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

VEGETABLE VIEWS

FALL 2021, ISSUE 2

Processing Tomato Disease Update:

Curly Top Virus and Beet Leafhopper

Zheng Wang, PhD, UCCE Vegetable and Irrigation Advisor, Stanislaus County

If you ask tomato growers in the Northern San Joaquin Valley what is the most seen disease in 2021, beet curly top virus (BCTV) is the one that stands out. Undoubtedly, we have seen an exceptionally high incidence of BCTV on processing tomatoes vectored by the beet leafhopper (BLH). Most of my farm calls from April to July 2021 were about field infestation of BCTV. Field visits spanned from Vernalis in San Joaquin County down south to Gustine in Merced County. This unusual high incidence seems to be associated with drought, which caused an earlier withering of the vegetations on the western foothills. Presumably due to the impact of drought on BLH's habitats, they flew down the Central Valley much earlier than usual to affect field crops, including processing tomatoes. Unfortunately, none of the processing tomato varieties are resistant to BCTV. An interesting thing is that BCTV was also found in the lower Sacramento Valley, where it has not been a common tomato disease in the past.

With the support of the California Tomato Research Institute (CTRI) and collaboration with the CDFA's BCTV Control Program, we began a research project to monitor the BLH population dynamics and BCTV incidence in processing tomato fields. Since March 2021, we have set up 30 yellow sticky traps at 10 sites comprising of 22 processing tomato fields in Stanislaus County (Westley to Crows Landing) (**Fig. 1 and Table 1**). The gross acreage of the monitored tomato fields is 2,180 acres. During the study, we replaced sticky traps biweekly and took sweep net samples monthly. By inspecting collected traps and sweep net samples, we submitted all suspicious BLHs together with diseased tomato tissues to CDFA-Integrated Pest Control and UC Davis for laboratory confirmation prior to estimating the BLH population and BCTV incidence at each monitored location. As fields are being harvested, we will work closely with growers to estimate the potential yield loss. Besides the 22 monitored fields, eight additional tomato fields were also reported for BCTV infection by growers or PCAs.

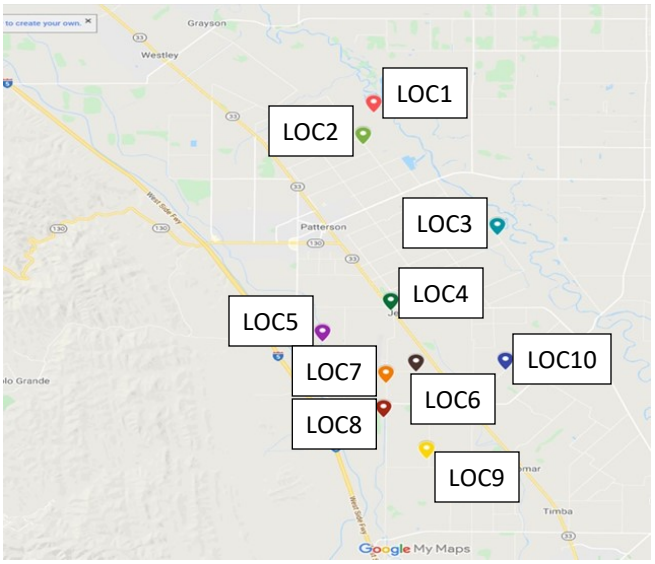

Figure 1. Locations of the 10 sites where yellow sticky traps were installed (LOC = Location).

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Zheng Wang, PhD
UCCE Vegetable and Irrigation Advisor
3800 Cornucopia Way, Suite A
Modesto, CA 95358
zzwwang@ucdavis.edu
(209) 525-6822
@StanVEG_Up

Table 1. Information of the 10 monitored sites.

