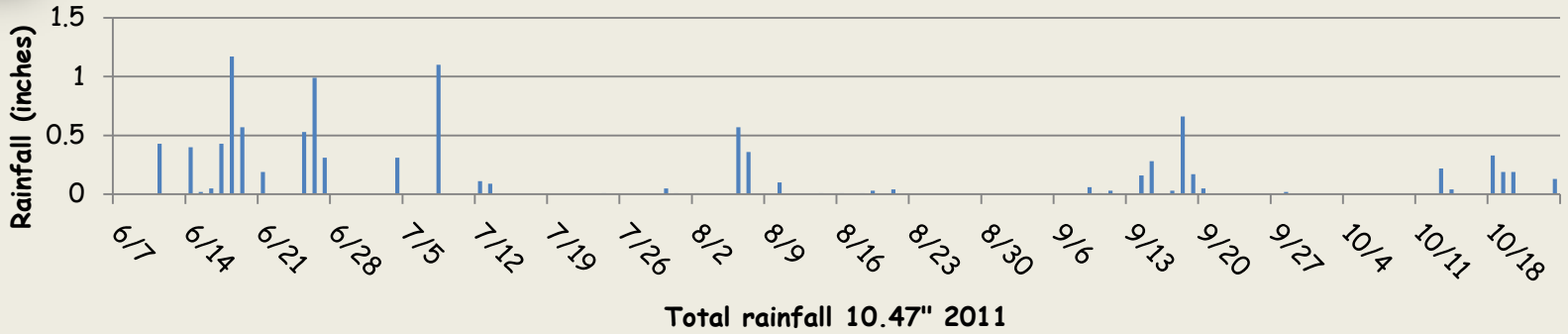

Watermark Sensors

# Soil Moisture at 6 & 12 Inch Depth for Quasi-Pulse & Manual Irr., 2011 – McCormick Blueberry

Start: 6/7/2011

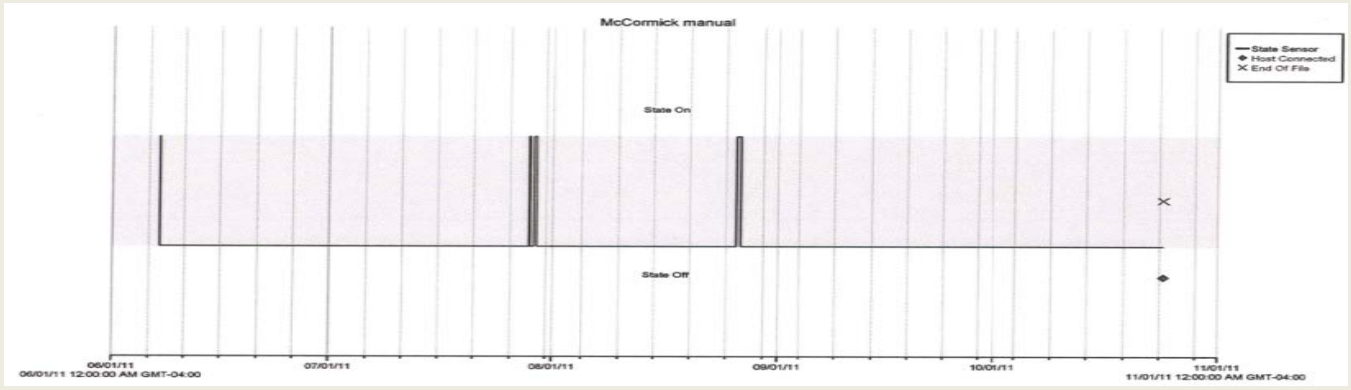
Stop: 10/24/2011



# McCormick Blueberries - 2011

## Manual

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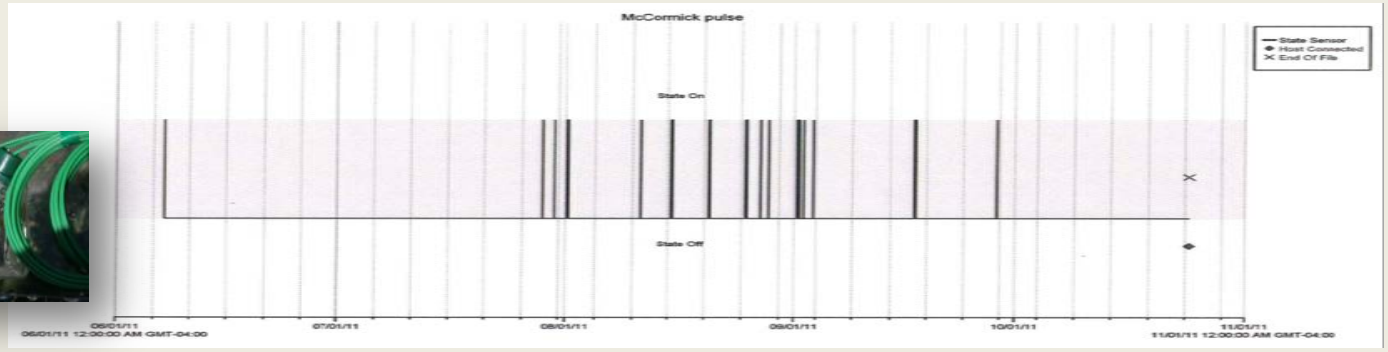
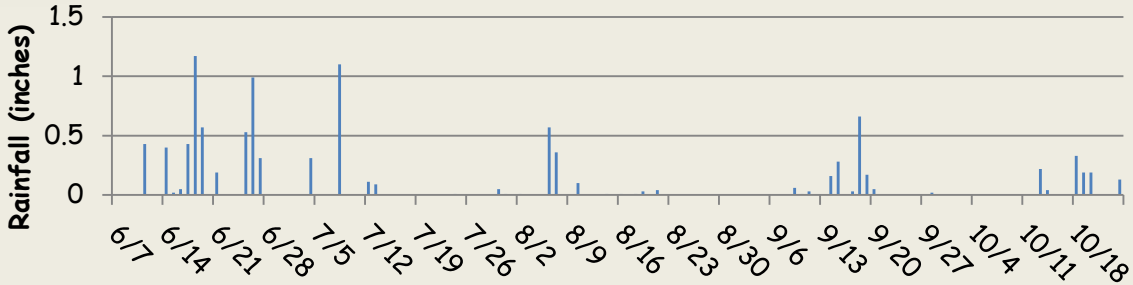



