University of California
Agriculture and Natural Resources

Results from Past and On-going Research on Citrus ET & Kc

Advances in Citrus Water Use Workshop
Strathmore, CA – March 26, 2019

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FAO IRRIGATION AND DRAINAGE PAPER

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ISSN 0254-5284

TABLE 1 Published monthly crop coefficients (K_c) for different mature orange cultivars from different locations. All studies used the water budget to determine consumptive use.

Source:	Castel & Buj, 1989	Castel *et al.*, 1987	Van Bavel *et al.*, 1967	Hoffman *et al.*, 1982	Kalma and Stanhill, 1969	García-Petillo and Castel, 2007
Cultivar:	Salustiana	Washington Navel	Washington Navel	Valencia	Shamouti	Valencia
Location:	Valencia, Spain	Valencia, Spain	Tempe, Arizona	Yuma, Arizona	Rehovot, Israel	Kiyú, Uruguay

Most of these studies were conducted in Orange orchards grown with infrequent irrigation (surface or sprinkler irrigation) and using the soil-water budget to estimate ETc and Kc

All these studies highlighted the uncertainty of the field water balance approach as factor limiting the precision of the ETc estimates.

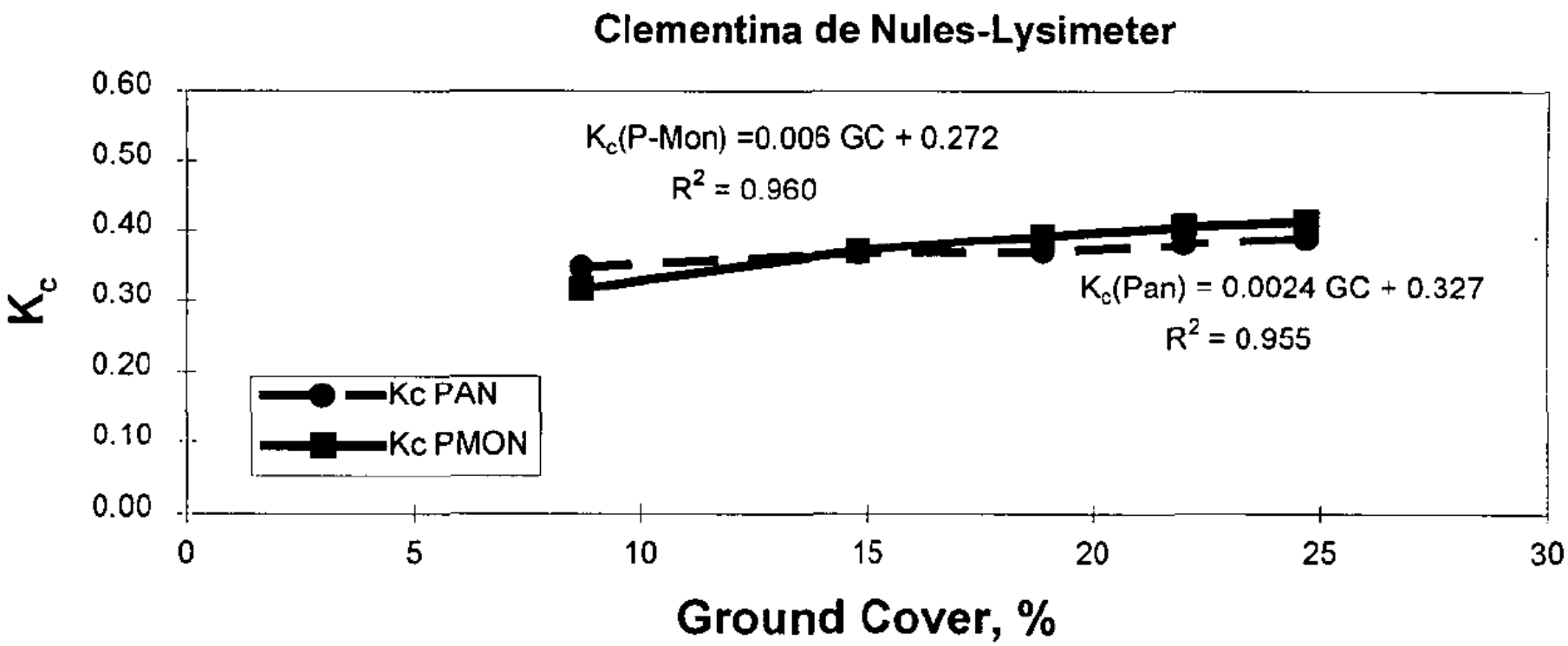
They also indicated the need for more precise measurements of Citrus ET in commercial field production conditions and ET interactions with climatic variables and cultural practices

Working with drip irrigated clementines in a precise weighing lysimeter in Valencia, Spain, Castel found that the annual K_c was linearly related to ground cover and reported the following relationship:

Castel, 1997

$$K_c = 0.006 \text{ ground cover} + 0.272 \quad (R^2 = 0.96)$$

He also emphasized that the K_c will depend on the frequency of wetting of the orchard floor; he found that without rain, surface evaporation for young drip irrigated trees varied between 8 to 30 percent of total ET_c while after a rain, it reached 30 to 50 percent of total (Castel, 1997).



The McKeller P on Washington Navel Orange on in the SJV

J. Amer. Soc. Hort. Sci

Economic anagement

72 combinations o vels (80%, 100% and 120% E acids (±) and fungicide-nematoc nic analysis).

Irrigation appeare eld

The overall results ere higher for the +fungicide-nem enerally more with increased irrig

The combination o le, medium or high N showed the mbinations.

Results

The project has provided insights into many areas of citrus production. While we cannot review all of the data here, several points can be made. Irrigation appears to have the largest effect on yield. The highest production level occurred at 120% of evapotranspiration demand of the trees. This result was surprising, since we felt that overirrigation would lead to root health problems by encouraging Phytophthora populations. To date this has not occurred, and the trees receiving 120% of evapotranspiration yielded 12% more fruit than the trees receiving 100% of evapotranspiration. Those trees receiving only 80% of evapotranspiration demand yielded only 3% less than those receiving 100% of evapotranspiration. While these figures may encourage growers who face water shortages, we should add that the trees receiving 80% of evapotranspiration are losing leaves and declining, and the fruit are smaller and of poorer quality. Nevertheless, citrus appears able to weather short periods of water stress with relative ease. Irrigation effects were uniform across the other variables.