Site location	No. of fields included	Total acreage	Field code	Traps set at (vegetations)	Varieties	Planting date (2021)
Patterson	2	68	LOC1	Ditches, grass land, alfalfa	DRI 319	April 5
Patterson	3	106	LOC2	Between the edges of tomato and almond fields	HM 4521	April 20
Patterson	1	93	LOC3	Wild grass land, ditches	BOS 811, SVTM 9014	April 10
Jet	2	340	LOC4	Roadside, edges of tomato and orchard fields	HM 4521, SVTM 9014, DRI 319, SVTM 9013	April 22
Jet	2	127	LOC5	Edges of tomato and almond fields, ditches near canal	HM 58841	May 16
Crows Landing	2	190	LOC6	Roadside, ditches, wild grass land, edges of tomato and orchard fields	HM 4521, SVTM 9014, SVTM 9013, BOS 811, HM 9905	May 20
Crows Landing	4	570	LOC7	Edges of tomato and almond fields, ditches, roadside	N6474, SVTM 1082, DRI 319, BP74	May 4, 7, 9, and 11
Crows Landing	1	90	LOC8	Roadside, wild grass	SVTM 1082	April 29
Stomar	4	500	LOC9	Edges of tomato field and walnut fields	DRI 319, HM 58801, N6420, HM 8163 (pear), HM 7885 (pear)	April 27, May 3, 12, 14
Stomar	1	100	LOC10	Roadside, ditches	HM 5522	May 1

Of all the 10 monitored sites (22 fields), six sites including 14 tomato fields were identified to have a BCTV incidence of 5-10%. The disease incidence levels of 0-5% and >10% each was found in 2 monitored sites containing 4 fields (**Table 2**). For the additional 8 infested fields reported by growers, there were 3, 4, and 1 field with an estimated BCTV incidence of 0-5%, 5-10%, and >10%, respectively. The BLH populations on yellow sticky traps and in sweet net samples are currently being counted.

Table 2. BCTV incidence at each site.

Site location	Field code	0-5%	5-10%	>10%
Patterson	LOC1			√
Patterson	LOC2	√		
Patterson	LOC3		√	
Jet	LOC4			√
Jet	LOC5		√	
Crows Landing	LOC6		√	
Crows Landing	LOC7		√	
Crows Landing	LOC8	√		
Stomar	LOC9		√	
Stomar	LOC10		√	

Quick Facts About BCTV and BLH

- The BCTV has a wide host range and can cause disease in over 300 plant species.
- The virus only spreads from plant to plant by the beet leafhopper.
- The BLH can overwinter in the foothills of the Central Valley and migrate down to the valley crops in late spring.
- Beet leafhopper itself does not contain the virus. It becomes infectious to susceptible plants usually after feeding on infected vegetations in the foothills.
- Tomato is not a desired host for BLHs, but they will keep tasting tomatoes when flying down into the valley and transmit the virus to plants with just a few minutes' feeding.
- The virus-carrying BLHs must feed on plant phloem, which is the food-conducting tissues, to inoculate the BCTV to susceptible plants.
- It seems that field margins are more vulnerable, but we did see infected plants in the middle of a field.
- Younger plants usually die after infection with BCTV, while plants infected at a later stage may survive, but premature green fruit, if any, will turn red.
- There is currently no resistance to BCTV in processing tomatoes.
- Although a statewide control program sprays the western foothills where BLHs congregate, the sporadic occurrence of BCTV and the indiscriminating feeding habit of BLH make the control very difficult.
- Eliminating host weeds before transplanting and delaying planting are usually tried.
- The following links provide you with more detailed and useful information: https://www2.ipm.ucanr.edu/agriculture/tomato/Curly-Top/ https://www.cdfa.ca.gov/plant/IPC/curlytopvirus/ctv_weekly_reports.htm

Figure 2. Tomato plants infected with BCTV exhibit purpling of veins and stunting.

Is There A Pathway to Profitability For Grafted Watermelon - What Do Production and Economics Tell Us?