**Total rainfall 10.47" 2011**

# McCormick - 2010

- 7.10" Rainfall from 6/7-10/16
- 18.7 Acre inches recommended at ("Rule of Thumb") 1" per week for time period

- 12.2 Acre inches total applied Manual
  7.1 + 5.1 = 12.2
- 9.2 Acre inches total applied Quasi-Pulse
  7.1 + 2.1 = 9.2

# McCormick Water Application
## (Silt Clay)

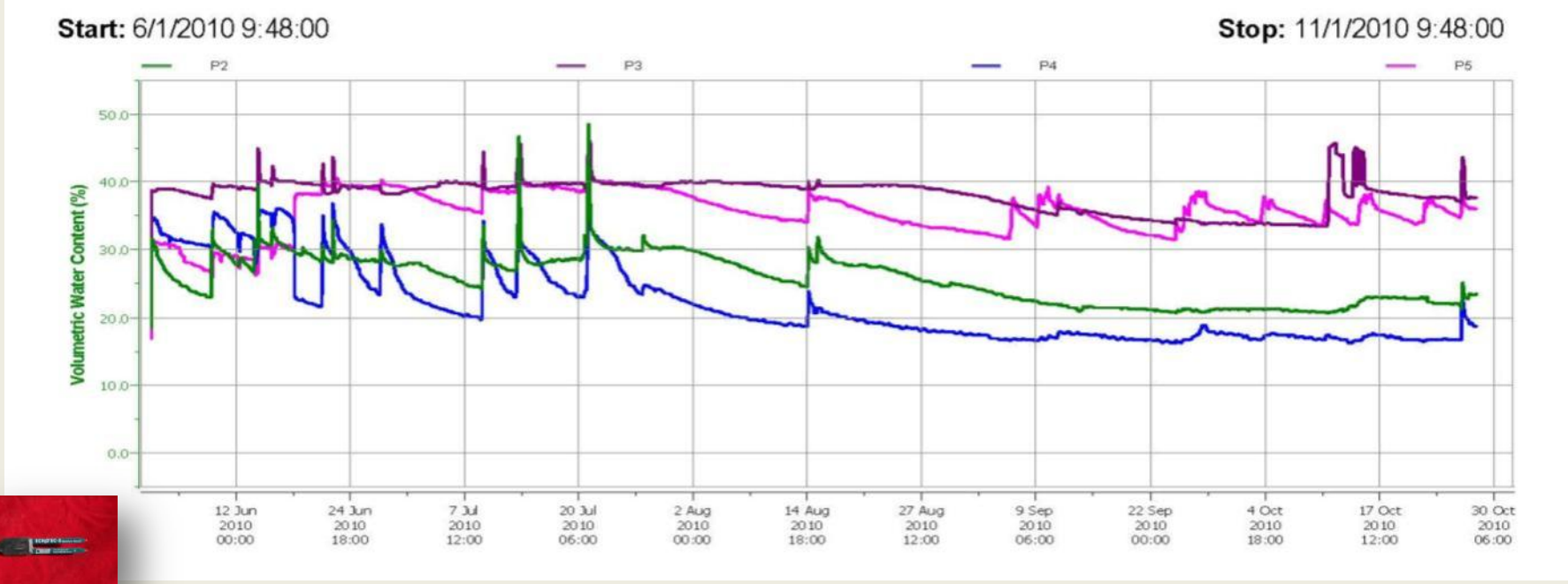
| Year | Dates | Quasi-Pulse (gal/A) | Manual (gal/A) | Quasi-pulse Versus Manual (%) | Quasi-pulse versus 1 in/week (%)[1] |
|---|---|---|---|---|---|
| 2010 | 6/7-10/16 | 57,467 | 137,896 | 58.3 less | 60.4 less |
| 2011 | 6/7-10/24 | 310,845 | 566,421 | 45.1 less | 50.3 more |

[1]Example calculation 18.7 weeks (6/7-10/16 X 4 ft plant spacing/14 ft row spacing X 27,154 gal/ac-ft. = 145,080 gal/ac. (145,080-57,467)/145,080 X 100 = 60.4%

