Transplanter Evaluation Trial: Full Report

I. Experimental overview

Automated planters are able to plant more quickly with less labor than traditional planters. However, there is uncertainty whether there may be associated penalties in stand establishment, yields, fruit quality.

This report gives results from a replicated field study. Our goal was determine whether we could detect any consistent differences among planter types (a finger planter, a Ferrari FMAX carousel-type planter, and the Ferrari Futura and Agriplanter automated planters) for planting depth, skips, yields, and quality. **The automated planters tended to have more planting skips, especially the Agriplanter. However, skips were mostly small. Planter type did not affect yields or quality in any of the three field trials.**

In the second part of this study, a combination of observations from the trial and interviews with equipment distributors, growers and custom planters is employed to do a cost-benefit analysis for the different planter types. Results include:

1. A table comparing average selected costs for each planter type
2. Case studies of purchase, labor, and maintenance costs from two custom planters
3. An analysis of strengths, weaknesses, opportunities, and threats associated with each

II. Methods

Field trial design

Large replicated side-by-side trials were planted in three fields, each with different growers, locations, varieties, and planting dates and conditions. All planters were tested in the three-row configuration. Transplants for each planter were randomly chosen from the lot supplied to the grower for planting the whole field. Plants came from a different transplant house for each field but were generally a good size, healthy, and fairly uniform within the trays. Trial planting in all fields started around 7:00 am. Agriplanter rows were planted by each grower, using their own machine and crew. The other planters were operated by custom transplant businesses accustomed to their use, using their own machines and crew.

Field site	Winters	Dixon	Clarksburg
Variety	SVTM 9034	H 2016	SVTM 9016
Planting date	March 27, 2024	May 8, 2024	May 17, 2024
Temp at planting (Low/High °F)	47° / 60°	58° / 82°	52° / 80°
Avg transplant height & variability*	6” (CV=9.8%)	4.6” (CV=10.2%)	5” (CV=16.2%)
Harvest date	July 24-25	Sept 11-12	Sept 29-30
Trial size	19.8 acres	13.8 acres	18.1 acres
Main soil type	Silt loam, silty clay loam	Silty clay loam	Clay
Site-specific challenges	Heavy bindweed and vine decline in one replicate	Strong north wind whole of planting day	Weed pressure, early-season irrigation challenges

* *“Height”= plant height in the tray from the soil line to the growing tip. Variability measured as coefficient of variation (CV=standard deviation/average*100)*

Three replicates were planted per field, using a layout that allowed for harvest in a carousel pattern (Figure 1). Each replicate consisted of two passes of each three-row planter (6 rows * 3 replicates = 18 rows per planter field). Planter order was randomized within each replicate separately, so that no planter would always be at the center or outside position.

Finger (3 rows)	AgriP (3 rows)	Futura (3 rows)	FMAX (3 rows)	FMAX (3 rows)	Futura (3 rows)	AgriP (3 rows)	Finger (3 rows)

Figure 1. Example design of one replicate in one field. There were three replicates in each field.

Cost study design

In consultation with Dr. Brittney Goodrich, an agricultural economist formerly working with the UC Davis Cost & Return Study team (now working for the University of Illinois), two surveys were developed. One contained questions for the manufacturers and distributors, and the other for growers or custom planters with experience using the machine in question. In the case of the Futura, the custom planting business is also the US distributor for Ferrari, so in this case the two questionnaires were administered to the same team (MTD Transplanting). Other interviewees were Eric Puehler (of Puehler Ag, the US distributor for AgriPlanter), and Ray Yeung, who uses the AgriPlanter, FMAX, and finger planter in his custom transplant business and on his own farm. I also interviewed a grower who is using the 5-row configuration of the AgriPlanter, although this was not a part of the field study, given local interest. I received additional input from two local growers using the 3-row AgriPlanter.

Surveys contained questions concerning costs such as purchase price, labor needs, maintenance costs, and resale value, as well as more general questions about special challenges associated with the machine, or conditions under which it performed especially well or poorly. Since the automated planters are relatively new some information which would be part of a formal cost study, such as lifespan and end-of-life resale value, are not available.

III. Field Trial Results

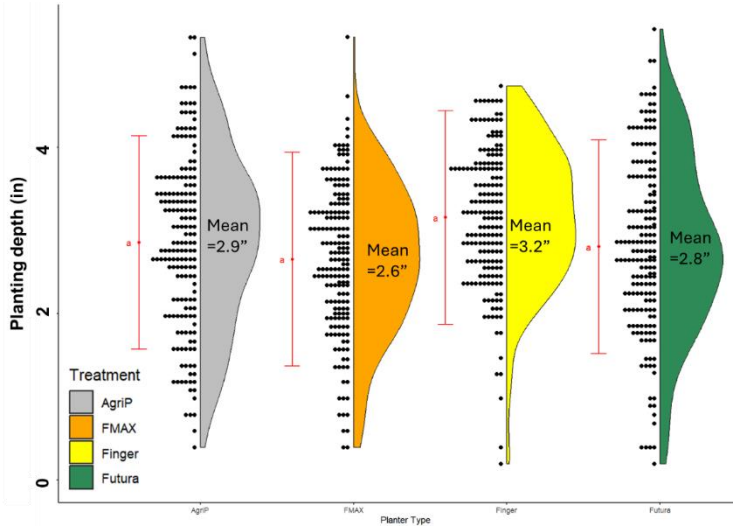

Figure 2. Range, mean, and variability of planting depth in the 2024 field trials. Black dot = one plant measurement.