Zheng Wang, PhD, UCCE Vegetable and Irrigation Advisor, Stanislaus County
Anthony Fulford, UCCE Nutrient Management/Soil Quality Advisor, Stanislaus, San Joaquin, and Merced Counties

Grafting woody crops to pursue the synergy of rootstock and scion has become a standard practice. This is now also becoming true for vegetable grafting, particularly for tomato and watermelon, that creates a recombined seedling from two different types of varieties for the sake of soil disease resistance, fruit productivity, and quality. Although an increasing number of on-farm grafting evaluations have been conducted in the US over the last ten years, this ancient vegetable production tool remains a low-adopted practice among vegetable growers. Their concerns range from lack of yield superiority or limited rootstock choices to hesitations regarding increased production cost.

Grafted vegetables can be grown profitably but this depends on how costs compare to non-grafted vegetable production. Recent changes in the past two to three years indicated a growing demand of grafted watermelon plants and consequently planted acreage in California. Based upon my interviews with major watermelon growers and industry (seed companies, local and out-of-state nurseries), they all agree that grafted watermelon acreage increased from less than 100 acres five years ago to approximately 1,500 acres in 2021, accounting for 15% of the state's commercial watermelon acreage. The actual acreage could be higher because this estimate lacked sufficient production information from growers in the desert areas of southern California. There is nearly 1,000 acres of grafted watermelons from the northern San Joaquin Valley, whereas this was only a double-digit acreage five years ago. You may start to question why this ten to twenty-time acreage increase happens to watermelons in California instead of other graft-eligible vegetables, such as processing tomatoes. Hold your questions for a moment and let's look at how production costs, incomes, and net gains compare between producing grafted and non-grafted watermelons.

Before we dive into the comparison table, it is important to clarify the background information.

- Majority of grafted watermelons are seedless, full-size varieties. In contrast to mini watermelons, full-size varieties produce marketable fruit with an average weight between 12 to 24 lbs. and currently account for about 80% of the California watermelon market according to the USDA-Agricultural Marketing Service.
- All seedless watermelons, regardless of grafting, must be transplanted.
- The average watermelon yield in California is 28 tons per acre across all types. Full-size varieties can reach an average yield of 50 tons per acre.
- Costs for seeds of seedless and rootstock varieties vary by seed treatment (e.g., primed and fungicide treatment), disease resistance, order size, and among growers & nurseries. Growers usually get extra discounts for large orders.
- Growers typically order 30-40% (35% by average) more seeds to compensate for any loss and to ensure adequate supply for planting.

Plant spacing and population Grafted watermelons are usually planted in a wider in-row spacing because of vigorous root systems. Therefore, according to the table, plant population is reduced by 25-50% per acre compared to that of non-grafted plants. The most common spacings used for grafted watermelons are 4 and 5 feet in contrast to 3 feet used for non-grafted plants.

Seed cost According to the online seed catalogs of 36 seedless watermelon varieties, the average cost is $336 per 1,000 seeds. With the extra discount, growers may get an average price of lower than $300 per 1,000 seeds. In the table, we use $300 as the standard price. Interestingly and surprisingly, rootstock seeds cost much less than the seedless cultivars. The actual cost varies by rootstock type (bottle gourd vs. hybrid squash/pumpkin) and ranges from $50 to $150 per 1,000 seeds. We use $100 as the standard price in the table. Even using this conservative cost estimate, it is nowhere near that of processing tomatoes for example, which can have rootstock costs that are more than 5 times that of scion seeds. This is a crucial factor for why watermelons are more suitable for grafted production than processing tomato, especially when considering the additional plant population requirement for processing tomato compared to watermelon (1,400 vs. 9,000 per acre).

Transplant production cost The higher cost of transplants from greenhouses is one reason why growers hesitate to adopt grafted vegetable production. According to the table, growers pay 2.5 to 4 times more for grafted transplants even though they grow fewer plants per acre and get extra discounts for large orders. The added costs come from growing both scion and rootstock seeds, grafting, and healing of grafted seedlings. Successful and high-quality grafting plays the most critical role in rewarding growers with superior yields over non-grafted plants. Poor quality of grafted plants can cause rootstock shoots arising from the stump of rootstock or the graft union after transplanting (Figure 1). Additional time and labor must be invested to remove the rootstock shoots and prevent competition and yield reduction. Overall, the cost for seeds and transplants if growing grafted plants is $600 - $1,500 per acre more than non-grafted plants.

