PVMRP Annual Report
No-till vs. Plasticulture Tomatoes: Examining Yield, Earliness, and Soil Health
Elsa Sánchez, Sjoerd Duiker, and Francesco Di Gioia

We compared tomato on its own root system and grafted onto a vigorous rootstock in two no-till systems and a plasticulture system. The experiment was arranged in a split-plot design. Main plot treatments were 1) early no-till, 2) main-season no-till, and 3) plasticulture systems. Split-plot treatments were 'Red Duce' on its own rootstock or grafted onto DRO141TX, a highly vigorous rootstock with resistance to Fusarium races 1 and 2, Fusarium crown and root rot, leaf mold, corky root rot, tomato mosaic virus, and verticillium wilt.

How the experiment was conducted

The study took place at Pennsylvania State University's Russell E. Larson Research Center in Pennsylvania Furnace. Main plots were 7 ft x 22.5 ft and subplots were 7 ft by 11.25 in size. A single row of 15 plants with 18-inch in-row spacing was planted in each subplot. Treatments were replicated four times. A rye cover crop was planted in the field in the fall of 2020.

For the plasticulture treatment, the cover crop was flail mowed when it was between 4-6 inches tall and plots were chisel plowed on April 26, 2021. On April 27 plots were disced. On April 28 plots were rototilled and beds were shaped, drip tape was installed, and black plastic was laid. For no-till treatments, the cover crop was crimped on May 7. At this time, the rye biomass was on average 31 inches tall, provided 86% cover as measured with the App 'Canepeo', and had accumulated 4193 lbs dry matter per acre. The same day landscape fabric was installed over plots and secured with landscape staples. On May 17 planting holes were burned in the landscape fabric. On May 19 the early no-till treatment plots were planted. Approximately 2 weeks later, on June 2, the main-season no-till treatment plots were planted. On June 3 (delayed 1 day because of rain), the plasticulture treatment plots were planted. A drip irrigation system was used to supplement rainfall to supply 1 to 1.5 acre-inches of water to the plants weekly. The plants received 200 lbs of nitrogen per acre throughout the growing season. Phosphorus and potassium were applied based on soil test analysis. Stakes were installed in all treatment plots with a pattern of stake-plant-plant on May 26. The Florida weave system was used to trellis plants with each string installed as needed. Pests were monitored and managed with pesticides when needed.

Harvest of red ripe fruit occurred three times per week from seven plants per subplot beginning on August 2 and continuing through September 26. Fruit were categorized as marketable and unmarketable. Marketable fruit was graded by size according to USDA criteria.

Yield data were analyzed using the mixed procedure in SAS. Means were separated using pdiff.

Soil temperature near a tomato plant was measured with an analog soil thermometer every weekday morning at about 8 am and at 4 pm at 2 inches depth, in early planted no-till plots and plasticulture plots from May 21 to June 30.

Bulk density was measured in the treatment plots of three replications using the core method (3-inch diameter and 3-inch-high metal cores). In the beginning of July, two samples per plot were taken as close to the soil surface as possible (approx. 0.5-3.5 inches depth) 30 inches from the tomato rows, which was between the plastic-covered beds in the plasticulture plots or underneath the fabric in the no-till plots. The soil was dried in a lab at 105°C until oven dry and then weighed and expressed on a weight by volume basis.

Soil samples were collected in early July with a 0.75-inch-diameter soil probe to 6-inch depth to determine aggregate stability. Four samples were collected at similar locations as samples collected for determining bulk density. The samples were broken up, air-dried, and sieved through a 2 mm sieve. The soil was subsequently passed through a 1 mm sieve, and the material that remained on the 1 mm sieve was placed in a standard aggregate stability apparatus with 0.5 mm size sieve. The sieves were dunked into a shallow water bath for 3 minutes using the aggregate stability apparatus, and the soil that passed through the sieve was dried and weighed. After that, the soil remaining on the sieve was dispersed with a sonifier and similarly weighed after oven drying. Aggregate stability was calculated as (Dry weight of soil obtained after sonification) *100 / (Dry weight of soil obtained after sonification + Dry weight of soil after dunking).

