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# Water management strategies for hedgerow olive orchards in CA

**REPORT 1st Season (2020-2021)**

**Introduction:** Olive acreage has increased in California (CA) within the last two decades, as well as challenges related to climate change and groundwater management policies.
However, information on olive water use and efficient irrigation practices for high density systems is scarce. This project aims to develop and extend new information to enhance olive productivity through precision timing and quantities of irrigation. Our objectives are to: 1) characterize water use and develop crop coefficients for CA olive oil orchards, 2) develop protocols to reduce water during drought tolerant phenological stages without impacting productivity but improving oil quality, 3) develop irrigation guidelines to implement innovative proximate and remote sensing

technologies in water management (this last pending CDFA supporting funding).

**Methods:**

At the end of the summer 2020, we selected two orchards, one located in Corning and one located in Stockton, both super high density systems with cultivar Arbequina. Both orchards have similar age; the Stockton one was on a silty-clay-loam soil, the Corning one on a clay soil.

One ET tower was installed in each orchard at the beginning of March 2021 (Corning) or beginning of April 2021 (Stockton). Distribution uniformity of the irrigation systems was evaluated in April and was 86% in Stockton and 96% in Corning. A flow meter was installed in each orchard in July to monitor applied water and irrigation frequency in the full irrigated area where the ET station was installed.


Fig 1 - ET tower installation (left), flow meter and distribution uniformity measurements (right)

Four experimental blocks per treatment were selected and flagged in each orchard; each block was made of three consecutive rows, and the blocks were randomized along the orchard (Fig.2). All measurements were conducted on three trees selected in the central row of the four blocks, with the other two rows functioning as borders to ensure efficacy of the irrigation treatment. In one location per each treatment, we installed at the beginning of May soil moisture sensors (Watermark, Irrometer) at the depth of 18, 36 and 48 in. However, getting a good contact between soil sensors and soil was very challenging due to the very heavy soil structure. Sensor readings were partially affected by this poor contact between sensor and soil. We plan to reinstall them in 2022, although we rely more on plant measurements (water potential) to quantify the level of stress applied.

At pit-hardening (beginning of July) we implemented three deficit irrigation treatments that lasted until mid-September; out of 4 treatments one was the ‘Control’ (growers management, no changes to the irrigation system), in one we reduced water application by 20 percent (‘80%C’) and in two treatments we reduced water application by 75 percent ('25%C'). One of the two 25%C deficit irrigation treatments next season will be irrigated with 25% more water (125%C). This treatment was added based on this year tree water status results (see discussion).

On the three selected trees per block (12 trees per treatment), starting in March, we measured weekly midday stem water potential, and biweekly we characterized phenological development: vegetative growth on one selected branch per tree, fruit dimension, weight, color and pit hardening.

At harvest we measure yield, fruit dimension and weight and oil content. Oil was extracted for oil quality analysis.