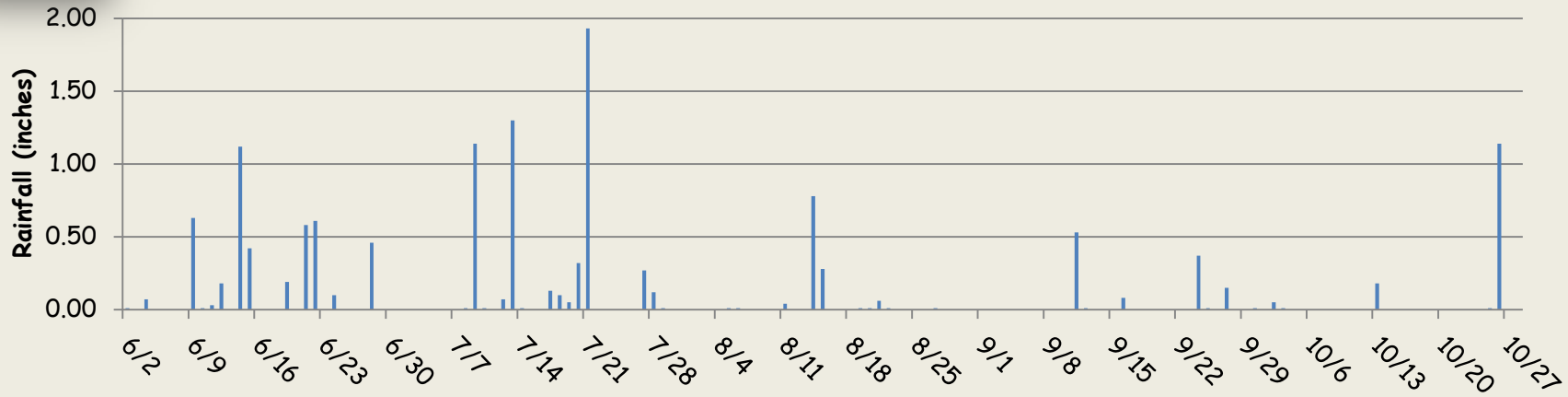
| Time period | Quasi-Pulse (gal/plant) | Manual (gal/plant) | Difference (gal/plant) |
|---|---|---|---|
| 2010 | 73.9 | 177.3 | -103.4 |
| 2011 | 399.6 | 728.2 | -328.6 |

1 acre inch of water =27,154 gal

# Soil Moisture at 6 & 12 Inch Depth for Quasi-Pulse & Manual Irr., 2010 – Reed Blueberry



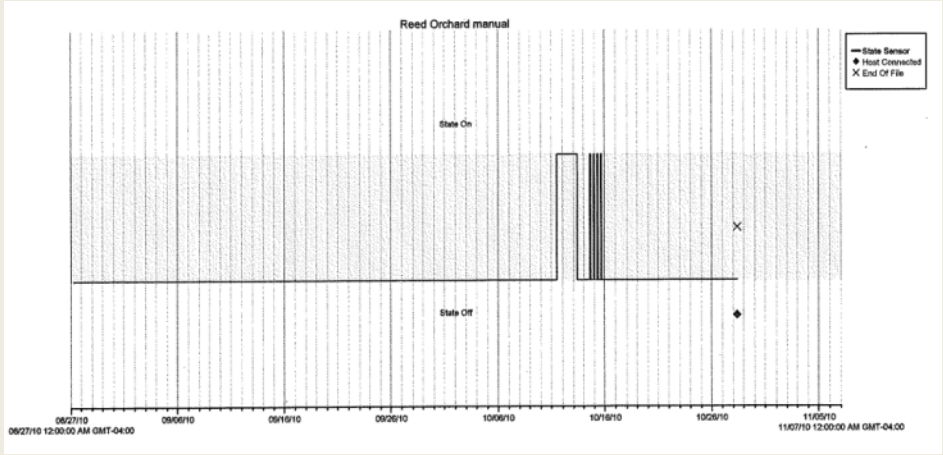


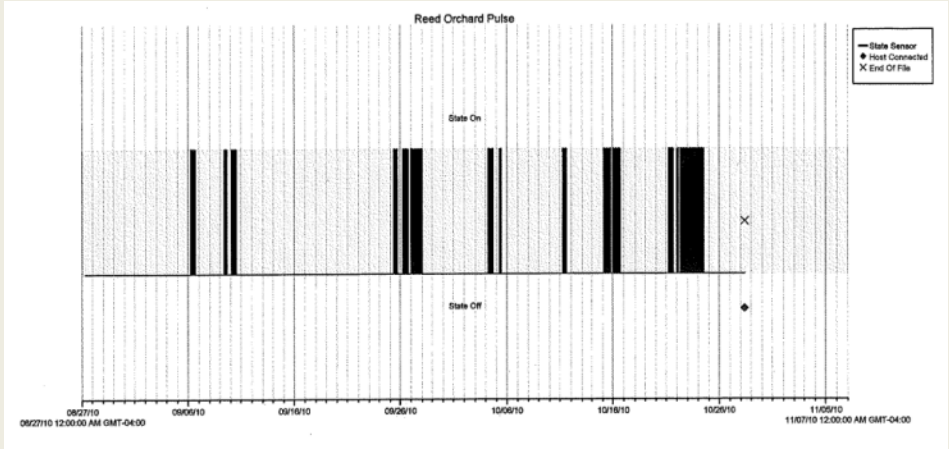

Total rainfall 13.8"