Field saturated hydraulic conductivity (Kfsat) was determined in the second half of July (July 19-26) with SATURO infiltrometers installed 30 inches beside the tomato rows, similar to the location where soil samples for bulk density and aggregate stability were collected. This automated method consists of installing 6-inch-diameter metal rings 2 inches into the soil and then clamping on the head after which water is ponded in the ring and the rate of infiltration is recorded automatically. The apparatus was programmed to run two cycles for a total of 75 minutes per run. Internal to the equipment, the Kfsat is calculated. One measurement was taken in each plot in the study (24 total; 4 replications).

What we observed

Grafting treatment by production system interactions were not significant for any yield variable presented.

Significant differences in marketable and unmarketable yield by weight or number were not observed between the different production systems (Table 1). Grafting resulted in higher mean marketable yields in terms of weight and number than not grafting. Grafting did not result in significant differences in mean unmarketable yields.

Unmarketable fruit were cracked, zippered, catfaced, rain checked, or were damaged by tomato hornworm or blossom end rot. The largest category of unmarketable fruit was cracked. We also did not observe significant differences in the number of fruit that were cracked by the production system or grafting treatment (Table 1).

Significant differences in fruit yield in each grading category were not observed between the production systems evaluated (Table 2). Grafting resulted in a higher yield of extra-large fruit by weight but not by number compared to not grafting. Grafting also resulted in a higher yield of small fruit by weight and number compared to not grafting. Grafting treatment did not result in significant differences in fruit in the large or medium size categories.

Harvest started about a week earlier in the early no-till plots regardless of grafting treatment compared to all other treatments. Although, the amount of fruit harvested was small.

The soil temperature at a 2-inch depth was significantly higher in plasticulture treatment plots in the morning as well as in the afternoon. The mean soil temperature in the plasticulture plots was 68°F, while in the no-till plots it was 65°F. The mean soil temperature in the afternoon was 83°F and 76°F, respectively, in plasticulture and no-till plots. The soil in the plasticulture plots was 3°F warmer than in the no-till plots in the morning and that difference was 7°F in the afternoon.

There were no significant differences in bulk density due to production system or grafting treatment. The average bulk density was 1.55 g/cm^3. According to the Soil Quality Physical Indicator Information Sheet from USDA-NRCS, the ideal bulk density for plant growth in a silty soil is less than 1.40 g/cm^3, while root restricting bulk density is greater than 1.65 g/cm^3. For clay soils these values are lower (1.10 and 1.47 g/cm^3, respectively). The soil therefore had suboptimal bulk density suggesting it was highly degraded due to past management.

Similar to bulk density, there were no significant tillage or grafting effects on aggregate stability. The average aggregate stability was 37%, which is low, also showing the highly degraded nature of the soil we used for this trial.

Grafting treatment by production system interactions were significant for the Kfsat (Table 3). The mean Kfsat in the early no-till + grafted plots was higher than in early no-till + not grafted, plasticulture + grafted, and plasticulture + not grafted plots. Additionally, the mean Kfsat in the early no-till + grafted treatment was not different than the main-season no-till + grafted and main-season no-till + not grafted treatments.

What this means

A limiting factor to the adoption of no-till systems is lower yields compared to plasticulture systems. In this study, we observed that yields were not different when using no-till or plasticulture treatments. This study should be conducted again to verify results are repeatable and economic analysis should accompany results; however, this result provides preliminary evidence that a no-till system using landscape fabric can provide comparable yields to plasticulture systems. Other benefits should be factored into using landscape fabric including weed suppression and the ability to work in plantings (for stringing, scouting, and more) when the soil is wet.