Figure 1. Pumpkin rootstalk shoots arise from the graft union of a watermelon plant.

Fruit yield and total income According to my observations and responses from growers, we use 50 tons per acre as a reasonable yield estimate for non-grafted, full size, seedless watermelons. To compensate for the increased cost and breakeven, grafted watermelons must outyield over non-grafted ones. Fortunately, records from growers in California indicated that grafted watermelons increased yield by an average of 15% compared to the non-grafted plants. In the meantime, overwhelming reports from the literature document yield increases when commercial watermelon cultivars were grafted onto various rootstocks under both diseased and disease-free conditions. It is also fortunate that California's 4-year average market price of watermelon is the highest among major watermelon production states, averaging $360 per ton according to the USDA-National Agricultural Statistics Services. Based upon this data, a grafted watermelon field reporting a 10% increase of yield relative to its non-grafted counterpart will end up with a conservative net income increase of $260 per acre. For a grafted field yielding 20% more,

the net income increase can be $2,060 and $2,647 per acre when the in-row spacings are 4 and 5 feet apart, respectively. For a field planted at a 6-foot spacing, though uncommon, the net income increases are as much as $1,240, $3,040, and $4,840 per acre when grafted plants produce 10, 20, and 30% more fruit than the non-grafted plants, respectively.

Now it is time to answer the questions you may have had in mind earlier and make the summary:

- **Does the greenhouse production cost remain a decisive factor?** Greenhouse production cost remains one of the decisive factors for growers considering the economic feasibility of growing grafted watermelons.
- **Is the cost for rootstock seeds a big burden compared to nongrafted production?** Rootstock seeds cost is much lower than that of triploid seeds; therefore, it is not a limiting economic factor to consider for grafted watermelons. This is opposite to the scenario of processing tomato, in which rootstock seeds cost as much as five times more than scions.
- **What is the yield increase threshold of grafted watermelons that guarantees growers net gains compared to planting regular watermelons and is this yield increase widely achievable?** The crux of the matter to keep watermelon grafting an economically attractive production practice is to maintain the yield advantage after grafting. Thankfully, the growing number of rootstocks on the market supports more research and commercial production test trials to find out optimal rootstock-scion combinations and avoid grafting incompatibility (Figure 2).
- **Does the market play any role in promoting the adoption of watermelon grafting?** The market price fluctuation is another decisive factor impacting the use of grafted plants and determines the breakeven cost threshold of grafted watermelons. Overall, the higher the market price paid to growers, the lower the yield increase threshold for grafted plants, making it easier to achieve profitability with grafted plants.
- Growers considering these cost recovery scenarios can plug their own numbers into the table prior to deciding if grafted watermelon production provides a pathway to profitability for their operation.

