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RESEARCH REPORT

Grafting for organic low-tech greenhouse tomatoes

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IN A NUTSHELL

As a follow-up to their 2019 multi-farm trial, we compared 5 large tomato varieties and 4 cherry tomato varieties grown by grafting onto four different rootstocks and an ungrafted control.

- The best choice of rootstock was specific to the scion, with some rootstocks producing no improvement or even reducing yield for some varieties of scion.
- Compared to ungrafted plants, Caiman F1 large tomatoes had great yield and profitability when grafted DR0141TX rootstock.
- Preliminary data suggest that only Sakura cherry tomato may benefit from grafting on Fortanimo or Estanimo, but more replicates are needed to be confident.
- Preliminary data suggest that grafting "heirloom-like" hybrid varieties tested does not confer a yield advantage, but that open pollinated Striped German maybe benefit from being grafted onto Fortanimo.

MOTIVATION

This is a follow-up to a 2019 multi-farm tomato grafting trial on the effect of grafting (mostly) heirloom- like scions to Estanimo root stock in protected culture (reference 1). Unlike the other farms in that study, we used a greenhouse tomato variety (Caiman F1) as our scion, and saw no improvement for Estanimo. We also tried other rootstocks, and found an improvement, especially for Maxifort. We were light on replicates, partly because of concern that the growth patterns would be significantly different and we lacked the rows to devote to the trial. From experience with that trial, we found the growth patterns between grafted and ungrafted plants similar enough to do multiple treatments in one row. Herein we report on Caiman trials with more replicates, more root stocks, and more varieties of scion.

New to Nith Valley Organics is a protected culture of grafted cherry tomatoes and tomatoes bred to appeal to customers looking for the heirloom look and flavour and to farmers looking for modern hybrid performance (Granadero F1, Cherokee Carbon F1, Damsel F1 and Striped German). (We've previously field-grown Striped German). Where others have found improvements from grafting cherry tomatoes and heirlooms, our interest is in which rootstocks perform well for them. Resources (time and greenhouse space) dictated that this portion of the trial could not include replicates: our results are only preliminary.

DESIGN

Rootstocks

We found four root stocks on the market for organic production: **Estanimo**, **DR0141TX**, **Fortanimo** and **Shin Cheong Gang**. (Our supplier of Maxifort, Johnny's, discontinued that variety, and in 2020 it was unavailable in an untreated format.)

We grafted large tomatoes and cherry tomatoes on the four rootstocks and compared to ungrafted controls, for a total of five treatments.

Photo 1. Caiman shortly after planting. Cucumbers were planted into the side beds.

We did this in three trials - one fully replicated and two partially replicated - as follows:

Large Tomatoes

1. **Caiman;** with four replicates of 9±1 plants per treatment. The plant count was not always exactly nine because one too few Shin Cheong Gang grafts survived, and we had enough DR0141TX to fill in for it.
2. **Cherokee Carbon F1** (C), **Grenadero F1** (G), **Damsel F1** (D), **Striped German** (open pollinated; S); we compared these varieties together and randomized treatments to reduce the effect of location within the greenhouse. The small numbers of each variety meant we can only report a little more than qualitative results. We hoped that one rootstock might outperform the others across the range of scions allowing us to treat the different scions as replicates.

Cherry Tomatoes

3. **Sakura**, **Bartelly**, **Five Star** and **Toronjina**; we used an average of 8 plants per treatment, which was too few for proper replicates. We hoped for a strong correlation across scions, so as to treat the scions as four replicates. As such, the locations were randomized as if the different scions were replicates. From a practical standpoint in the long run, we would not want to be growing four scion-specific rootstocks.

Table 1. Layout of blocks of four replicates of Caiman. Each column is a row in the greenhouse. Letter codes are as follows: C-Control; D-DR0141TX; E-Estanimo; F-Fortanimo;S-Shin Cheong Gang. We planted the left two rows on April 15 and we planted the right two rows April 17.