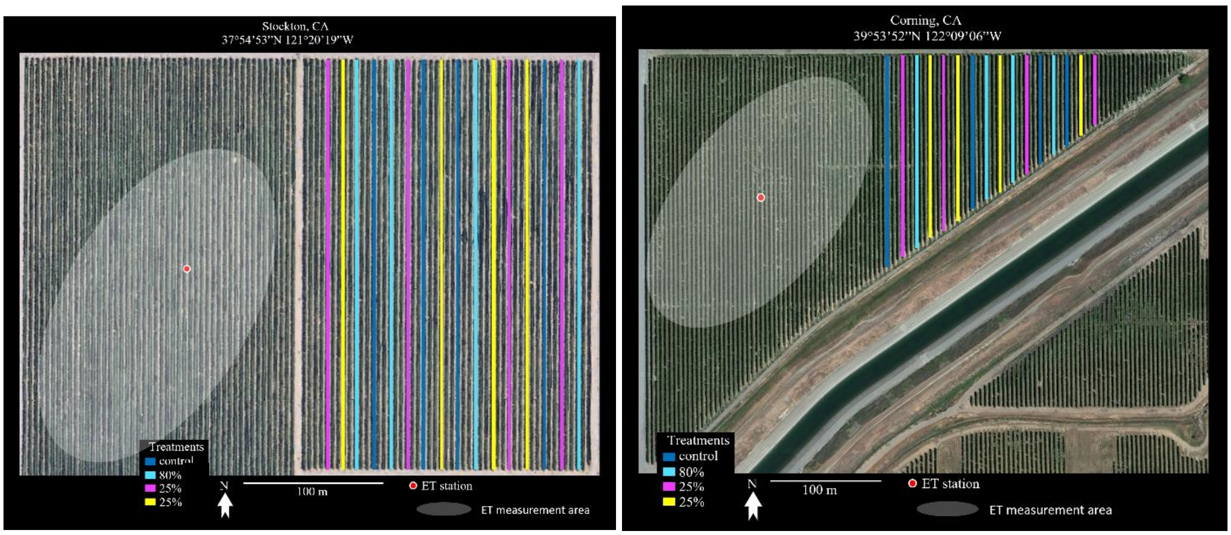


Figure 2. Map of the experimental design with the replication of the different blocks in Stockton (left) and Corning (right), location of the ET station (red dot), and an example of the measurement area of the station (white circle); in the legend the correspondence between the colors and irrigation treatments.

**Results:**

<u>Water use and crop coefficient</u>

The ET values increased from 0.7 in per week in April to maximum values of 1-1.4 in/week at the beginning of June (Fig. 3). Maximum values were maintained until the end of August. In the same period, Kc increased from 0.45 to 0.7 in Stockton while in Corning it fluctuated between 0.5 and 0.6. Kc in Stockton kept between 0.6 and 0.7 for the rest of the season, while lower and more variable values were observed in Corning (varying between 0.5 and 0.65).

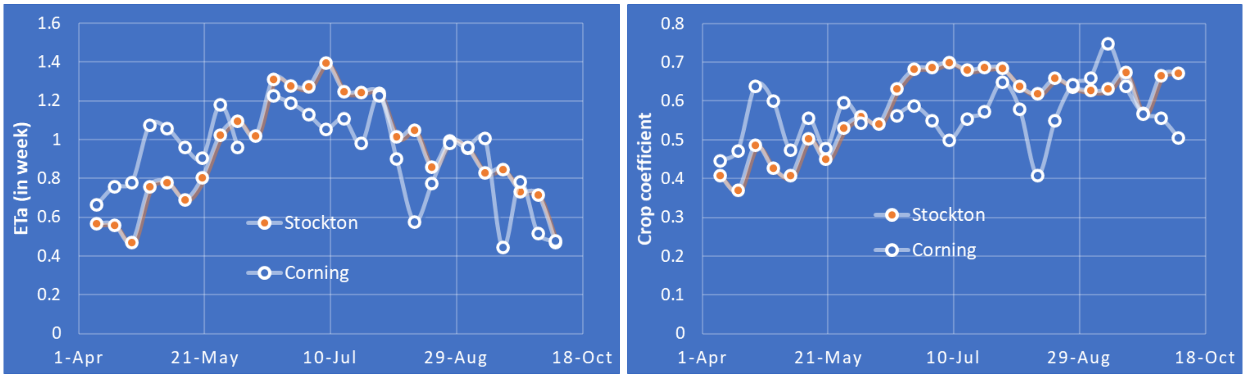


Figure 3 – Weekly values of actual evapotranspiration (ETa, in per week) and crop coefficient for the two experimental locations located in Stockton and Corning. Orchards were irrigated following grower's management practices.

Seasonal cumulated ET (Fig. 4) from mid-April until mid-October was about 25 in.