# Watermark Sensor Irrigation - Reed
# Aug. 27- Oct. 10, 2010

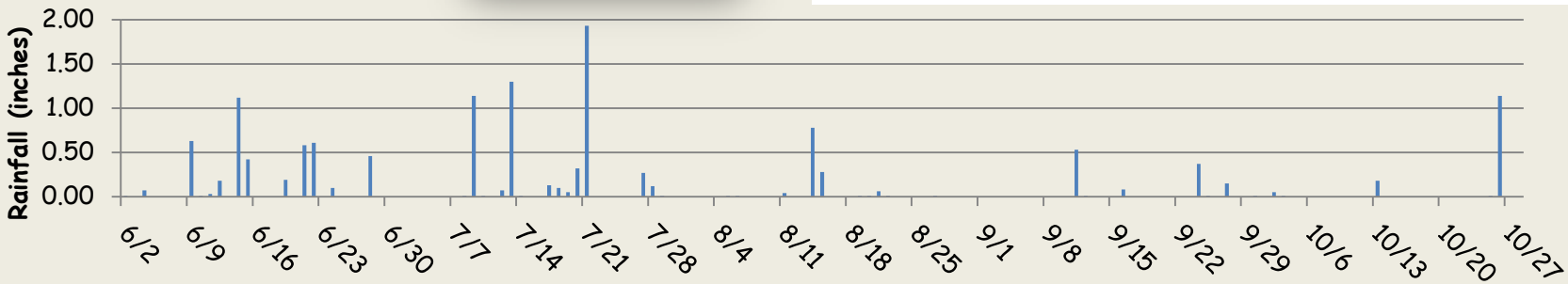
Manual
47,922 gal/A




Quasi-Pulse
109,810 gal/A



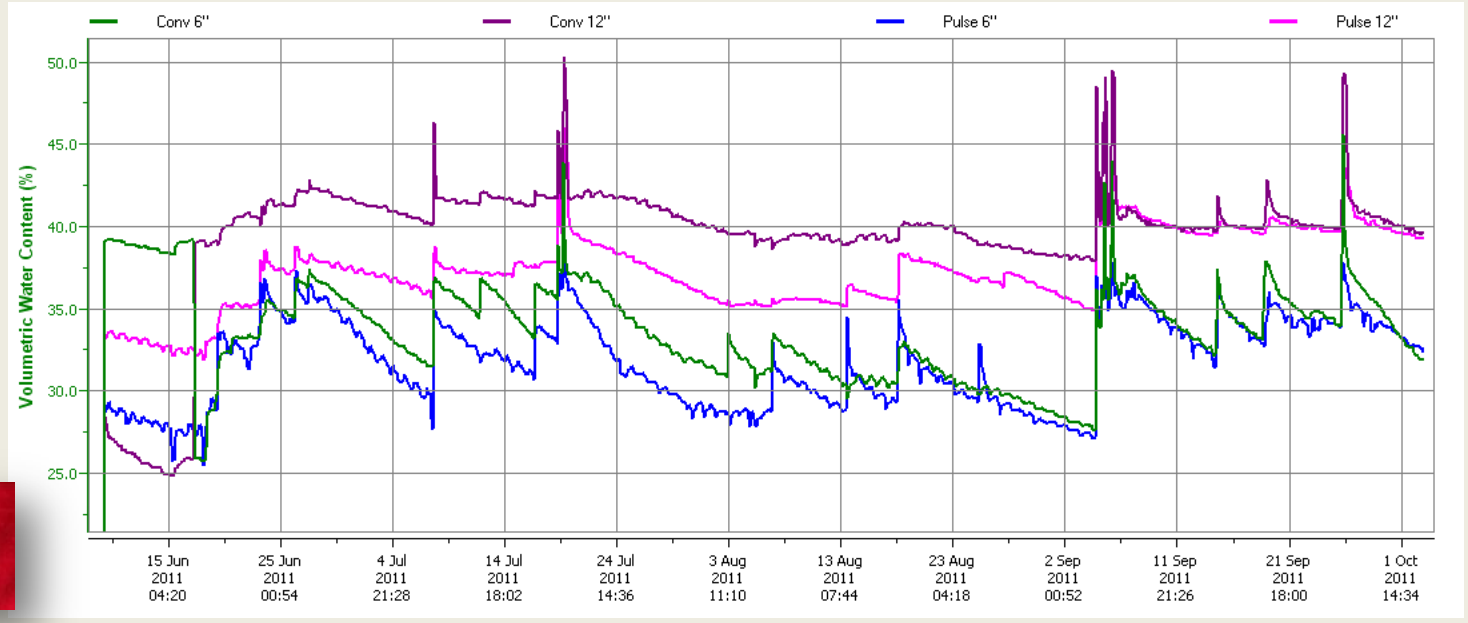

27,154 gal/A =
1 acre inch

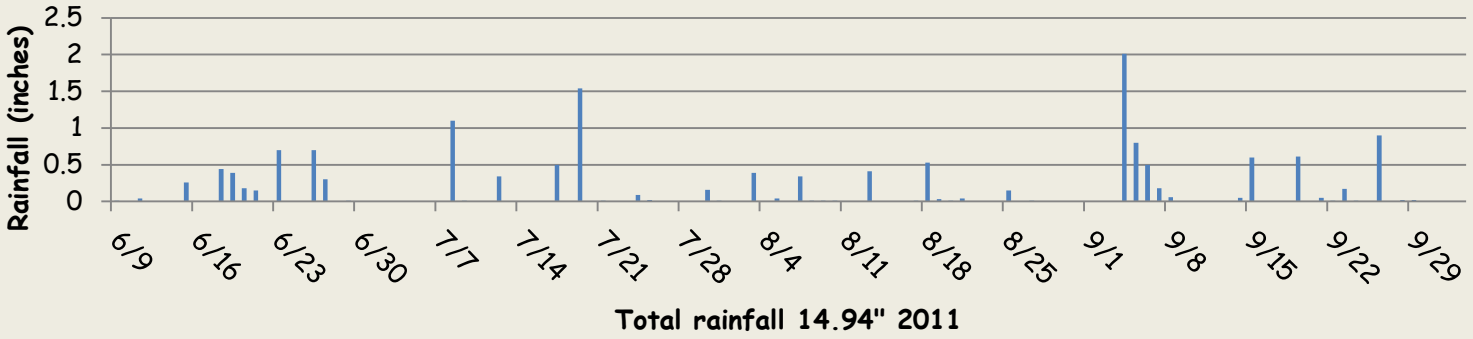


# Soil Moisture at 6 & 12 Inch Depth for Quasi-Pulse & Manual Irr., 2011 – Reed Blueberry

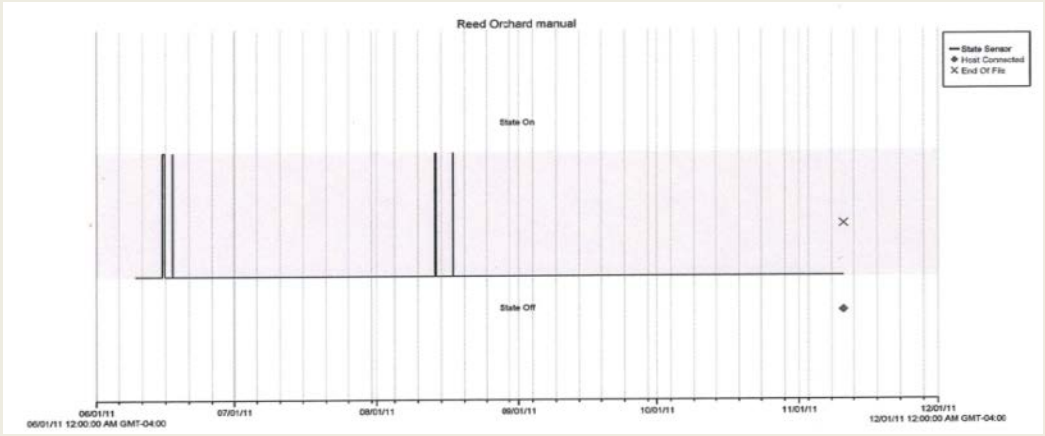
Start: 6/9/2011

Stop 10/3/2011

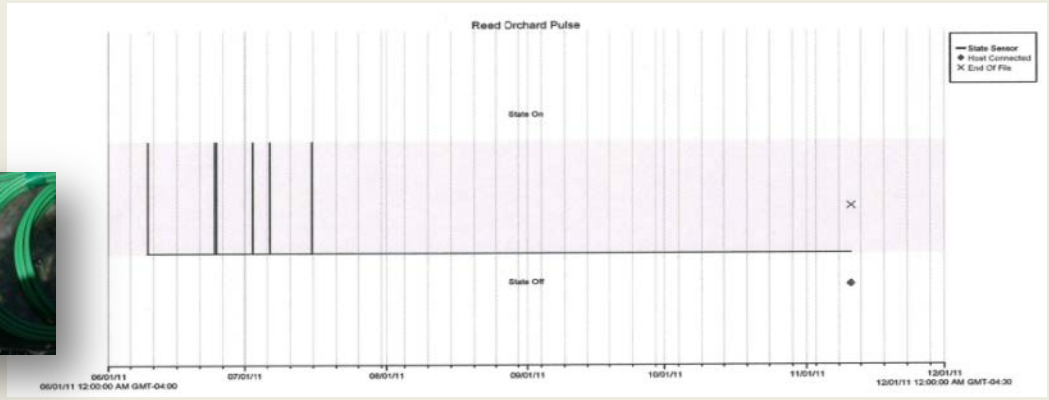