Research on micro-sprinkler irrigated mature citrus (70% GC) in Tulare County (2001-2004)

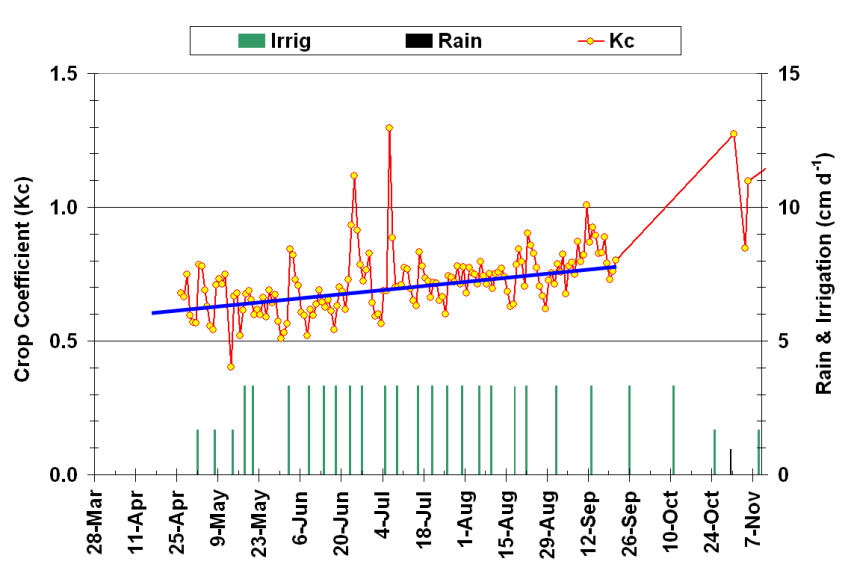
by R. Snyder and N. O'Connell

- ✓ Measured ET and Kc of mature trees (2001-2004)
- ✓ ET and Kc of orchards with four different canopy coverages (2004)
- ✓ Light Interception and Percent Cover (2004)

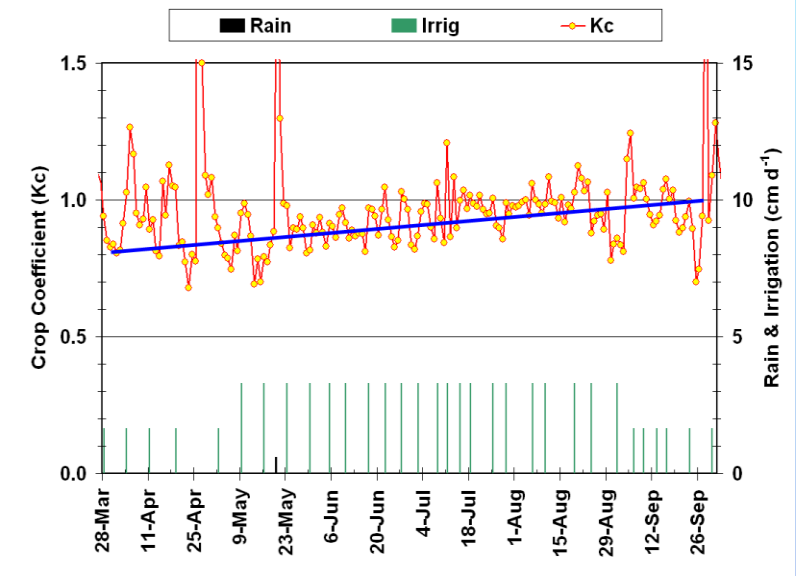
Kc ~ 1.00 was observed for a mature Navel orange orchard (~ 70%) that also had 2.5 times the average yield observed in Tulare County in the same year (2003)


East-West Rows
Near Lindsay
(photo @ ~ 8:00 am)
Little Light
Penetration
Light hits the
ground only near
sunrise & sunset

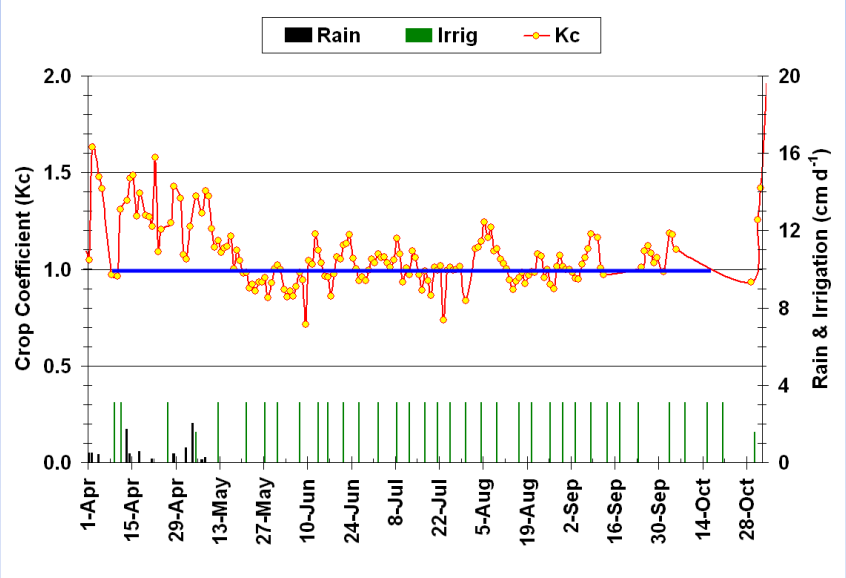
Mature Navel Orange Orchard – Clean Cultivated (2001-2004)