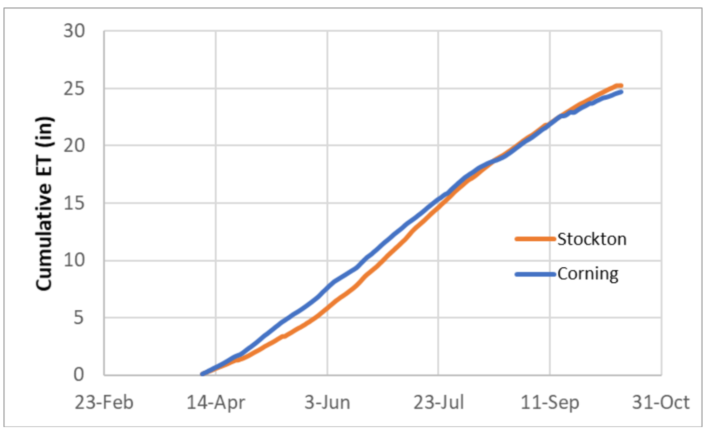


Figure 4 – Cumulated seasonal values of ETa for the two experimental locations located in Stockton and Corning. Orchards were irrigated following grower's management practices.

## <u>Olive phenology</u>

Olive fresh weight increase showed three stages of rapid growth interrupted by two periods where olives weight was stable. The first period was longer in Stockton (from the last week of June to the beginning of August) than in Corning (first two weeks of August); the second period happened in the first two weeks of August and in the first two weeks of October in Corning (Fig. 6 A). Pit texture increased rapidly from the beginning of July until the beginning of August and then stayed constant until harvest (Fig 5 B and Fig 6 B). Fruit longitudinal diameter increased rapidly until mid-June, less rapidly until mid-July and then stayed constant until harvest (Fig 5 C and Fig 6 C). Transversal diameter increased rapidly until mid-June, less rapidly until mid-July and, as opposed to the longitudinal diameter, it continued growing at a slower pace until harvest (Fig 5 D and Fig 6 D).

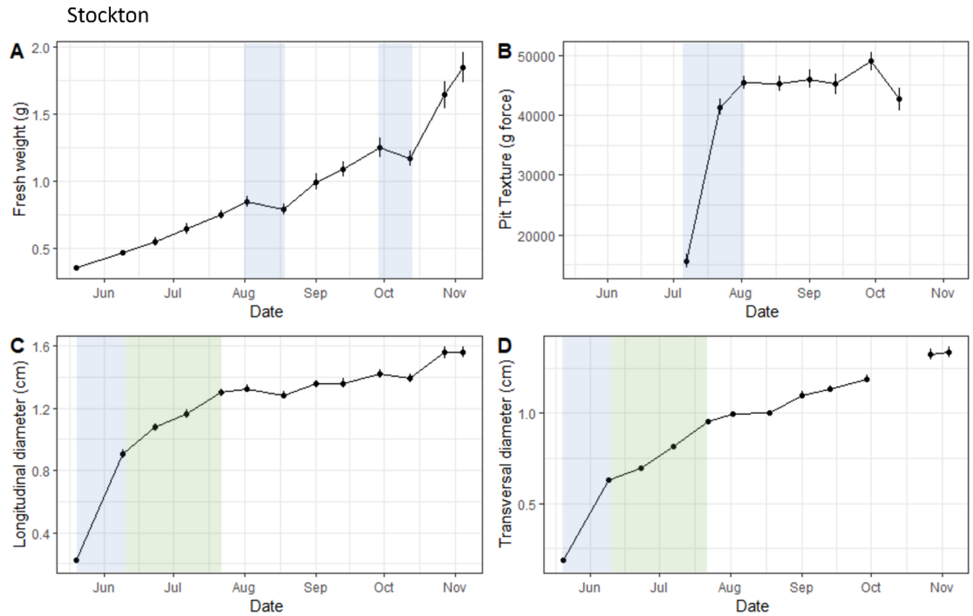


Figure 5. Seasonal trend (biweekly measurements) of fruit fresh weight (A, g), pit texture (B, pit hardness, grams force) and fruit longitudinal and transversal diameter (C and D, cm) measured in the control area in Stockton. Blue and green areas indicate significant phenological stages as described in the text. Red arrow indicates the start of the irrigation deficit.

