University of California
Agriculture and Natural Resources
Cooperative Extension, Stanislaus County California

VEGETABLE VIEWS

FALL 2023, ISSUE 3

Updates for the 2023 Applied Vegetable Crop Research Projects

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If we need to use a few words to summarize the crop year of 2023, the following must stand out: raining, flooding, delay, low temperature, and re-arrangement. Therefore, I want to first focus on the climatic data of the past crop years before summarizing this year's research projects.

- *Total precipitation*. The tremendous amount of pre- and early-season precipitation in the northern San Joaquin Valley in 2023 posed extra work on vegetable growers to reschedule planting dates to deal with field flooding and cope with material availability (transplants, seeds, field equipment, and labor). As shown in Table 1, the total precipitation in the 2023 crop year tripled and doubled the amounts in 2021 and 2022, respectively. During the busiest planting months (March to May 2023), over four inches of rain added additional challenges to the beginning of the season.

Table 1. Monthly precipitation (inches) in Modesto based on the CIMIS Weather Station #71 for the crop years of 2021 to 2023.

Crop year	Oct.*	Nov.*	Dec.*	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Total
2021	0	0	0.18	3.76	0.77	0.68	0	0	0	0	0	0	5.39
2022	2.96	0.13	3.91	0.09	0.02	0.66	0.12	0	0	0	0	0.11	8.00
2023	0	0.91	6.65	2.75	1.62	3.51	0.14	0.37	0	0	0	0	15.95

*from prior year (one vegetable crop year = Oct. to Sept.)

- *Growing degree days*. Growing Degree Days, or GDD, are used to estimate crop growth and development during the growing season and help growers make strategic decisions such as planting and

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harvest date, variety selection, irrigation, and nutrient applications. Crops require a certain amount of cumulative heat to progress from one growth stage to the next and then to maturity. May and June are the key months for warm-season vegetable growth and development. Frequent days with low maximum and minimum daily temperatures during these months delay the overall crop development and maturity due to low accumulated GDD. The chart below obviously demonstrates a trend of much lower daily GDD from mid-May to June 30 in 2023 vs. the same timeframe in 2022 (Figure 1). Cumulatively, there were 310 degree-days lower in 2023 vs. 2022 for this 1.5-month period. Actually, if we zoom in on the whole season (April 1 to September 30), July 2023 is the only month with cumulative GDD slightly higher than 2022 (Table 2). Eq. 1-3 in the dialogue box explained how GDD was calculated (Pathak and Stoddard, 2018).

$$\textbf{Equation 1.} \quad GDD = \frac{Tmax + Tmin}{2} - Tbase; if\ Tbase < \frac{Tmax + Tmin}{2} < Tupper$$

$$\textbf{Euqation 2.} \quad GDD = Tupper - Tbase; if\ \frac{Tmax + Tmin}{2} \geq Tupper$$

$$\textbf{Equation 3.} \quad GDD = 0; if\ \frac{Tmax + Tmin}{2} \leq Tbase$$

Tmax and *Tmin* are the maximum and minimum daily temperature. *Tbase* and *Tupper* are the base temperature and the maximum limit temperature that a crop can grow under. It is a cut-off value, which assumes that degree days above this limit are not counted (Eq. 2). Here, we define Tbase as 50 ºF (10 ºC) for most warm season vegetables and Tupper as 90 ºF (32.2 ºC) for processing