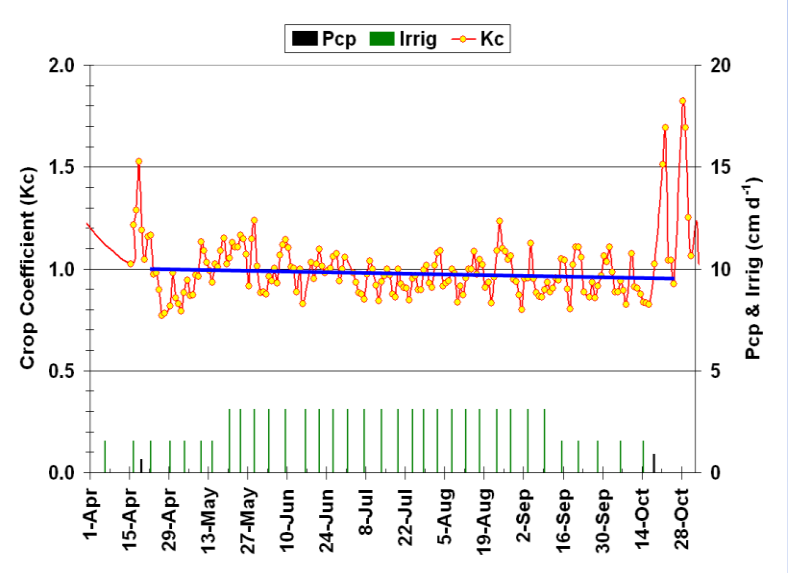
2001



2002

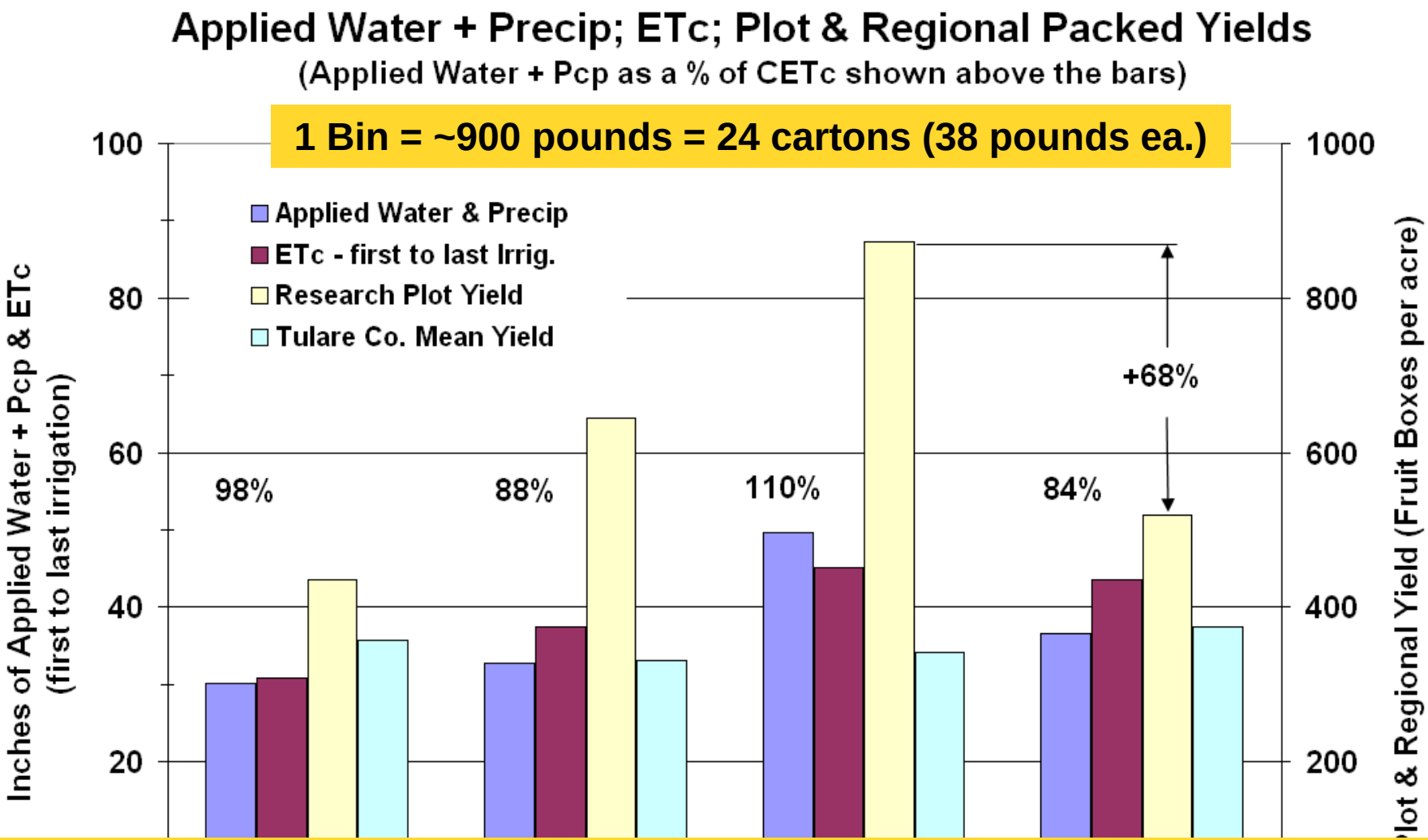


2003



2004

Citrus Applied Water & Yield



Clearly, this research indicates that citrus growers could potentially increase water productivity (crop x drop or $$/unit water) using crop coefficient higher than Kc = 0.65.

Citrus Tree Size and Kc (2004)

LAI = 1.4; GC = 20%; Kc = 0.58

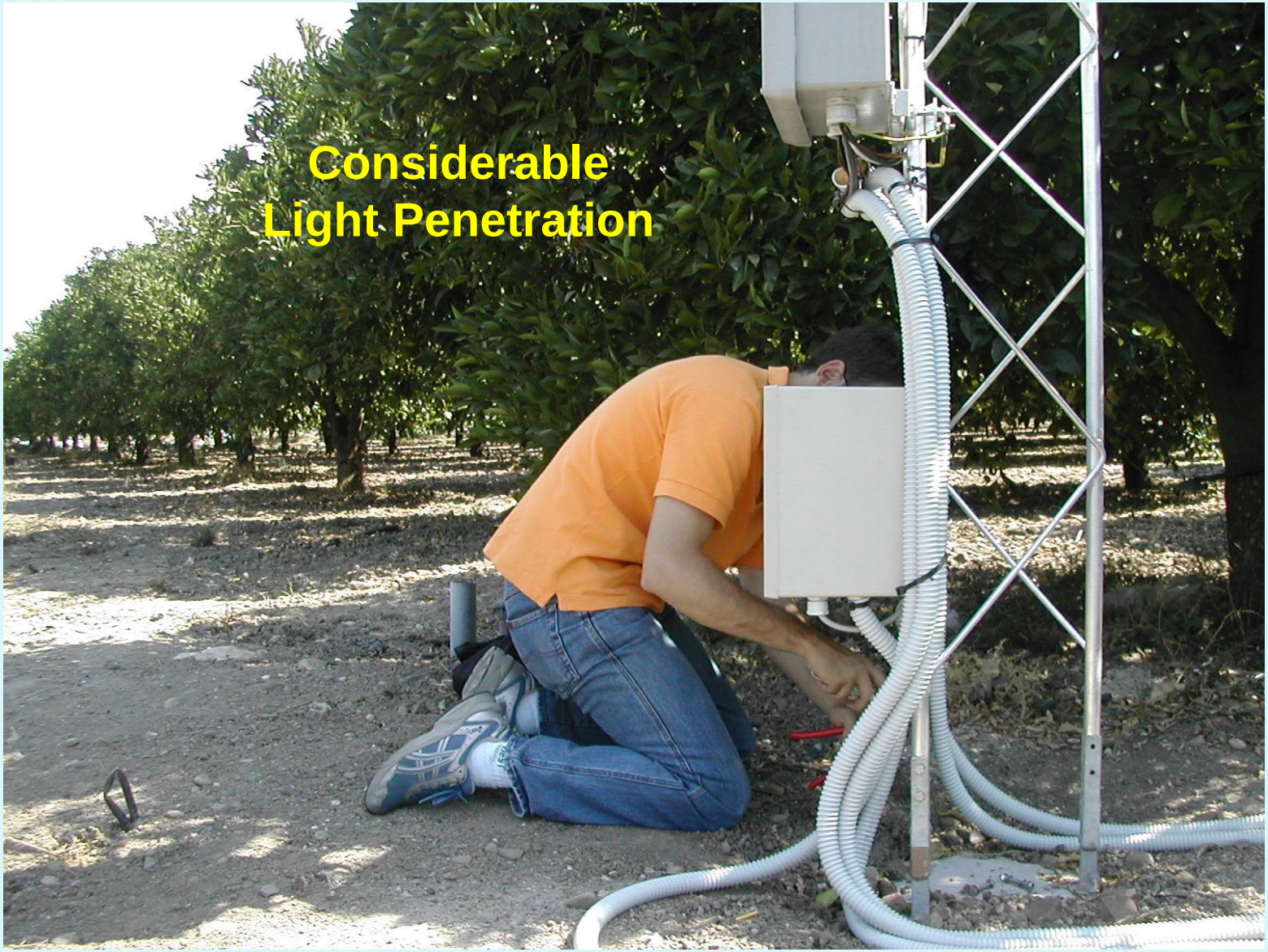
LAI = 2.5; GC = 47%; Kc = 0.75

LAI = 3.4; GC = 70%; Kc = 0.94

Measurement of light interception by navel orange orchard canopies: the case study of Lindsay, California.

Consoli, S, O'Connell, NV and Snyder, RL 2005. **Journal of Irrigation and Drainage Engineering**, 132(1): 9-20.