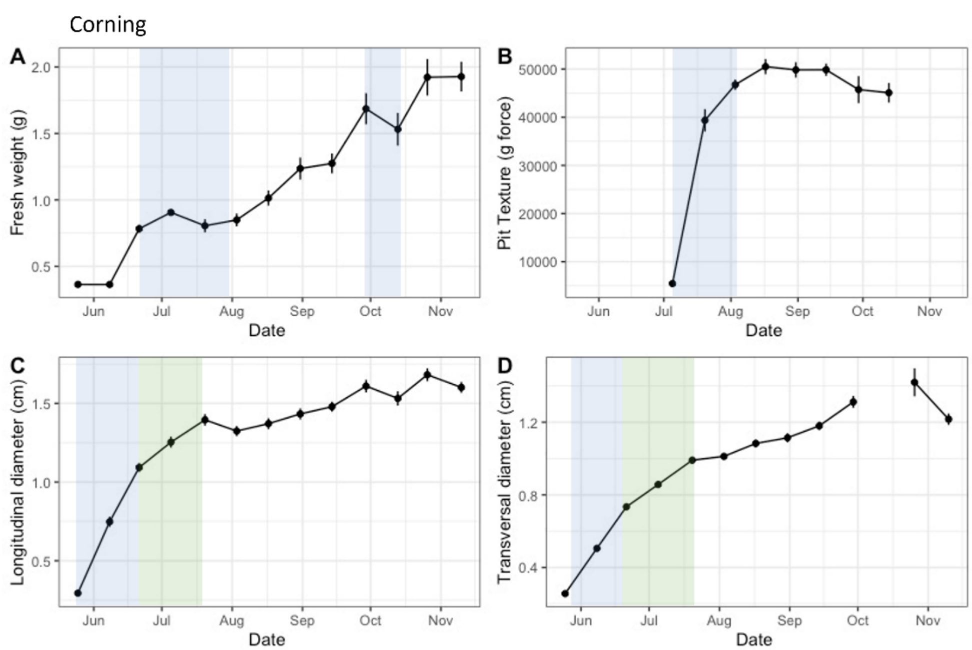


Figure 6. Seasonal trend (biweekly measurements) of fruit fresh weight (A, g), pit texture (B, pit hardness, grams force) and fruit longitudinal and transversal diameter (C and D, cm) measured in the control area in Corning. Blue and green areas indicate significant phenological stages as described in the text. Red arrow indicates the start of the irrigation deficit.

<u>Plant water status</u>

Tree water status measured with the pressure chamber in the Control trees (growers management, blue line in Fig. 7) will be discussed in relation to the baseline values (Grey line in Fig. 7) recently published by prof. Shackel and collaborators (Shackel et al. 2021). The baseline represents the highest stem water potential (SWP) achievable for that day-specific weather conditions - maximum level of tree hydration when soil moisture is not a limiting factor. It must be pointed out that the baseline gives information about the maximum level of hydration an olive tree can reach, which is not necessarily the optimal water status from a horticultural/commercial point of view, but it is good practice to refer to the SWP as bars below baseline since it standardizes the level of stress to different climatic conditions.

The SWP of Control trees in Stockton was close to the baseline (grey line) until the beginning of June then started to decrease (from -8 to -15 bars from June to July) and settled at 5 bars below baseline. In Corning trees were always 5 bars below the baseline, apart from the April measurement, and values were around -18 bars from June forward.

Since the deficit irrigation started only in mid-July, treatments were not significantly different until then in any of the monitored sites. Differences among treatments were detectable only in September and the first half of October in Stockton and the 80%C treatment was never different from Control. In Corning the stress applied with the deficit irrigation was more severe, and from July until harvest the deficit irrigated trees had lower SWP than the Control, and the 80%C treatment was also more stressed than the Control.