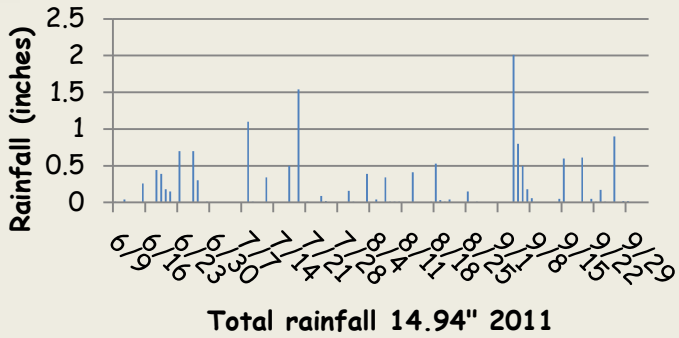
# Reed Blueberries - 2011




Manual




Quasi-Pulse




Total rainfall 14.94" 2011

# Reed Water Application
## (Silt Clay)

| Year | Dates | Quasi-Pulse (gal/A) | Manual (gal/A) | Quasi-pulse Versus Manual (%) | Quasi-pulse versus 1 in/week (%) |
|---|---|---|---|---|---|
| 2010 | 6/2-10/28 | 109,810 | 47,922 | 56.3 more | 33.0 less |
| 2011 | 6/9-10/3 | 172 | 140,104 | 99.9 less | 99.9 less |