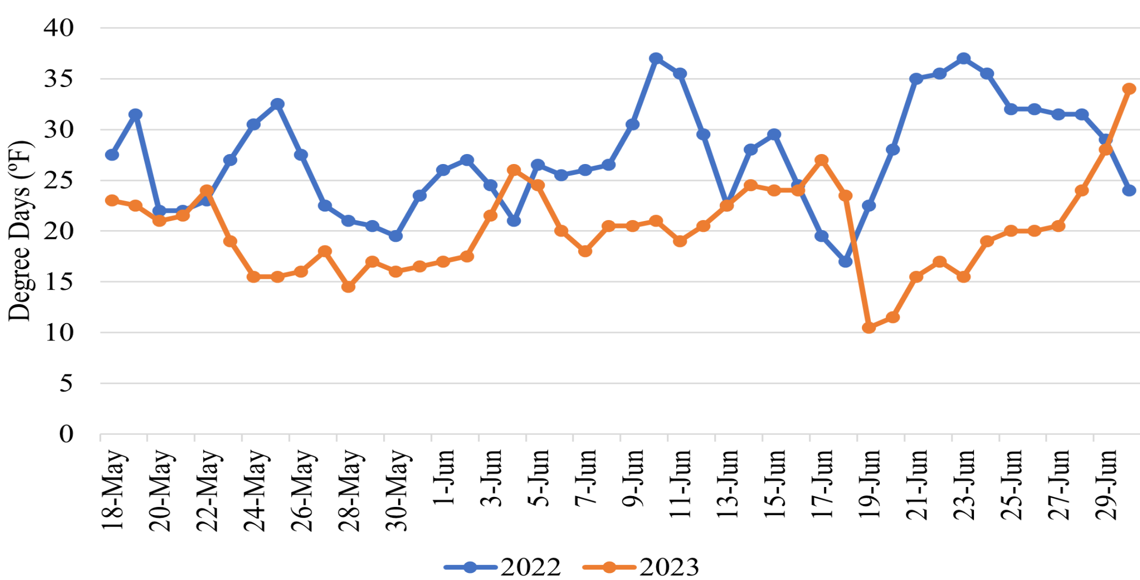


Figure 1. Comparison of daily growing degree days from May 18 to June 30 in 2022 and 2023 based in Modesto, CA.

Table 2. Monthly GDD (ºF) between April and September in 2022 and 2023 based in Modesto, CA.			
Month	**2022**	**2023**	**Difference**
April	388	250	+138
May	629	467.5	+161.5
June	850	627	+223
July	872.5	948	-75.5
August	903.5	918.5	-15
September	799.5	648.5	+151
Sum of total	4442.5	3859.5	+583

Watermelon rootstock variety trial

The grafted watermelon project has entered its fifth year since 2019. The 2023 watermelon rootstock variety trial focused on identifying rootstock-scion combinations that could outperform non-grafted plants (NonG). Seven commercially available watermelon rootstocks were grafted with the field scion, 'Warrior', by the Tri-Hishtil located in Mills River, NC. These rootstocks represent three types: interspecific hybrid squash, *Citrullus amarus*, and *Lagenaria siceraria* (Table 3). All grafted and non-grafted watermelons were transplanted on April 19, 2023, at a commercial field in Modesto, CA. Each treatment plot was 80 feet long and contained 13 grafted or nongrafted triploid plants and four pollenizers (grafted or non-grafted). All treatments were replicated four times. Four harvests were conducted from July 25 to October 17. Total yields at each harvest and fruit quality from the first harvest were recorded and compared among varieties and combinations. For fruit quality, fruit length and width were measured by yardstick. Sugar content (ºBrix) was measured by scooping the center flesh of each half and reading through a portable reflectometer. Fruit/flesh firmness was measured using a fruit penetrometer at the spots 1/3 and 2/3 distance from the blossom end after a melon was cut into half (Figure 2). Rind thickness at the blossom and stem ends was measured using a caliper.

Table 3. List of watermelon rootstocks that were included in the 2023 rootstock variety trial.	
Rootstock list	**Type**
Carnivor (CAR)	Interspecific hybrid squash (*Cucurbita maxima* x *Cucurbita moschata*)
Camelforce (CAM)	Interspecific hybrid squash
Cobalt (COB)	Interspecific hybrid squash
UG29-A (UG)	Interspecific hybrid squash
RS841	Interspecific hybrid squash
Carolina Strongback (CSB)	Citron rootstock (*Citrullus amarus*)
Pelops RZ (PEP)	Bottled gourd (*Lagenaria siceraria*)