Kc = 0.85 for GC = ~ 65-70% => near Catania, Italy



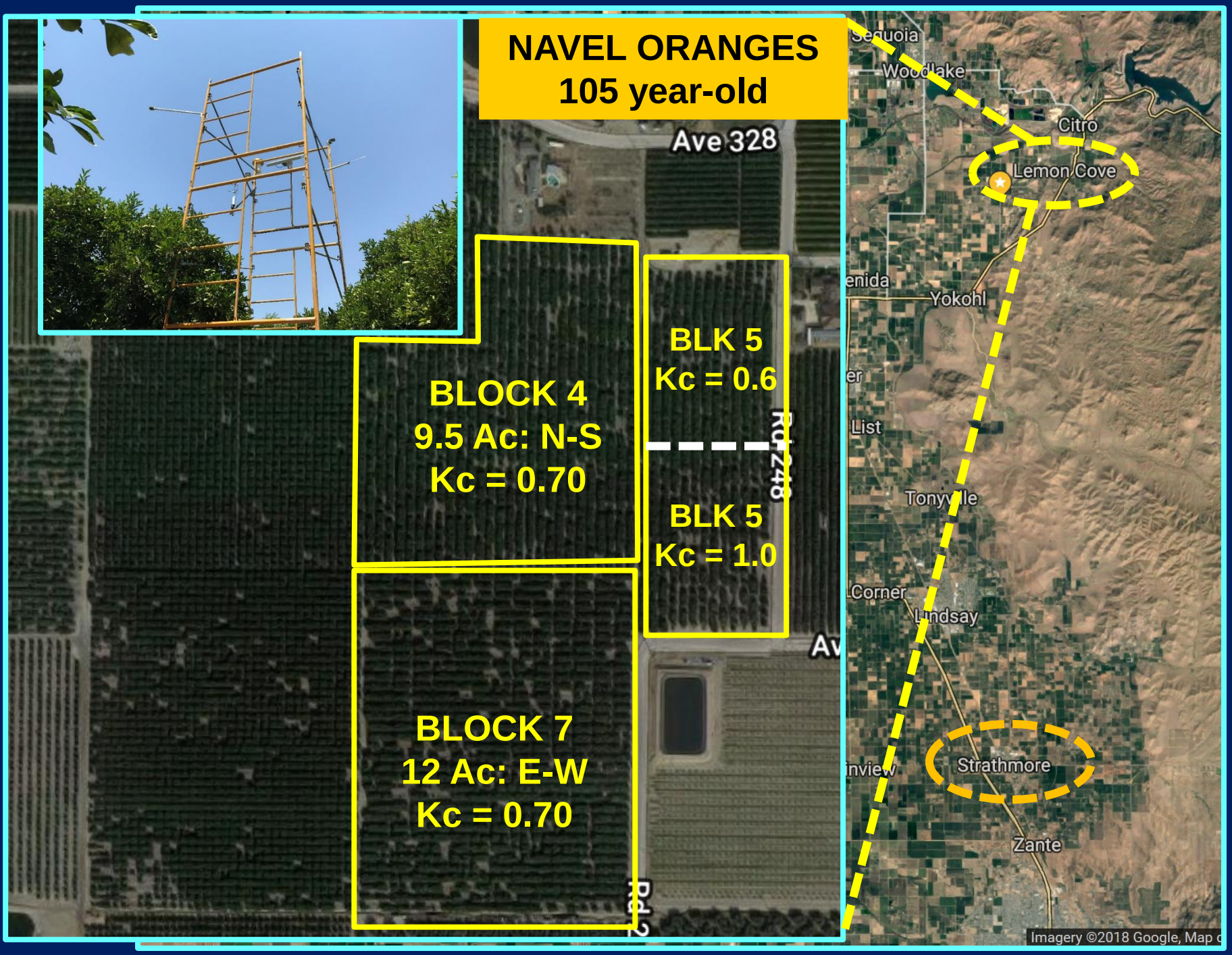
THE UC RESEARCH PROJECT ON CITRUS ET MEASUREMENTS

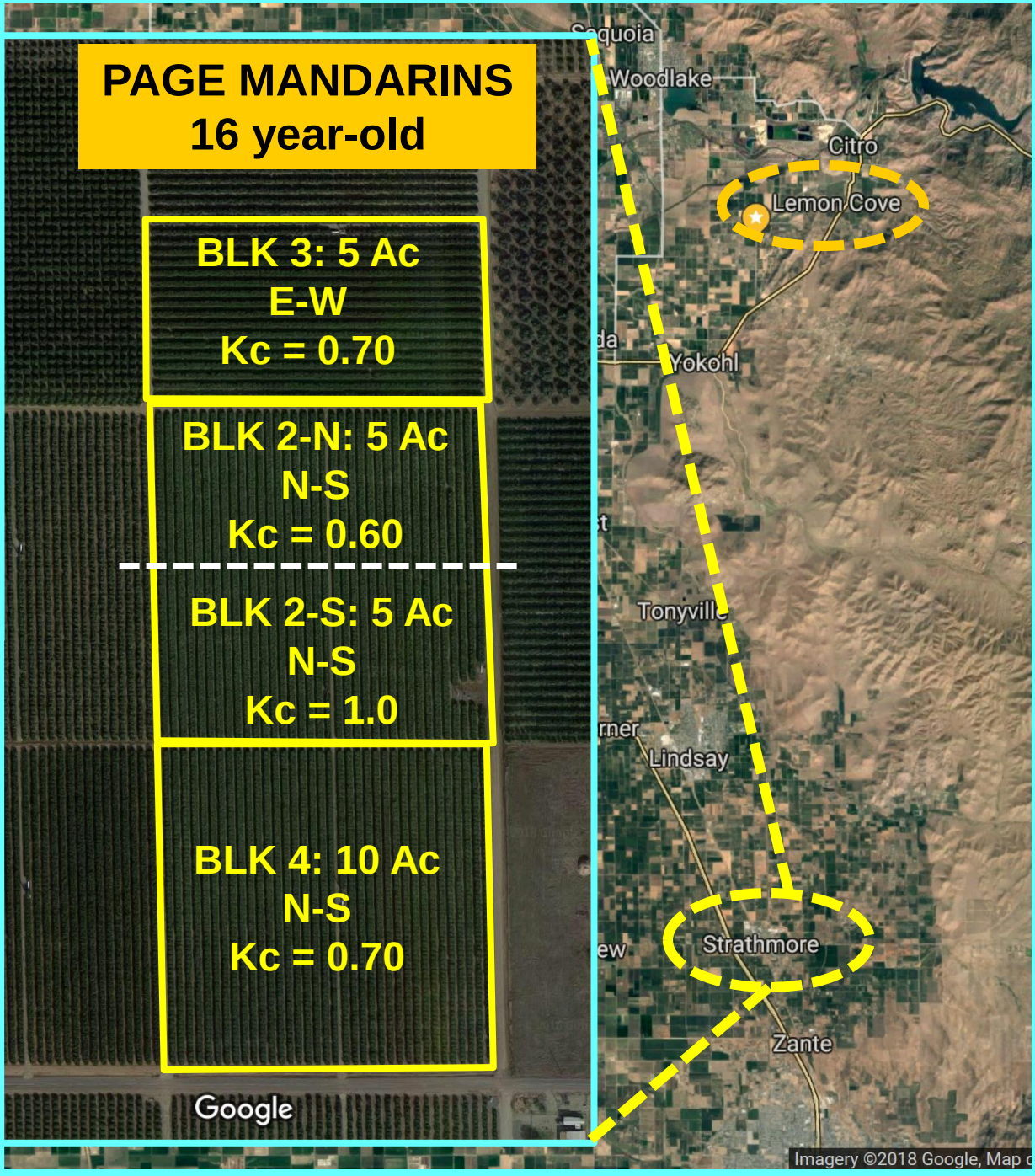
Instrumented 3 Navel orange and 3 Page mandarin orchard blocks.