Root	Count	Root	Count	Root	Count	Root	Count
C	9	S	9	E	9	F	9
S	9	F	9	C	9	E	9
D	9	C	9	D	9	S	8
F	9	E	9	F	9	D	10
E	9	D	9	S	9	C	9

Table 2. Layout for other large tomatoes. First letter is scion: C-Cherokee Carbon, G-Grenadero, D-Damsel, S-Striped German; the second letter denotes the variety of root stock as abbreviated as in Table 1. Digit, if present, represents the replicate index. We planted Striped German and Damsel on April 24; and Cherokee Carbon and Grenadero May 20.

Code	Count	Code	Count	Code	Count	Code	Count
Cf	4	Sd	4	Df	4	Gc1	6
Gs1	6	De	5	Sc	6	Ge1	5
Cc	3	Cd	5	Ss	4	Gs2	6
Gc2	9	Ce	4	Dd	4	Ge2	5
		Cs	4	Sf	4		

Grafting

We grafted the tomatoes using methods described in reference 1, and grew them to the transplant size before moving them to greenhouses. The greenhouses were covered in double-walled plastic, and, while we have supplemental heat, the main purpose of the heat is for winter growth of greens – lettuce, spinach, baby kale, and arugula. Roll-up sidewalls provided some ventilation when the sun made the greenhouse too hot.

Planting

We planted cherry tomato plants at 18" spacing, and the large tomatoes at 24" spacing, in rows 5' apart. The greenhouses are 30' wide, with either cucumbers or peppers in the two outer rows. We covered the soil with landscape cloth and used automatic watering through drip lines. We incorporated fertilizer into the soil before laying the landscape fabric, and mixed additional fertilizer into the irrigation water.

Management and Harvest

We pruned plants approximately weekly to two leaders, clipped to strings hung from overhead wires, and leaned and lowered as needed. We harvested thrice weekly during the peak growing season; twice weekly in the fall once the fruit were ripening more slowly, weighing marketable fruit after each harvest. Harvest continued until yield fell below commercially viable levels. Four weeks before the end of harvest, we topped Caiman plants. That, along with an

increase in sunny days the next week, resulted in a substantial increase in yield, which gradually fell over the remaining weeks.

FINDINGS

Observations

Not all rootstocks graft alike

An ideal rootstock has uniform, predictable germination (or, if being grafted to a topstock with very non-uniform germination, matches the top stock), and produces its cotyledons at least 2-3 cm above the soil on a sturdy stem. These traits are in addition to any disease resistance or yield improvement that it might confer.

We found Estanimo lacking in uniformity and, when combined with Caiman, it resulted in many wasted rootstocks. Not all rootstock/scion combinations had equal success grafting.

Grafting changes growth patterns

Early in the season, grafted cherry tomato plants had a more compact growth habit, resulting in a fuller, denser plant, with more foliage per foot of stem. We observed that this tendency disappeared later in the season. We also observed less bushy plants among the Caiman controls, an effect which was less accentuated as the season progressed. Plants grafted to Estanimo were a week earlier with sending spurious shoots, although the others caught up. There was a mid-season period in which the ungrafted controls were visibly less leafy than the grafted plants, however this only lasted for maybe 4-6 weeks. All blocks showed symptoms of diseases by the end of the trial, mostly grey mould, but also several other diseases; there was no obvious difference among treatments.

Table 3. Cherry tomato layout. First letter denotes scion: B-Bartelly, F-Five Star, S-Sakura, T-Toronjina; the second letter denotes the variety of root stock as abbreviated as in Table 1. We planted the remainder of row 3 with out-of-scope (non-cherry) tomato plants. We planted Sakura and Five Star on May 13 and the others on May 22.

Code	Count	Code	Count	Code	Count	Code	Count
Fc	2	Fc	8			Td	14
Ss	9	Ff	5			Tc	4
Sf	9	Sd	10			Bs	4
Fd	14	Sc	8			Tf	7
Se	9	Be	12			Ts	4
Fs	5	Bd	6	Te	9	Bc	7
Fe	12					Bf	6
						Bd	6

General observations on cherry tomatoes

Sakura produces large cherry tomatoes, while Bartelly produces small ones. From a harvest perspective, Bartelly makes up for the small size with the cluster size. While we did not harvest them that way, the tomatoes are advertised as being cluster-harvestable, so we dropped to twice-weekly harvest and could harvest more tomatoes from one cluster without moving on to another. Grafted or not, Sakura and Bartelly outperformed Five Star and Toronjina. Five Star performed so poorly that most were evicted early in favour of planting greens. This was surprising as we had been pleased with the performance of Five Star in the past. This may have been a bad year for them. Toronjina, as advertised, has a thicker skin than Sun Gold (not tested in this study), for which it is advertised as a substitute. The flavour, at least in greenhouse culture, was not as good. More importantly, they did not hold very well on the plant, or ripen well off the plant. Furthermore, the tomatoes on the sunny side of the plant were ready to harvest when they began to turn orange, where the tomatoes on the shaded side were soft and unmarketable once they turned orange.