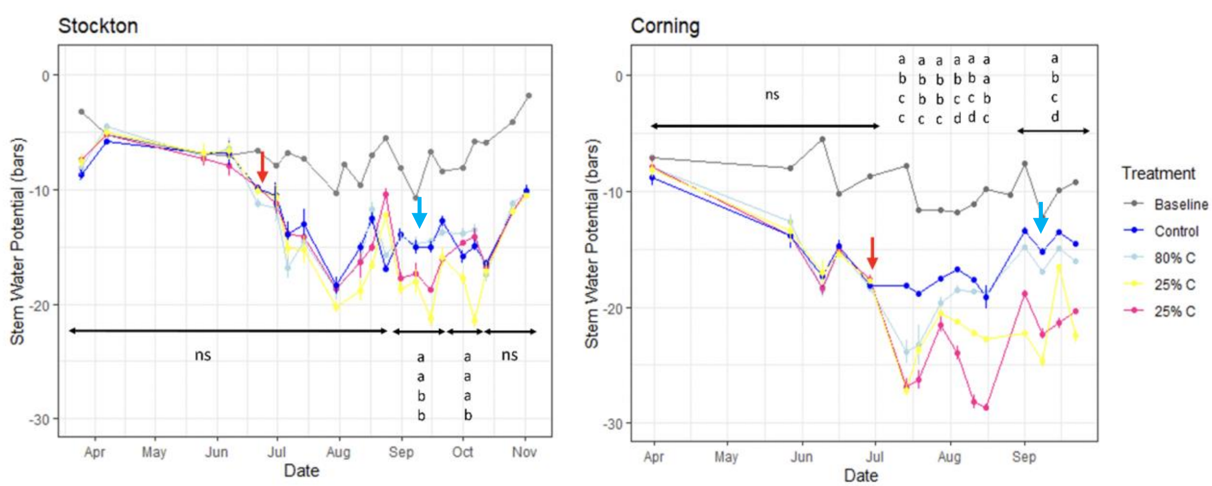


Figure 7. Seasonal variation of the stem water potential (bars) of the Control treatment in comparison to the baseline (Shackel et al., 2021), and the three deficit irrigation treatments for Stockton (left) and Corning (Right). The baseline represents the potential SWP values of fully hydrated olive trees from data on literature. Red arrow indicates the start of the deficit irrigation, blue arrow the stop of the deficit irrigation.

Considering all the season together from mid-July forward (Fig. 8) in Stockton the SWP was about -12 in Control and 80%C, and no differences were observed between these two treatments. The 25%C deficit treatments were slightly lower –14 bars. In Corning Control was ~ -18 bars, 80%C was -19 bars, and the 25%C were between ~ -21 bars and ~28 bars.

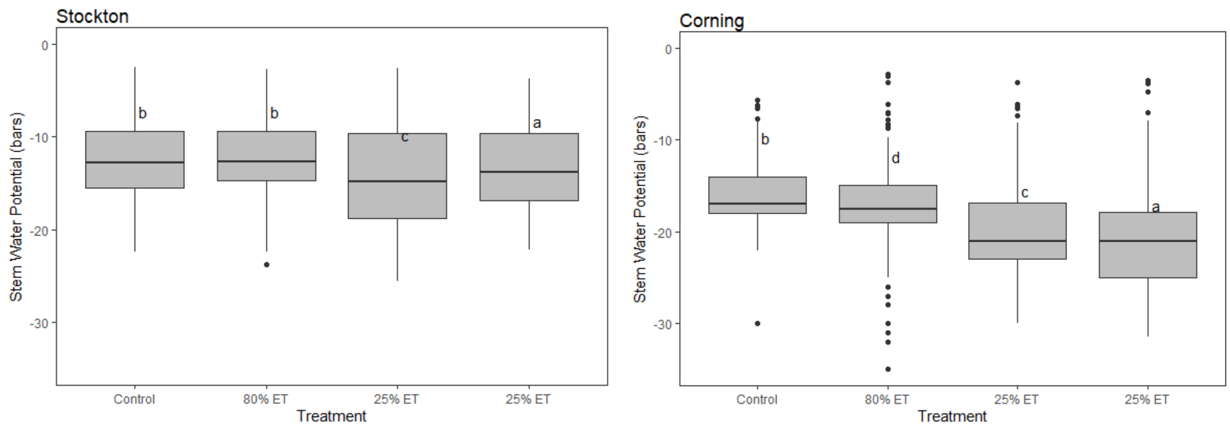


Fig. 8 – Average SWP values observed during the period when deficit irrigation was applied for the different irrigation treatments in Stockton (left) and Corning (right).