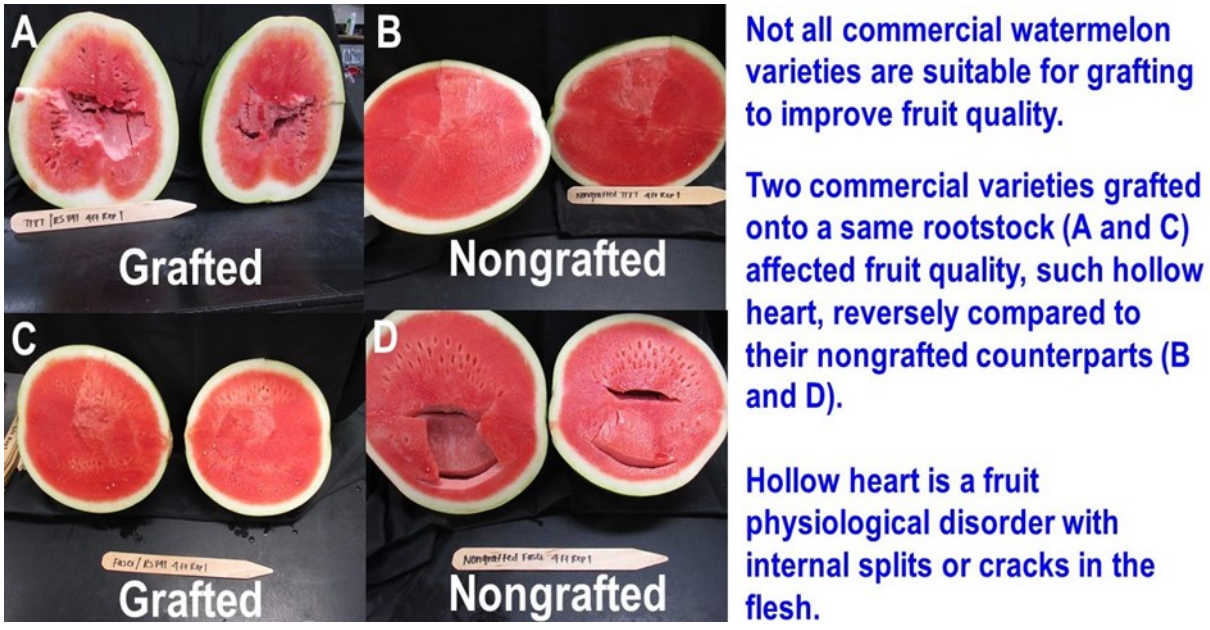

Figure 2. Fruit quality can be weakened due to the rootstock-scion incompatibility.

Comparisons of production practices, costs, incomes, and net income gains between grafted and regular watermelons.

	Non-grafted	Grafted								
In-row spacing	3 feet	4 feet			5 feet			6 feet		
Between-row spacing	7 feet	7 feet			7 feet			7 feet		
Population per acre[1]	2,075	1,555			1,245			1,037		
Seed cost (seedless plants)[2,3]	$840	$630			$504			$420		
Seed cost (rootstock plants)[4]	N/A	$210			$168			$140		
Transplant production cost[5]	$560	$2,100			$1,681			$1,400		
Total cost for seed and transplants[6]	$1,400	$2,940			$2,353			$1,960		
Yield (tons/acre)[7]	50	55 (10% more)	60 (20% more)	65 (30% more)	55 (10% more)	60 (20% more)	65 (30% more)	55 (10% more)	60 (20% more)	65 (30% more)
Total income[8]	$18,000	$19,800	$21,600	$23,400	$19,800	$21,600	$23,400	$19,800	$21,600	$23,400
Net income increase[9]	N/A	$260	$2,060	$3,860	$847	$2,647	$4,447	$1,240	$3,040	$4,840

[1]The plant population does not include pollinizers.
[2]All cost and income in this table are calculated at a per-acre basis.
[3]The average seed price of seedless watermelons is estimated to be $0.3 per seed, and growers usually order 35% extra seeds.
[4]The average seed price of watermelon rootstocks is estimated to be $0.1 per seed, and growers usually order 35% extra seeds.
[5]According to the information from greenhouses, the average costs for producing a regular and grafted watermelon transplant are $0.2 and $1, respectively.
[6]This is only the cost for seeds and producing transplants. Field management cost (e.g., labor and machine), rental fee, and irrigation and fertilizers are not included as they are presumably the same between grafted and non-grafted watermelon production.
[7]The average yield of full-size, non-grafted seedless watermelon is set at 50 tons per acre based upon growers' responses.
[8]According to the USDA-NASS and growers' responses, the average price for seedless watermelon (2017-2020) was $360 per ton.
[9]The net income increase per acre by growing grafted watermelons is calculated by subtracting the difference of total cost from the difference of total income. For example, the $260 is derived from ($19,800 – $18,000) – ($2,940 – $1,400).