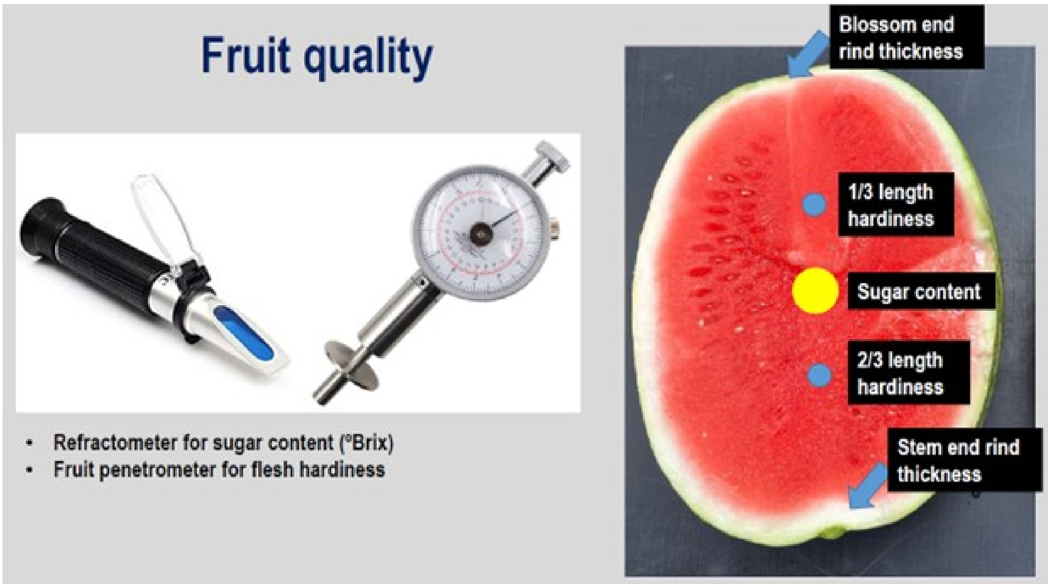


Figure 2. Tools for the measurements of fruit quality and a pictorial example noting the general protocol of fruit quality assessment.

The biggest yield difference between each grafted combination and NonG occurred at the second fruit harvest with an increase in yield ranging between 36.5 and 142% (Table 4). For the total yield, the percent increase for each grafted combination compared to the NonG ranged between 29.6 and 71.5% (PEP: 46.8 and CAR: 61.9 tons/acre vs. 36.1 tons/acre; Table 4). Plants grafted onto each hybrid squash rootstock produced yields over 50 tons/acre, which is considered as an average level for a 45-ct variety. As a citron rootstock, Carolina Strongback (CSB) which was released in 2019 produced the biggest yields in the last two harvests (Table 4). Pelops RZ (PEP) which is a bottled gourd rootstock yielded the least in the second pick among other rootstocks, making it the only rootstock in this study yield less than 50 tons/acre (Table 4). For fruit quality, differences between grafting and NonG were primarily observed for fruit firmness (Table 5 and Figures 3b). Slight increases in fruit width and stem end rind thickness after grafting were also found (Table 5 and Figure 3a). The results of fruit quality followed previous observations that there were no apparent changes in fruit sugar content but a dramatic increase of flesh firmness after grafting according to the taste sensory evaluations.

Take-home message and going forward

Do I need grafted watermelons? From a bigger picture, this is a question you should always ask before making the decision. Watermelon grafting is a production tool and not designed to replace breeding and other well documented techniques of developing new cultivars. The purpose of grafting is to offer growers and other agricultural industry with special needs a quicker and more unique way to solve production problems (e.g., soil borne fungal pathogens, limited lands for rotation, and environmental stresses). If you have the related issues but with limited solution, you may consider grafting as your “icebreaker”. Using grafting should be proceeded in a case-by-case protocol.

Rootstock selection. Without knowing too much characteristic information of watermelon rootstocks, it is recommended to select an interspecific hybrid squash because majority of the current rootstocks fall into this group. Carnivor, Camelforce, Cobalt, UG29-A, and RS841 included in this variety trial are the hybrid squash rootstocks that are now widely used for cucurbit grafting. All of them produced a yield equal or over 53 tons/acre after they are picked four times. Cumulative yields of the first three harvests were over 46 tons/acre for all hybrid squash rootstocks, providing some growers would not wait such a long time for the last pick depending on the market and weather. Rootstock varieties can be found at http://www.vegetablegrafting.org/resources/rootstock-tables/cucurbit-rootstocks/ .

Oversized fruit. It is probably not uncommon to see oversized or over-weighed fruit in a grafted field. Scion selection, plant in-row spacing, and fertility management are key components to maintain fruit size within the general marketable range. 45-ct varieties (single fruit wt. between 16 and 20 lbs.) are much more commonly used for grafting than other types of watermelons because there is more wiggle room for oversized fruit. Size and weight requirements for 60-ct varieties or minis (single wt. below 12 lbs.) are more restrictive leaving almost no room for size increase. Likewise, average fruit weight of 30- and 36-ct varieties (single wt. 20-22 lbs.) is already close to the upper ceiling without grafting. For the in-row spacing, we do not recommend planting grafted watermelons over 60 inches apart. Although this will dramatically reduce population and still increase yield, chances of getting oversized fruit will increase according to our previous observations.