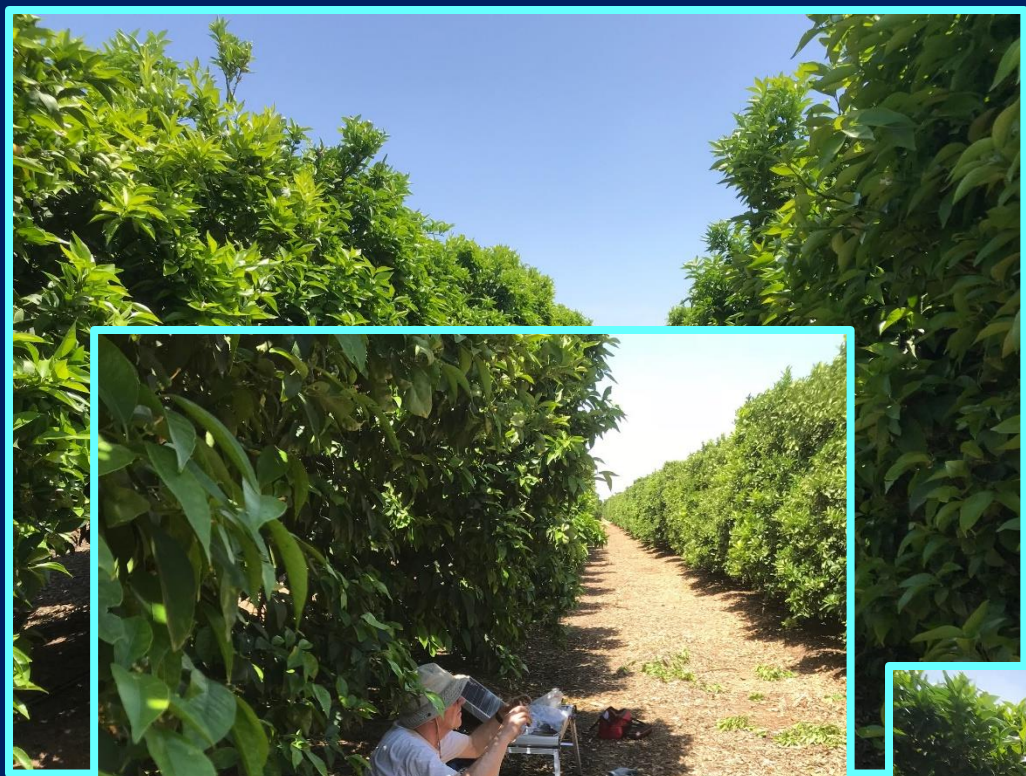
Measuring actual ET and Kc with N-S vs. E-W row orientations, + 3 water applications corresponding to Kc = 0.60, Kc = 0.70, Kc = 1.0

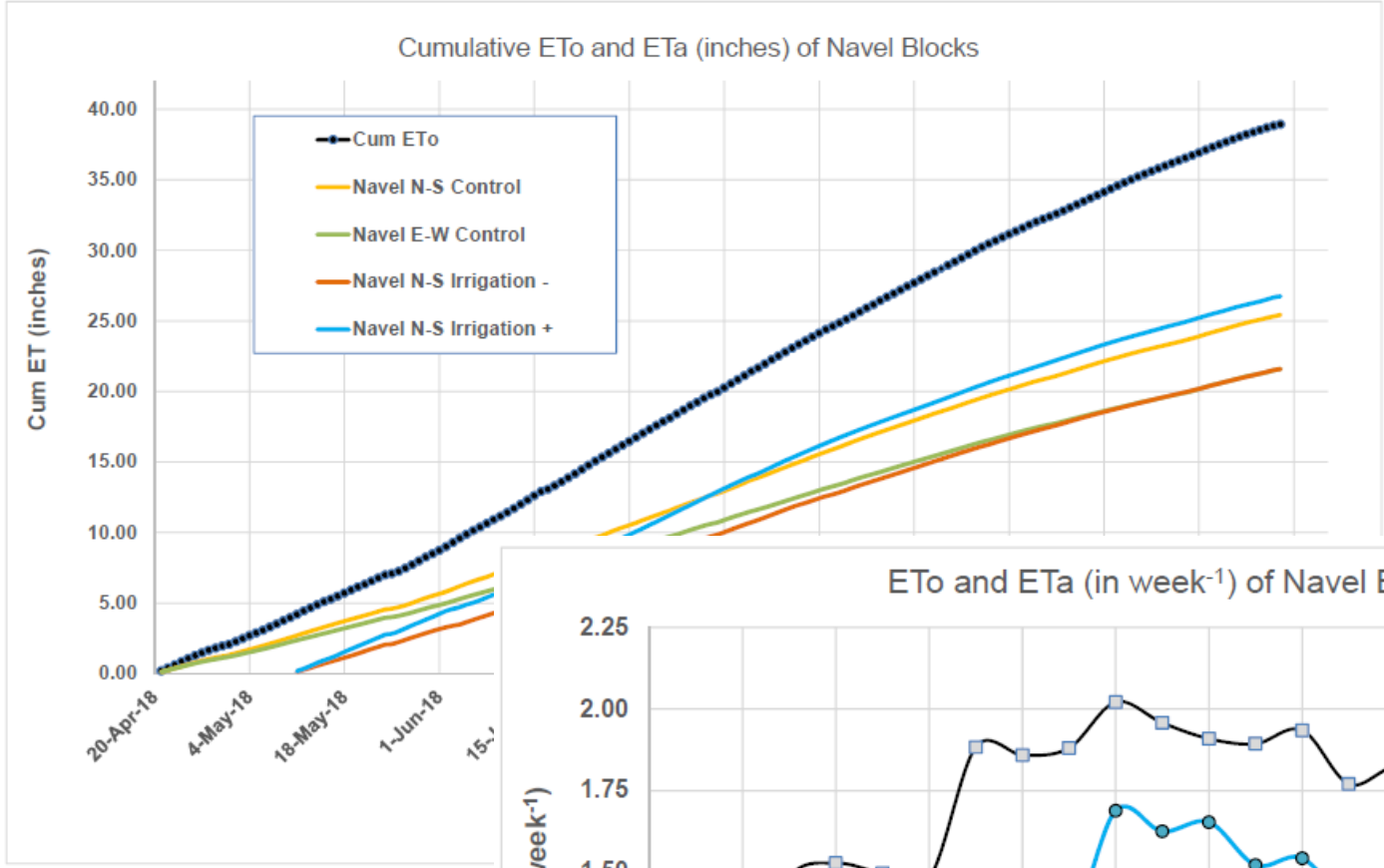
The 2 Control blocks are irrigated based on Kc = 0.70, whereas the 2 irrigation treatments with N-S are irrigated based on Kc = 0.6, and Kc = 1.0