Quantitative Results

Caiman

The trial with Caiman had four replicates that were randomized, however they did experience differences in their environment. First, there were two plantings a few days apart. These were seeded at the same time, but transplanted on different days because the space did not come available at the same time. Second, the end blocks were more subject to drafts in the early season when the doors opened,

and better ventilated in the summer due to being close to the doors (and we considered that as a potential treatment variable). Thirdly, we also considered the effect of being on one of the two edge rows, rather than one of the two centre rows. The side beds were potentially cooler and disadvantaged in spring and fall, but advantaged in the summer.

- The transplant date had no significant effect (paired t-test comparing two transplant dates; P=0.31), neither did being in an end block (non-paired t-test comparing ends of the greenhouse, P=0.157).

- Being on an edge bed conferred a slight advantage, approximately 1.3kg more fruit per plant (P=0.017).

We adjusted yield values before testing the effect of graft treatment by adding half the difference to the yields from interior beds and subtracting the same amount from the yields of the edge beds. Since the different (graft) treatments were balanced with respect to being on an edge bed, this adjustment affected the variance, and not the mean. After adjusting the effect of grafting, relative to the controls, we found that Caiman had higher yields when grafted to DR0141TX and Estanimo as compared to ungrafted controls (**Figure 3**). The yield per plant compared favourably to those in Johnny's Selected Seeds trials (reference 2) where the top performer produced 1.35 kg per plant.

We also looked for any yield advantage by subtracting yield of control plants from yield of grafted plants, and found that only DR0141TX and Estanimo showed improvements, as shown below.

- **DR0141TX: 2488g improvement (16.8%, P=0.0074, CI=[1485,3492])**

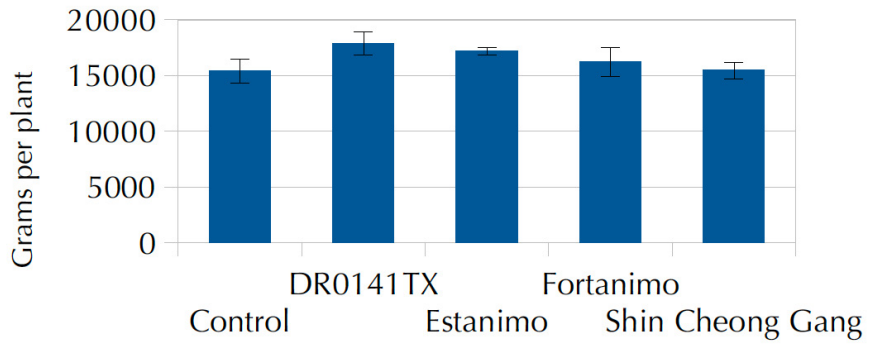

Figure 3. Caiman performance on 5 rootstocks. Error bars at at the 95% confidence level: twice the standard error of the mean, after controlling for bed location.

- **Estanimo: 1788g (11.63%, P=0.0098, CI=[1435,2141])**
- Fortanimo: 829g (5.39%, P=0.182, CI =[-466,2124])
- Shin Cheong Gang: 58g (0.38%, P=0.466, CI=[-656,772])

We used $3/kg (our price for #1 fruit from these plants) to calculate the economic advantage for DR0141TX and Estanimo, which showed a yield advantage. At this price, grafting to DR0141TX is worth about $7.30 per plant. Growing a grafted seedling costs around this much, depending on grafting yield, the value of labour, greenhouse space, and healing chamber space at that time of year. **DR0141TX offers relatively uniform germination, which improves grafting yield.**

Estanimo, has the largest germination variability we've seen, increasing all costs associated with grafting tomatoes. With an increase in only $5.25 per plant from Estanimo, we do not find grafting to Estanimo to be economically worthwhile.