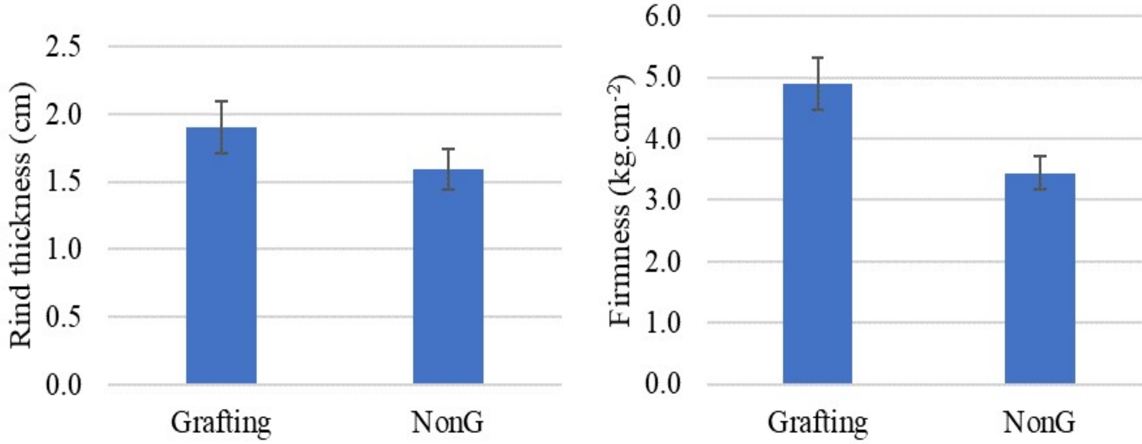
Going forward. We will continue doing needs assessments and monitoring any pressing issues of watermelon grafting in California. Tentative plans for 2024 will include implementing a grafting compatibility trial. Instead of a rootstock variety trial, we will go to an opposite direction by grafting multiple scions grouped by horticultural characteristics (e.g., relative maturity, fruit size, rind pattern) onto one of each of the three types of rootstocks. We hope to address the concern on scion suitability/compatibility to grafting.

Table 4. Fruit yield (tons/acre) of each harvest and the total for grafted and non-grafted plants.

Rootstock	First harvest (July 25)	Second harvest (August 7)	Third harvest (August 30)	Fourth harvest (October 17)	Total
CAR	13.4	35.8	4.8	8.0	61.9
CAM	19.8	25.1	4.0	6.9	55.9
COB	16.2	25.1	5.0	6.6	52.9
UG	13.8	32.3	3.9	5.5	55.5
RS841	13.0	27.8	5.3	7.3	53.4
CSB	16.6	23.0	8.5	8.4	56.5
PEP	13.7	20.2	7.3	5.6	46.8
NonG	12.6	14.8	3.5	5.2	36.1
P-value	0.83	0.06	0.16	0.35	0.03

Table 5. Fruit quality for grafted and non-grafted watermelons using fruit from the first harvest.

Rootstock	Length (in.)	Width (in.)	Blossom rind (cm)	Stem rind (cm)	°Brix	Firmness (kg/cm^2)
CAR	12.1	10.0	1.13	1.48	12.2	5.16
CAM	12.0	10.2	1.16	2.12	11.7	5.11
COB	12.3	10.0	1.09	1.94	12.1	5.05
UG	11.9	9.7	1.12	1.87	12.8	4.71
RS841	12.3	10.1	1.17	2.09	11.8	5.46
CSB	11.9	9.5	0.99	1.78	12.3	4.39
PEP	12.0	9.7	1.18	2.02	12.9	4.35
NonG	11.9	9.5	1.17	1.59	12.5	3.44
P-value	0.97	0.17	0.82	0.35	0.17	0.02