Grafting also appears to be a promising technology to increase tomato yields regardless of the production system used. In this study, the increased yield because of grafting came from an increase in the weight of extra-large fruit and the weight and number of small fruit. The rootstock we used was highly vigorous and had resistance to several diseases. We also evaluated grafting in the muskmelon cultivar evaluation we conducted with PVMRP funding. In that study, grafting did not result in higher yields compared to not grafting. Grafting is commonly thought to provide a benefit to plants under stressful conditions. In the muskmelon study, the rootstocks used had resistance to diseases, however, disease pressure was low during the experiment. In this tomato study, aphids and Septoria leaf blight were problems and were treated with pesticides. This insect pest and disease were not listed as part of the DRO141TX rootstock resistance package. Plants were also under the stress of excess moisture from several extreme rainfall events that occurred during the 2021 growing season. This resulted in a lot of unmarketable fruit due to concentric and radial cracking. In fact, most unmarketable fruit were cracked. However, grafting plants did not result in a lower number of cracked fruit or reduce the overall amount of unmarketable fruit compared to not grafting plants. This suggests that the increased yields observed using the DRO141TX rootstock were the result of increased plant vigor.

Soil quality as measured by bulk density and aggregate stability was not different among any of the production systems and/or by the grafting treatments. Grafting increased water infiltration in both no-till systems compared to the plasticulture system. This is probably because in the plasticulture system few roots of grafted or not-grafted plants influenced the soil 30 inches from the row. Testing showed that the field soil was highly degraded. A single growing season using a no-till production system did not improve soil quality compared to using a plasticulture system as measured by bulk density or aggregate stability. Developing no-till production systems for other crops used in rotation with no-till tomato is likely needed to improve soil quality over the long term.

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Table 1. Mean marketable and unmarketable yield observed in a study evaluating grafted and not grafted tomatoes grown in two no-till and one plasticulture production system.

	Marketable yield*		Unmarketable yield		
Treatment	**lb**	**No.**	**lb**	**No.**	**Cracked (no.)**
Grafting					
Grafted plants	47.0 a	74.5 a	26.1 a	43.1 a	31.2 a
Not grafted plants	34.7 b	57.8 b	29.3 a	47.6 a	36.6 a
Production System					
Main-season no-till	42.6 a	69.8 a	28.9 a	48.0 a	35.3 a
Early no-till	46.2 a	75.1 a	30.5 a	50.0 a	38.3 a
Plasticulture	33.8 a	53.6 a	23.7 a	38.0 a	28.1 a

*Yield per 7 plants; Values within a column and treatment group followed by the same letter are not statistically significantly different.

Table 2. Mean marketable yield by grade observed in a study evaluating grafted and not grafted tomatoes grown in two no-till and one plasticulture production system.

	Grading Category							
	Extra large*	**Extra large**	**large**	**large**	**medium**	**medium**	**small**	**small**
Treatment	**lb**	**No.**	**lb**	**No.**	**lb**	**No.**	**lb**	**No.**
Grafting								
Grafted plants	26.7 a	32.5 a	15.8 a	29.5 a	3.9 a	11.2 a	1.1 a	3.8 a
Not grafted plants	19.7 b	24.3 a	13.1 a	25.6 a	3.1 a	8.1 a	0.3 b	1.3 b
Production System								
Main-season no-till	22.4 a	26.1 a	16.6 a	31.2 a	3.9 a	10.1 a	0.4 a	1.6 a
Early no-till	26. 4 a	34.4 a	16.6 a	32.4 a	4.2 a	12.0 a	1.0 a	3.5 a
Plasticulture	20.7 a	24.8 a	10.1 b	19.1 b	2.4 a	6.9 a	0.7 a	2.5 a

*Yield per 7 plants; Values within column and treatment group followed by the same letter are not statistically significantly different.

Table 3. Field saturated hydraulic conductivity as affected by tillage and tomato grafting

Treatment		Mean Kfsat	
		in/hr	
Early no-till	Grafted	4.062	A*
Main-season no-till	Grafted	2.298	AB
Main-season no-till	Not Grafted	1.651	ABC
Early no-till	Not Grafted	1.532	BC
Plasticulture	Not Grafted	0.874	BC
Plasticulture	Grafted	0.533	C

*Values followed by different letters are significantly different (Fisher's Protected LSD, $p<0.05$). Statistical analysis was done on log(1+x) transformed data to obtain normally distributed data set for analysis. Means presented are non-transformed.