Heirloom and "Heirloom-like" Hybrids

We saw no significant improvement in yield of any of the heirloom-like hybrid varieties, as shown in **Table 4**. This may be partly due to the lack of replicates; it may also be that we were just unlucky in selecting rootstock/top stock combinations. For example, it is possible that DR0141TX would boost yield on Cherokee Carbon or Striped German would perform substantially better with Estanimo. It may also be that the hybrid vigour is sufficient to make graft irrelevant. We did see what may be an economically significant improvement in Striped German - the only open pollinated large tomato that we tried. This year's wholesale value of these was around $8.80 per kg, so with the increase of 1500 g for grafting onto Fortanimo, this would represent just over $13 per plant. We had hoped for a correlation among varieties, so we could run statistical analysis using different varieties as surrogates for replicates, but this is not the case. The economic significance of grafting Striped German to Fortanimo is uncertain, therefore, because it depends on statistical significance.

Cherry Tomatoes

Results of the cherry tomato comparisons are shown in **Table 5**. While we had hoped for a correlation among varieties, only Sakura and Toronjina had a correlation greater than 30%. This is unfortunate, as it doesn't give us confidence intervals.

Performance of the best grafted Five Star is typical of our previous experience in ungrafted Five Star.

For some reason we had a bad year for grape tomatoes. The improvement due to grafting Sakura is quite compelling, even in the absence of confidence intervals: it would be worth conducting a more controlled experiment with Sakura to determine whether Estanimo is better than Fortanimo, or this is noise. If Estanimo is not significantly better than Fortanimo, using Fortanimo for all cherry tomatoes seems like a good compromise between performance and simplicity.

Table 4: Performance of Hierloom-like varieties. The error bounds on Grenadero are one standard deviation of two instances. The huge variabity of Grenadero control is real. Units in grams/plant.

Scion	F	D	S	E	C
Cherokee Carbon F1	10199	-	7395	9913	10076
Grenadero F1	-	-	5967±262	6152±1571	15193±11183
Striped German	9835	7081	9496	-	8348
Damsel F1	4163	5990	-	4102	6296

Table 5: Cherry tomato yields. Values in parentheses are percent improvement over controls. Units in grams/plant.

Scion	F	D	S	E	C
Five Star F1	2097 (10.0%)	3324 (42.7%)	2817 (21.0%)	3065 (31.6%)	2329
Sakura F1	7548 (91.3%)	5858 (48.5%)	6626 (67.9%)	8632 (118.8%)	3946
Bartelly F1	10601 (22.8%)	9437 (9.3%)	8185 (-5.2%)	5515 (-36.1%)	8635
Toronjina F1	4841 (31.3%	4616 (25.2%)	4092 (11.0%)	4474 (21.4%)	3687

TAKE HOME MESSAGE

We found that the best choice of rootstock was specific to the scion, with some rootstocks producing no improvement or even reducing yield for some varieties of scion. Whether to graft Caiman F1 scions to DR0141TX rootstock will be a decision that depends on the specific economics of a given farm, and the available resources in grafting season. We would not recommend grafting Caiman to any of the other rootstocks tested in this study. The value in grafting cherry tomatoes is relatively compelling for some varieties, but not others. In particular Sakura on Fortanimo or Estanimo doubled the yield, while Bartelly showed at best 23% improvement, but at worst a 36% drop in yield. We found no improvement to the "heirloom-like" hybrid varieties, but a significant (18%) improvement for open-pollinated Striped German grafted onto Fortanimo. Given the price advantage of these tomatoes, this may well be economically significant, if it is repeatable.

NEXT STEPS

For large hybrid tomatoes, a combination to consider, depending on specific farm economics, is Caiman F1 scions to DR0141TX rootstock.
It would also be worth testing more replicates of Striped German scion grafted to Fortanimo rootstock; and conducting a more controlled experiment with Sakura to determine whether Estanimo is better than Fortanimo. If Estanimo is not significantly better than Fortanimo, using Fortanimo for all cherry tomatoes seems like a good compromise between performance and simplicity.

Photo 2. Caiman at the time of the first fruit set. White signs on the strings denote block boundaries.

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