The shoots showed two peaks of growth: one in early June one in September (Fig. 9). In Stockton the shoot growth rate (how many cm per day the shoot was elongating) was between 0.15 and 0.3 cm/day, in Corning it was lower, between 0.05 and 0.1 cm/day. The irrigation treatment did not affect shoot growth in Stockton, but it did in Corning, for which during the September peak there was more growth in the Control and 80%C treatments than the two 25%C treatments. In Corning the shoot growth rate during the September peak was higher than in Stockton.

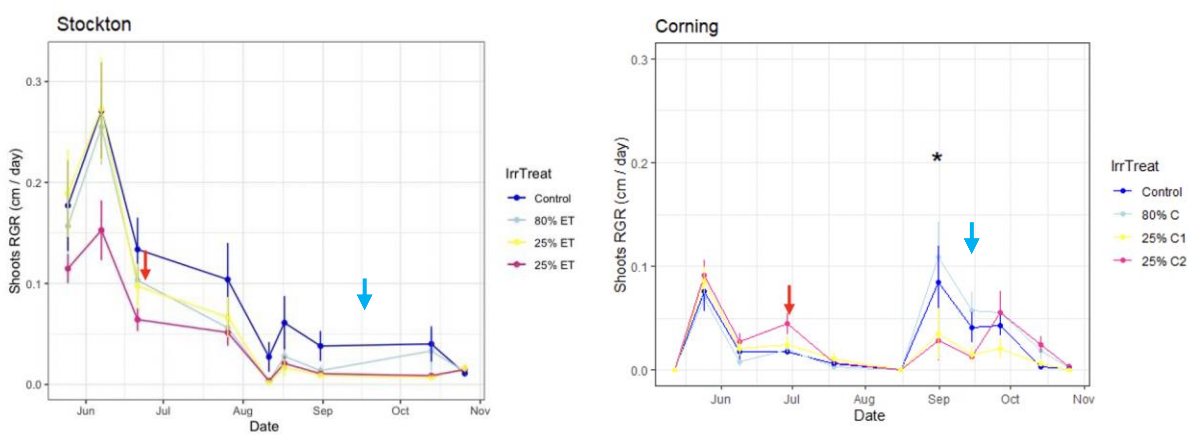


Figure 9 - Vegetative growth rate expressed as cm of new growth per day for the different irrigation treatments through the season. The red arrow represents the beginning of the deficit irrigation treatments, blue arrow the stop of the deficit irrigation.

Fruit yield and oil yield was not significantly affected by the irrigation treatments. Olive yield averaged 5 to 6.8 tons per acre in Stockton (Table 1) and 4.3 to 5.3 tons per acre in Corning (Table 2). Oil percentage was also not impacted by the irrigation in Stockton, while in Corning the 25%C treatment had slightly higher oil content than the Control and it was ~ 16% in Stockton and 15% in Corning. Oil yield averaged 222 to 292 gal per acre in Stockton and 185 to 218 gal per acre in Corning. Fruit volume, weight and dimension was lower in one of the two 25%C treatments in Stockton, while no differences were observed in Corning.