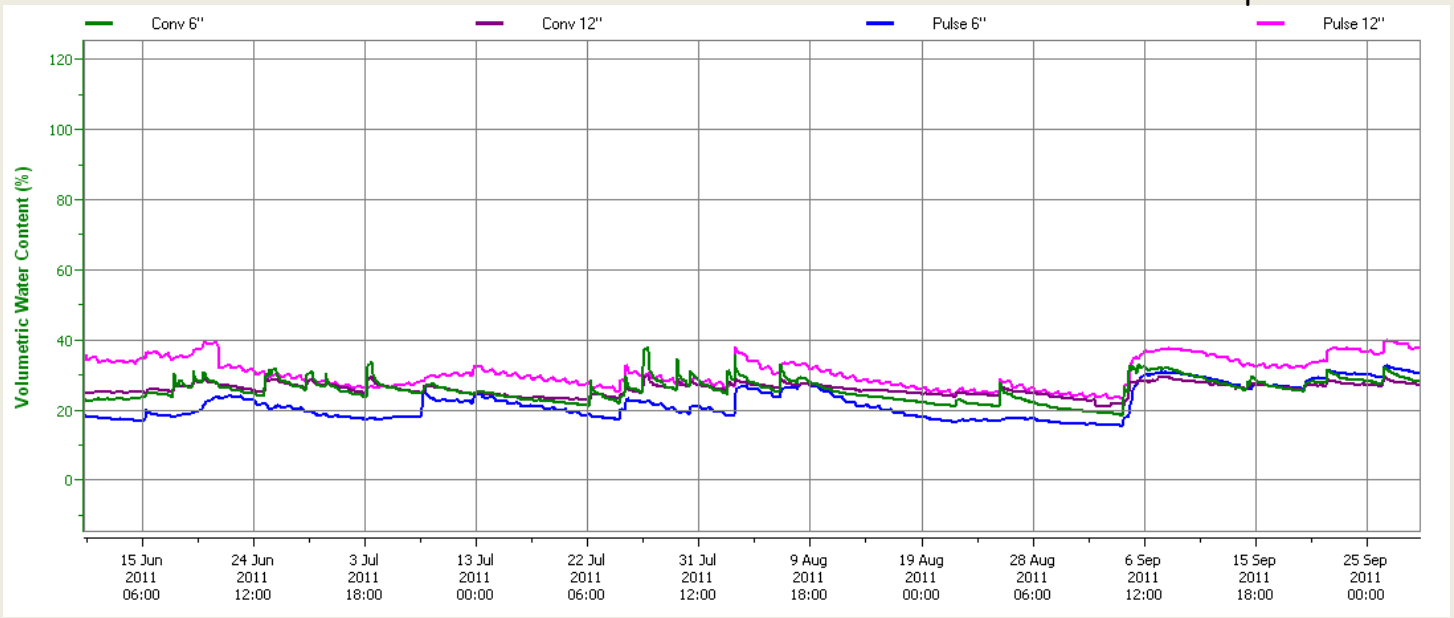
| Time period | Quasi-Pulse (gal/plant) | Manual (gal/plant) | Difference (gal/plant) |
|---|---|---|---|
| 2010 | 141.2 | 61.6 | 79.6 more |
| 2011 | 0.2 | 180.1 | 179.9 less |