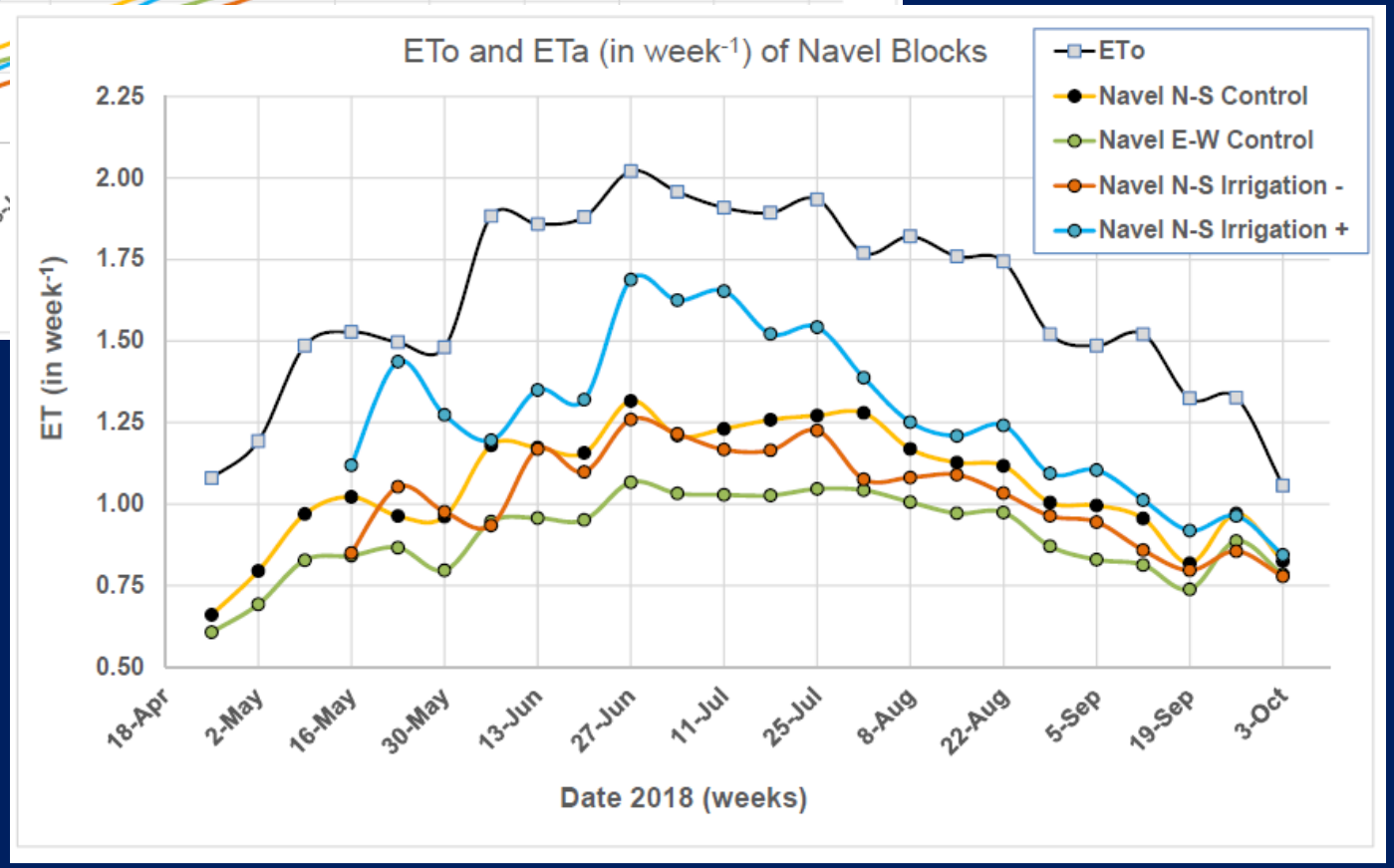
We measure the actual ET and Kc with EC-SR equipment, light interception by the tree canopy with the Mule Light Bar, while monitoring soil moisture with Watermarks, and tree water status with SWP, dendrometers and IR Thermometers.

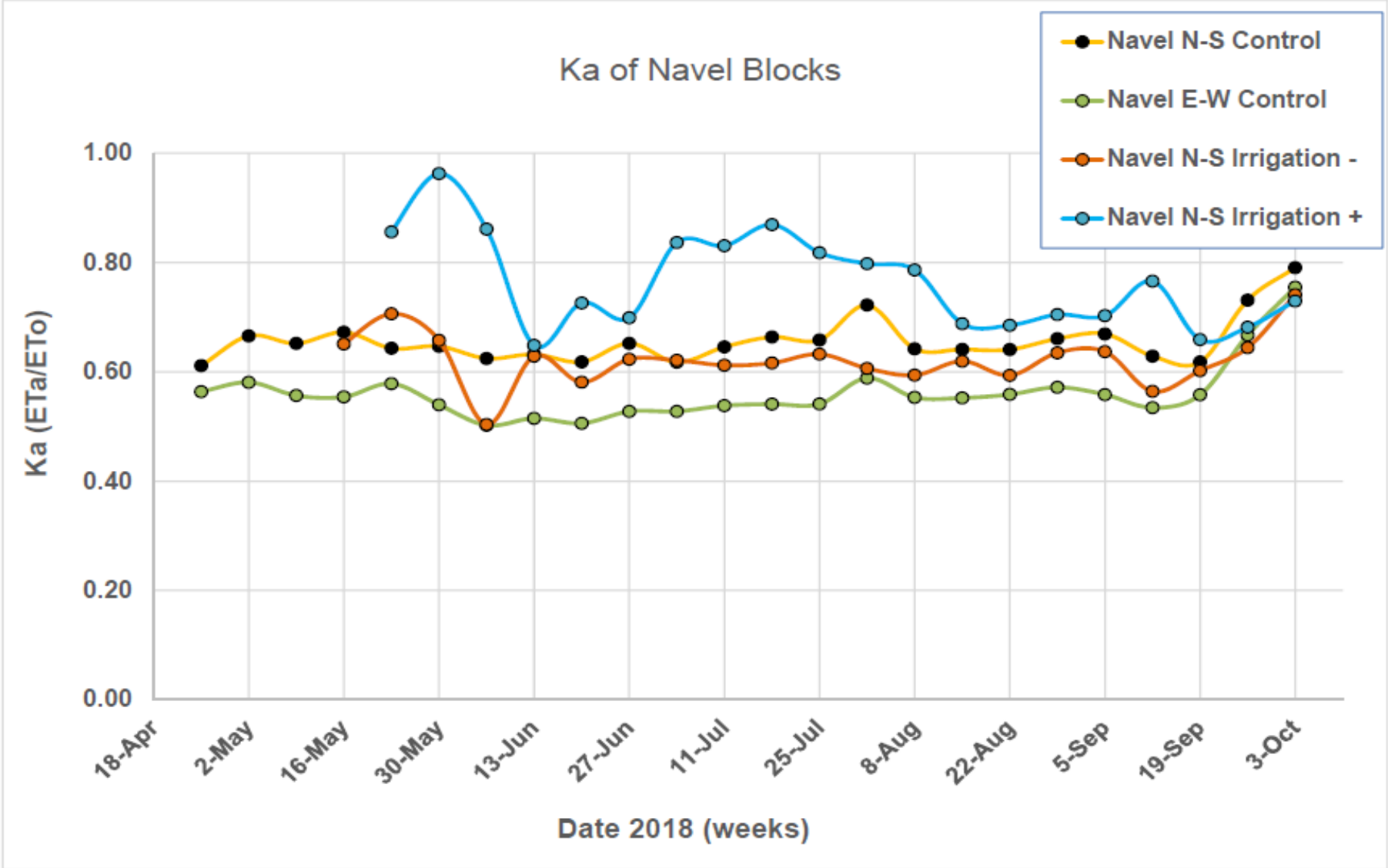

NAVEL ORANGES
105 year-old
Ave 328
BLOCK 4
9.5 Ac: N-S
Kc = 0.70
BLK 5
Kc = 0.6
Rd 248
BLK 5
Kc = 1.0
BLOCK 7
12 Ac: E-W
Kc = 0.70
Sequoia
Woodlake
Citro
Lemon Cove
Yokohl
List
Tonyville
Corner
Lindsay
Strathmore
Zante
Imagery ©2018 Google, Map