Table 1 – Yield and yield parameters measured at harvest in the Stockton orchard. Different letters indicate significant differences among treatments; ns indicate no significant differences among treatments

| Treatment | Yield (tons/acre) | Oil (%) | Oil (gal/acre) | Fresh fruit weight (g) | Fruit volume (ml) | Long. diameter (cm) |
|---|---|---|---|---|---|---|
| Control | 6.8[ns] ± 0.15 | 16.2[ns] ± 0.37 | 292[ns] ± 6.9 | 1.94[a]± 0.02 | 1.53[a] ± 0.02 | 1.60[a] ± 0.00 |
| 80%C | 5.5 ± 0.04 | 15.75 ± 0.27 | 230 ± 2.1 | 1.87[a] ± 0.02 | 1.52[a] ± 0.02 | 1.58[a] ± 0.01 |
| 25%C | 5.1 ± 0.03 | 16.47 ± 0.55 | 222 ± 0.9 | 1.60[b] ± 0.02 | 1.28[b] ± 0.02 | 1.53[b] ± 0.01 |
| 25%C | 5.0 ± 0.03 | 16.77 ± 0.85 | 222 ± 1.9 | 1.88[a] ± 0.02 | 1.47[a] ± 0.02 | 1.58[a] ± 0.00 |

Table 1 – Yield and yield parameter measured at harvest in the Corning orchard. Different letters indicate significant differences among treatments; ns indicate no significant differences among treatments

| Treatment | Yield (tons/acre) | Oil (%) | Oil (gal/acre) | Fresh fruit weight (g) | Fruit volume (ml) | Long. diameter (cm) |
|---|---|---|---|---|---|---|
| Control | 5.3[ns] ± 0.06 | 15.58[b] ± 0.23 | 218 [ns] ± 3 | 1.84 [ns] ± 0.03 | 1.55 [ns] ± 0.04 | 1.55 [ns] ± 0.01 |
| 80%C | 5.3 ± 0.05 | 14.42[ab] ± 0.42 | 201 ± 2 | 1.82 ± 0.03 | 1.58 ± 0.04 | 1.55 ± 0.01 |
| 25%C | 4.3 ± 0.05 | 16.11[a] ± 0.35 | 185 ± 3 | 1.82 ± 0.03 | 1.55 ± 0.06 | 1.53 ± 0.01 |
| 25%C | 4.6 ± 0.05 | 15.60[ab]± 0.45 | 188 ± 2 | 1.79 ± 0.02 | 1.45 ± 0.03 | 1.56 ± 0.01 |

## Discussion

We developed the first year of olive ET data, and we observed a crop coefficient ranging between 0.4 and 0.7 and water use between 0.6 and 1.4 in per week. Cumulated water use from April to October was 25 inches. Interestingly, the crop coefficient seasonal trend was different between orchards, and somehow different than what suggested in literature, since in Stockton it increased from March to August, while general recommendation is to use either a constant Kc of 0.65-0.75, or adopt higher values in spring (0.6/0.7) than in summer (0.5). In Stockton we had lower values in spring (0.3 to 0.5) and higher values in summer (0.6/0.7). More years of data and comparison with water applications and soil and plant water status is needed to better explain these trends. Interestingly, also tree water status of the two orchards was different, since the stem water potential (SWP) of the trees was slightly below the baseline in Corning almost all the season, while in Stockton SWP was the same as the baseline until June and slightly below baseline after that.

The deficit irrigation affected tree water status differently in the two locations, probably because of these initial differences, with the Corning orchard being more sensitive to the deficit irrigation than the Stockton orchard. Yield parameters were not affected by the deficit irrigation but this is predictable in olive due to its biannual productive cycle, so more years will be needed for reliable results. Interestingly, shoot growth was not affected by deficit irrigation in Stockton, while in Corning the two most stressed treatments had decreased shoot growth in September. This is in accordance with the difference in water stress between locations.

Based on the information reported and in consultancy with industry stakeholders, we decided that one of the two 25%C treatments will receive 125% water before and after pit hardening next season to try match water status with the baseline, instead of the initially planned 80%C.

We are also developing important information about the time course of processes such as fruit and shoot growth through the season, that is highlighting important time windows for improving the efficacy of irrigation management, when fruit and shoot growth is reduced.

We want to stress that this is a very peculiar year in terms of water availability, due to the very dry winter and summer, and we are looking forward to comparing this with wetter years in the future.