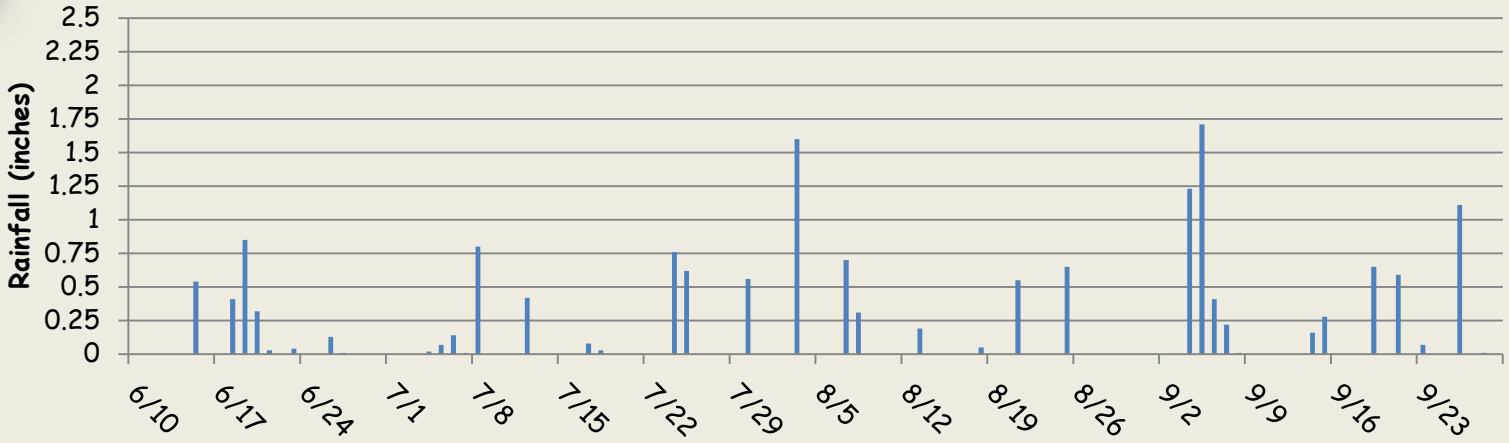
1 acre inch of water =27,154 gal

# Soil Moisture at 6 & 12 Inch Depth for Quasi-Pulse & Manual Irrigation – 2011 Blake Blueberry

Start: 6/10/2011

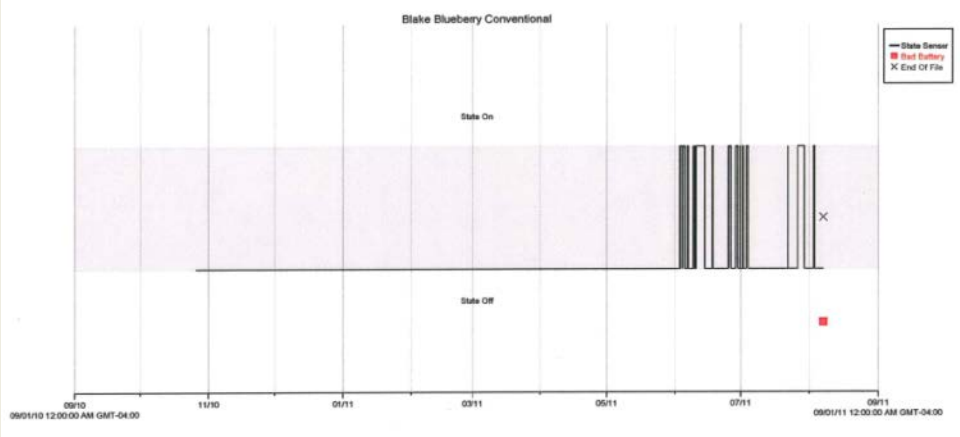
Stop: 9/29/2011



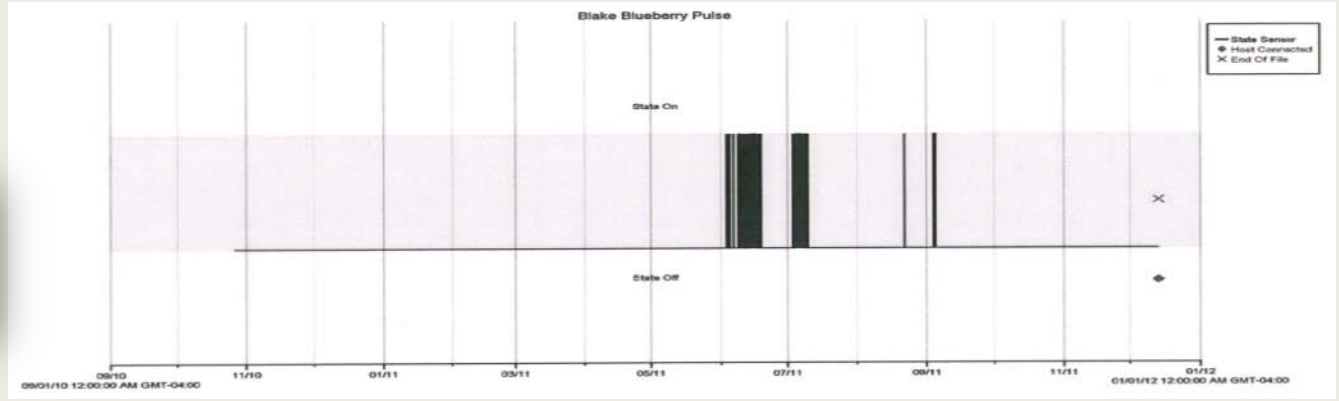



# Blake Blueberries - 2011

Manual




Quasi-Pulse



# Blake Water Application
## (Maury Silt Loam)

| Year | Dates | Quasi-Pulse (gal/A) | Manual (gal/A) | Quasi-pulse Versus Manual (%) | Quasi-pulse versus 1 in/week (%) |
|---|---|---|---|---|---|
| 2010 | 7/7-10/26 | * | * | | |
| 2011 | 6/3-19/29 | 117,365 | 318,015 | 63.1 less | 10.6 less |

*Wiring mistake precluded accurate measurement of water in 2010. It was corrected on August 10, 2010

| Time period | Quasi-Pulse (gal/plant) | Manual (gal/plant) | Difference (gal/plant) |
|---|---|---|---|
| 2010 | * | * | |
| 2011 | 203 | 549 | 346.5 less |