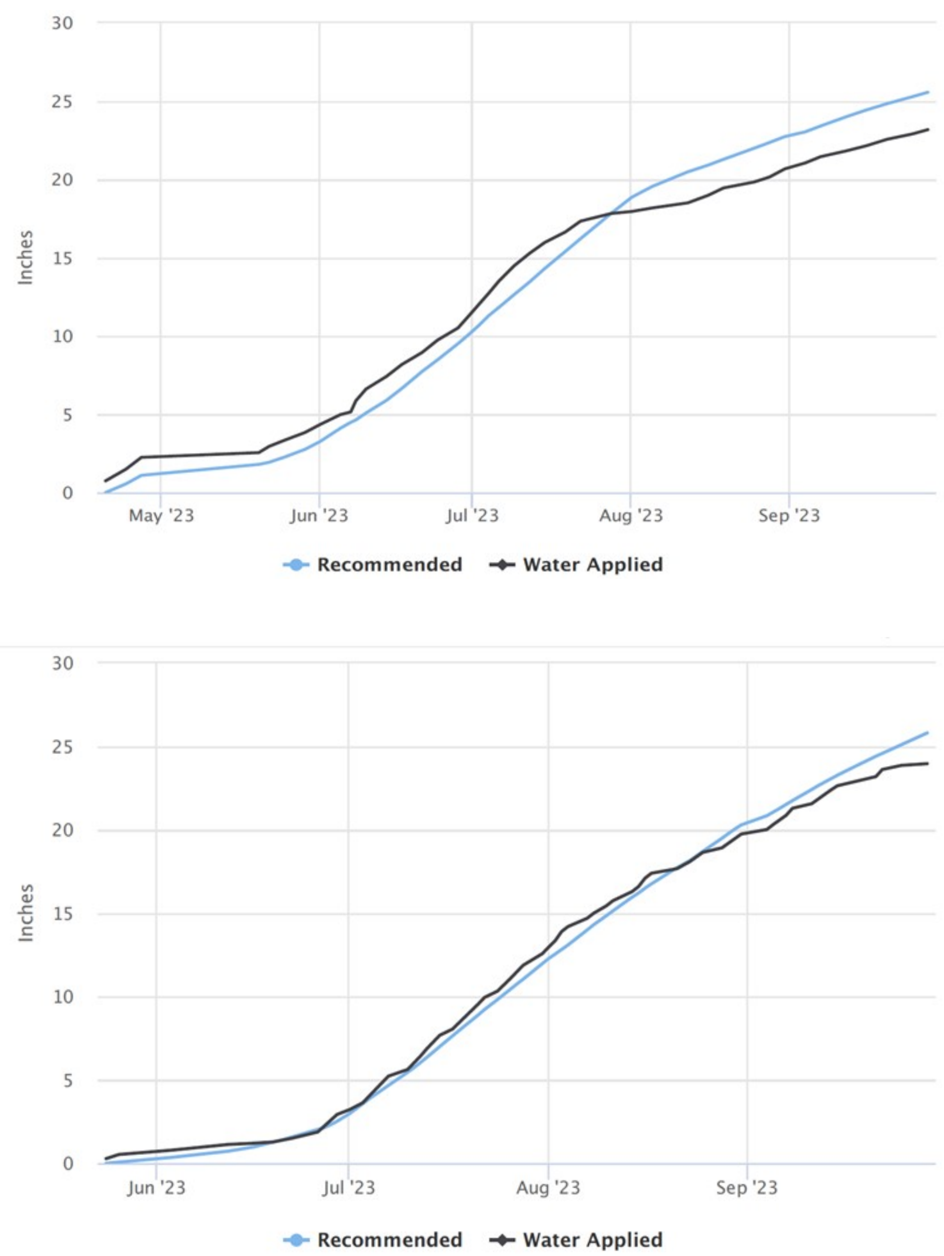
Figures 3a and 3b. The overall grafting effects on stem end rind thickness and flesh firmness compared to the non-grafted control.

Snapshots of other vegetable projects

- *Beet leafhopper and curly top virus in processing tomato*. Due to plenty of precipitation in the winter and early spring, the foothill vegetation did not begin to desiccate until late June. This is an indicator of a late or low migration of beet leafhoppers to the valley tomatoes. From our field inspections and sticky card analysis, the incidence of beet curly top virus, leafhopper population, and the associated yield impact were minimal.

- *Evaluating CropManage for effective irrigation management*. We continued working with tomato and watermelon growers to test the adaptability of CropManage toward sustainable irrigation applications. Two tomato and one watermelon grower participated in this year's trials, but one tomato field was abandoned at the beginning of the season. For watermelon, less than 25 inches of water was applied this year (Figure 4a), which was much lower than the past three years for this grower. Also, the grower followed the recommendation from transplanting to late July when harvest began (Figure 4a). Questions remain unsolved including better prediction of irrigation demand for watermelons at the harvest window, especially when plants are picked multiple times during the 2.5-month harvest window. Crop canopy fluctuation between each pick made accurate recommendations based on crop ET difficult. Future work needs to specifically tackle this problem. For processing tomatoes, the grower almost exactly followed CropManage (Figure 4b). A total of 24 inches of irrigation is at the average level for processing tomatoes. One question raised by the grower was that CropManage continued recommending irrigation even after the traditional irrigation cutoff date (two to four weeks before harvest). This may not be user-friendly for those new to CropManage and processing tomatoes.

- For other studies, data are being summarized and analyzed and will be reported soon after they are available. Stay tuned to the Vegetable Views Newsletter and feel free to contact me with your ideas, suggestions, pressing issues, and plans for the next season.



Figures 4a and 4b. Comparisons of the actual irrigation vs. recommendations made by CropManage for watermelons (4a; top) and processing tomatoes (4b; bottom) in 2023.

Reference

Pathak, T.B. and Stoddard, C.S. (2018). Climate change effects on the processing tomato growing season in California using growing degree day model. Modeling Earth Systems and Environment 4: 765-775. https://doi.org/10.1007/s40808-018-0460-y