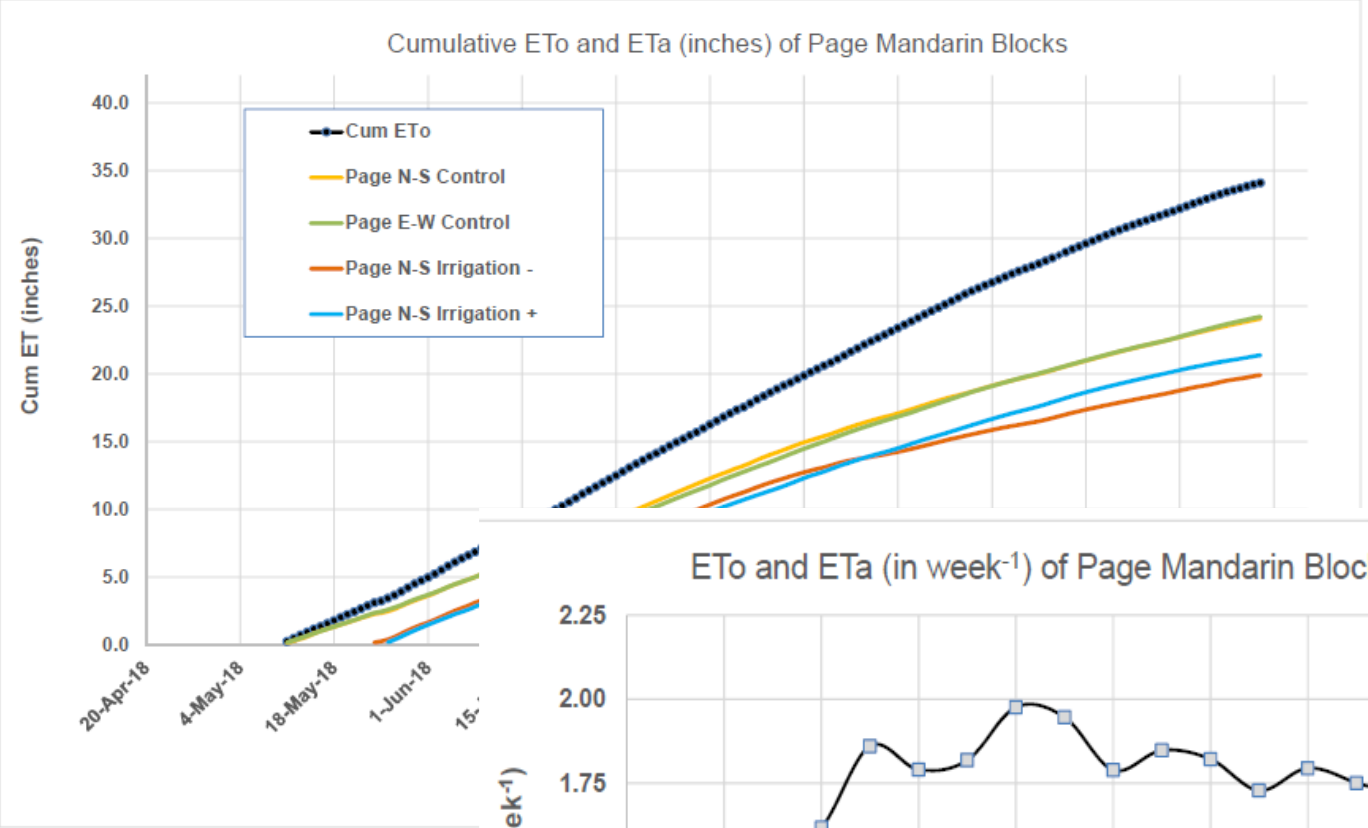

PAGE MANDARINS
16 year-old
BLK 3: 5 Ac
E-W
Kc = 0.70
BLK 2-N: 5 Ac
N-S
Kc = 0.60
BLK 2-S: 5 Ac
N-S
Kc = 1.0
BLK 4: 10 Ac
N-S
Kc = 0.70
Google
Woodlake
Citro
Lemon Cove
Yokohl
Tonyville
Lindsay
Strathmore
Zante
Imagery ©2018 Google, Map