1 acre inch of water =27,154 gal

# Blueberry Shoot Growth - 2010

| Treatment | McCormick 'Darrow' (in) | Reed 'Spartan' (in) | Blake 'Nelson' & 'Jersey' pooled[1] (in) |
|---|---|---|---|
| Manual | 15.9 a | 11.9 a | 12.8 a |
| Pulsed | 14.8 a | 11.9 a | 12.6 a |

[1]There was no statistical difference between varieties in shoot growth

# Fruit Yields 2011 & Irrigation - 2010

| Farm/Trt. | Yield (lb/A) | Berry size (oz) | Brix (%) | Irrigation 2010 (gal/A) |
|---|---|---|---|---|
| McCormick | (9 yr-old) | | | Soil: Clay loam |
| Pulsed | 13,624 A | 1.44 A | 10.7 A | 57,467 |
| Manual | 13,233 A | 1.44 A | 10.3 A | 137,896 |
| | | | | |
| Reed | (5 yr-old) | | | Soil: Clay loam |
| Pulsed | 2,791 A | 1.36 A | 12.9 B | 109,810 |
| Manual | 1,291 B | 1.31 A | 14.5 A | 47,922 |
| | | | | |
| Blake | (9 yr-old) | | | Soil: Silt loam |
| Pulsed | | 1.62 A | 12.0 A | |
| Manual | | 1.70 A | 11.9 A | |

Good yield is 6,000 lb/acre

Means within columns followed by the same letter are not significantly different, Waller-Duncan LSD ($P \leq 0.05$)

# Summary - Water Applied/A

| Grower | Year | Quasi-Pulse (Gal/A) | Manual (Gal/A) | Diff. Quasi-Pulse (Gal/A) | Diff. (A in)[1] | Quasi-Pulse Versus Manual | 2011 Yield Manual (lb/A) | 2011 Yield Pulsed (lb/A) |
|---|---|---|---|---|---|---|---|---|
| McCormick | 2010 | 57,467 | 137,896 | -80,429 | -2.96 | 58.3% less | 13,233 a | 13,624 a |
| | 2011 | 310,845 | 566,421 | -255,576 | -9.41 | 45.1% less | | |
| Reed | 2010 | 109,810 | 47,922 | +61,888 | +2.28 | 56.3% more | 1,291 b | 2,791 a |
| | 2011 | 172 | 140,103 | -137,731 | -5.15 | 99.9% less | | |
| Blake[2] | 2010 | | | | | | | |
| | 2011 | 117,365 | 318,015 | -200,650 | -7.35 | 63.1% less | | |

[1]27,154 gal/A = 1 acre inch
[2]Manual and quasi-pulse irrigation wires hooked up backwards at season start, corrected 8/10/10 .

Generally saved water with Quasi Pulsed

# Economics

| | Quasi-pulse Water Cost Savings[1] (ac) | Fruit Yield Increase (lb/ac) | Additional Fruit Revenue[2] (ac) | Cost Adjustment for 2010 Water Use | Additional Profit Adjusted for Quasi-pulse System Cost ($740.00/ac) |
|---|---|---|---|---|---|
| McCormick | | | | | |
| 2010 | $240 | | | | |
| 2011 | $770 | 391 | $1,670 | $1,910 | $1,170 |
| Reed | | | | | |
| 2010 | $-185 | | | | |
| 2011 | $420 | 1,500 | $6,405 | $6,220 | $5,480 |
| Blake | | | | | |
| 2010 | * | | | | |
| 2011 | $587 | | - $1,102 | ? | ? |

[1]Water cost $3.00/1,000 gal
[2]2011 FSA KY average blueberry retail price $4.27/lb

# Conclusions – McCormick Farm

- No significant difference in fruit yield, size or sugar content between the two systems
- Quasi-pulse system water usage was 58.3% and 45.1% less than the manual system in 2010 and 2011 respectively.

# Conclusions – Reed Farm

- Fruit yield was 1,500 lb greater for the Quasi-pulse system in 2011
- No difference in berry size, however fruit sugar content was higher in the manually irrigated plants
- Quasi-pulse system water usage was 56.1% more and 99.9% less than the manual system in 2010 and 2011 respectively.

# Conclusions – Blake Farm

- No significant difference in fruit yield between the two systems in 2011, there were wiring problems in 2010
- No difference in berry size or sugar content between treatments.
- Quasi-pulse system water usage was 63.1% less than the manual system in 2011 producing a $587 irrigation savings

# Conclusions

- No significant difference in annual terminal shoot growth between the two systems

# Conclusions

- The Watermark sensor system works
- The system is rugged and easier and less expensive to use than tensiometers
- Used extensively out west with manual valve operation
- Provides irrigation at critical times
- Can save water depending on how a grower irrigates
- Must be used on blocks with plants of the same age or size
- There is a learning curve for growers


# Conclusions/Plans

- Determining the exact centa bars to begin irrigation still needs some work.
- Amount of water needed depends on
  - Season
  - Soil type & structure
  - Mulched vs unmulched
  - Plant size
  - Rooting depth
  - Crop load

- Future plans
  - Use system with ½ gal./hr rather than 1 gal./hr emitters
    - Current system puts out almost 3 gal per pulse period
  - Reduce pulse period.
  - Look into better equipment to read Watermark sensor soil moisture levels.

# Learning Experience

- Can't walk away and allow this system to operate automatically
  - Moles
  - Decagon sensor failures
  - Water pressure
    - Too high
    - Too low
  - Leeks