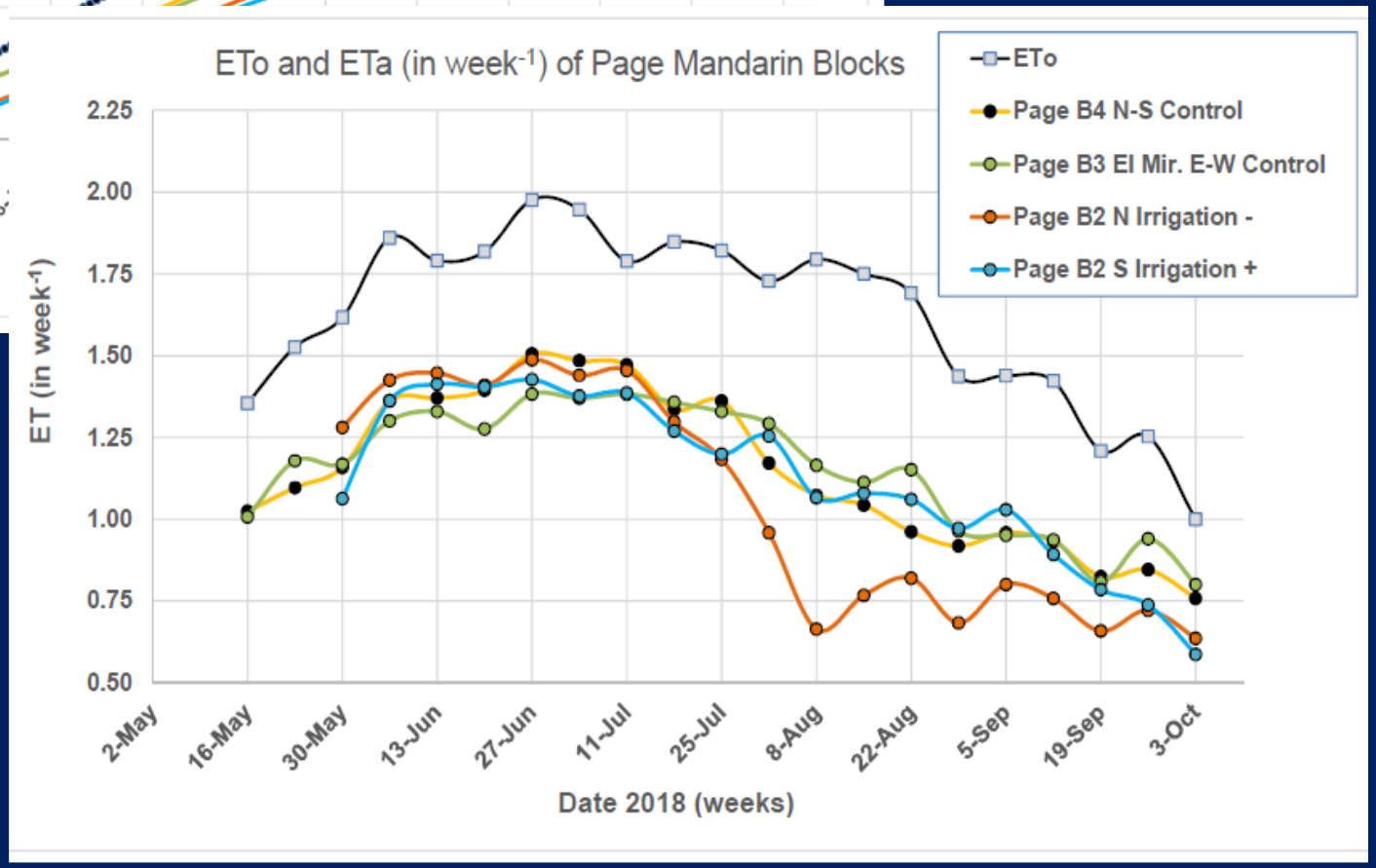


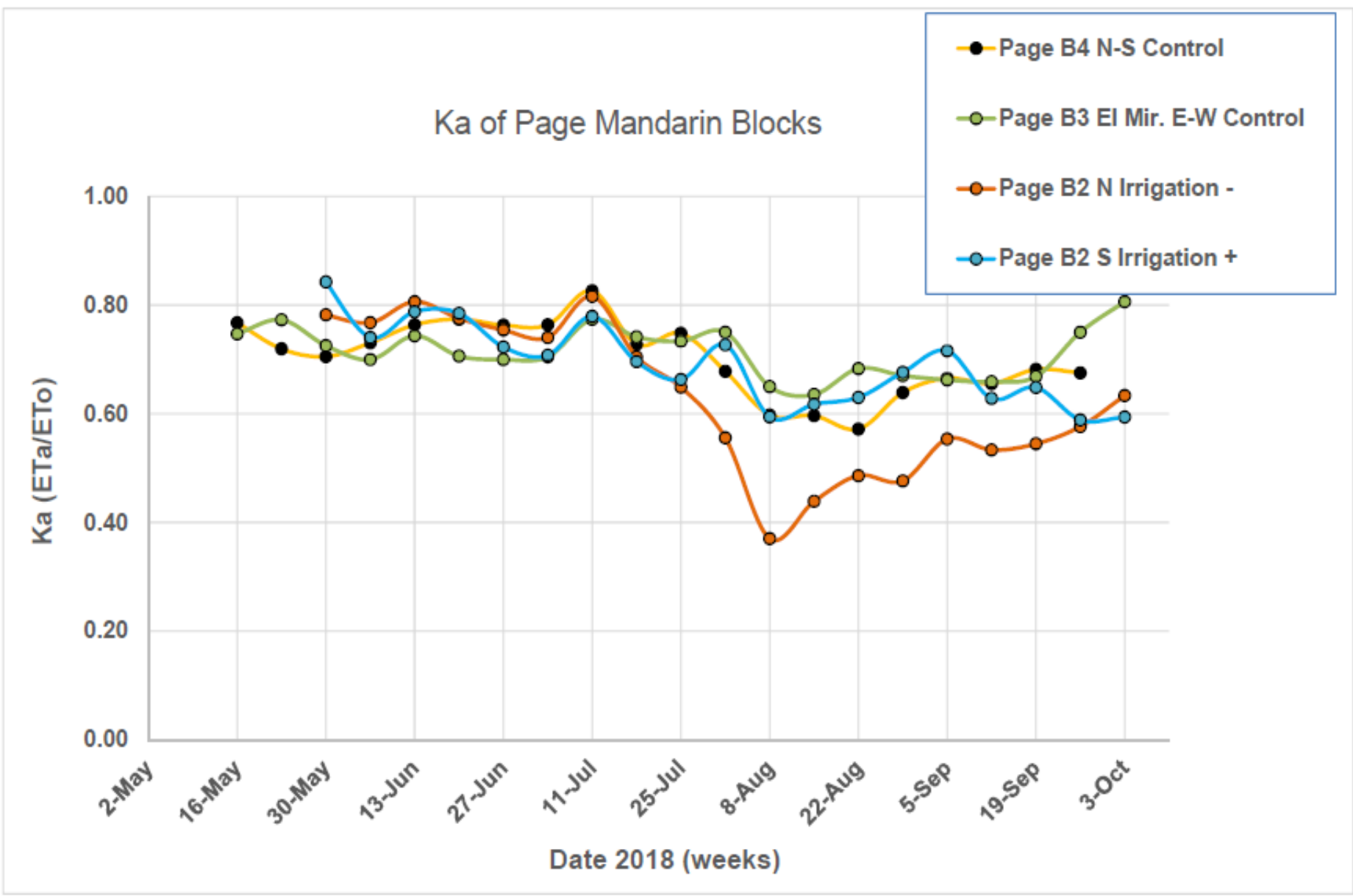

Cumulative ETo and ETa (inches) of Navel Blocks
Cum ET (inches)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
20-Apr-18
4-May-18
18-May-18
1-Jun-18
Cum ETo
Navel N-S Control
Navel E-W Control
Navel N-S Irrigation -
Navel N-S Irrigation +


ETo and ETa (in week-1) of Navel Blocks
ET (in week-1)
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
18-Apr
2-May
16-May
30-May
13-Jun
27-Jun
11-Jul
25-Jul
8-Aug
22-Aug
5-Sep
19-Sep
3-Oct
Date 2018 (weeks)
ETo
Navel N-S Control
Navel E-W Control
Navel N-S Irrigation -
Navel N-S Irrigation +


Ka of Navel Blocks
Navel N-S Control
Navel E-W Control
Navel N-S Irrigation -
Navel N-S Irrigation +
Ka (ETa/ETo)
1.00
0.80
0.60
0.40
0.20
0.00
18-Apr
2-May
16-May
30-May
13-Jun
27-Jun
11-Jul
25-Jul
8-Aug
22-Aug
5-Sep
19-Sep
3-Oct
Date 2018 (weeks)


Cumulative ETo and ETa (inches) of Page Mandarin Blocks
Cum ET (inches)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Cum ETo
Page N-S Control
Page E-W Control
Page N-S Irrigation -
Page N-S Irrigation +
20-Apr-18
4-May-18
18-May-18
1-Jun-18


ETo and ETa (in week-1) of Page Mandarin Blocks
ET (in week-1)
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
ETo
Page B4 N-S Control
Page B3 El Mir. E-W Control
Page B2 N Irrigation -
Page B2 S Irrigation +
2-May
16-May
30-May
13-Jun
27-Jun
11-Jul
25-Jul
8-Aug
22-Aug
5-Sep
19-Sep
3-Oct
Date 2018 (weeks)


Ka of Page Mandarin Blocks
Page B4 N-S Control
Page B3 El Mir. E-W Control
Page B2 N Irrigation -
Page B2 S Irrigation +
Ka (ETa/ETo)
1.00
0.80
0.60
0.40
0.20
0.00
2-May
16-May
30-May
13-Jun
27-Jun
11-Jul
25-Jul
8-Aug
22-Aug
5-Sep
19-Sep
3-Oct
Date 2018 (weeks)

THANK YOU !