Planting depth

Planting depth was calculated by subtracting an average plant height (obtained by measuring the distance between soil line and growing tip of five random plants in three random trays from each transplant box that was used to supply each planter) from the height of each of ten random plants measured along one row of each pass

In each of the three 2024 field trials, all planters had a similar planting depth ($p>0.05$). They also all had similar variability at all sites ($p>0.05$ for Levene’s test of homogeneity of variance). Figure 2 shows the combined data for all three sites in 2024.

This is in contrast to the results from the 2023 trial, in which the finger planter planted at a greater depth and with less variability than the Agriplanter or FMAX (the Futura was not included in the 2023 trial). These results show that while there can be differences depending on site-specific operating conditions, there very likely aren't any intrinsic issues with any of these machines that would make planting depth different or more variable than the others.

Planting skips

Normal / grower practice for replanting was followed for all planters-- for the finger and FMAX planters at all sites, workers followed behind filling in skips by hand. At the Winters site only, the grower filled in any long skips behind the Agriplanter using a single-row planter. Planting skips were counted just after planting on one entire row per pass (6 rows per planter per field).

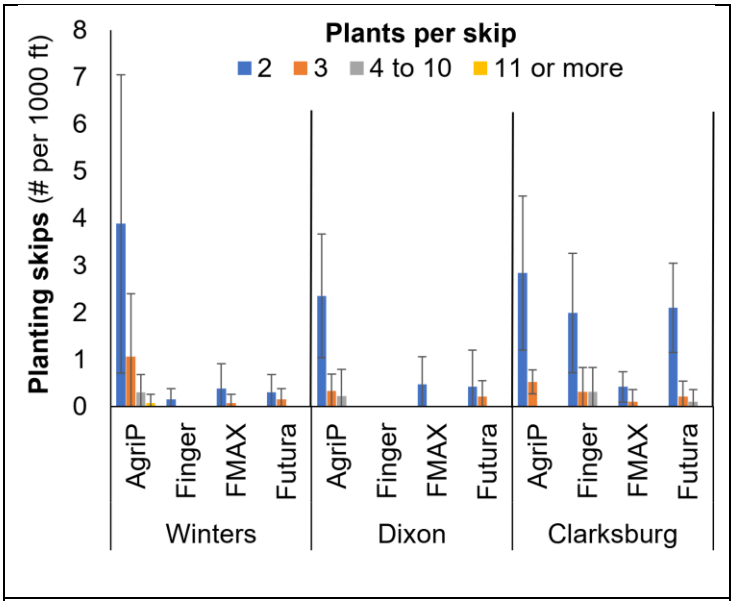

Figure 3. Skips approximately the length of 2 plants or greater, measured immediately after planting

For the skips counted immediately after planting, the Agriplanter generally had more 2-plant or greater skips than the other planters. At the Clarksburg site, the Futura had the greatest number of single-plant skips (not shown). However, all skips greater than 2 plants were relatively infrequent, on average less than one per thousand feet (Figure 3). Only one skip greater than ten plants was measured; a 40-ft skip in one of the Agriplanter rows at the Winters site.

Stand establishment was measured by drone on entire replicates about 3 weeks after planting. Skips were counted in a randomly chosen 1000-ft segment of each bed near the center of the field.

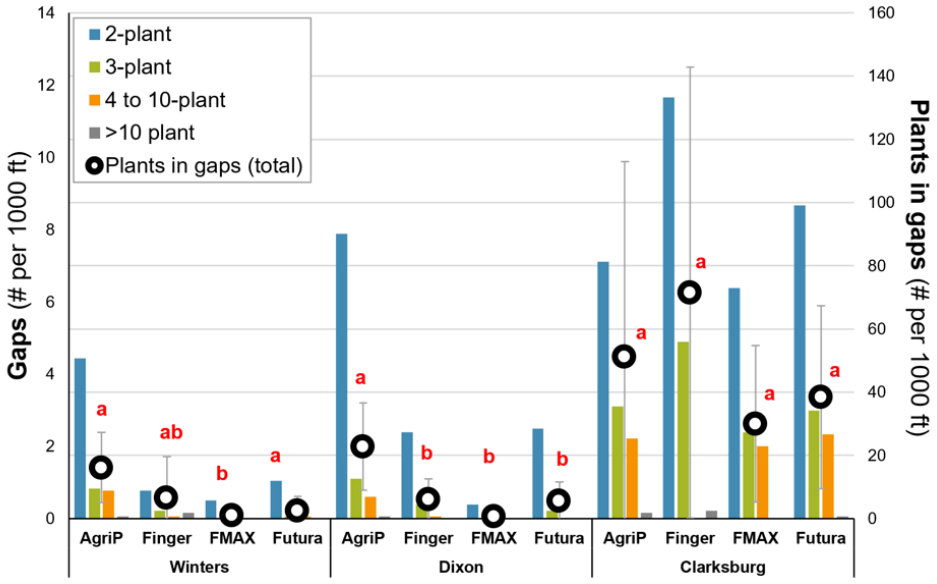

Figure 4. Gaps measured from 1000-ft segments of drone imagery

Mortality was relatively low at the Winters and Dixon sites. At the Winters site, the AgriPlanter and Futura both had significantly more plants in gaps than the FMAX, while at the Dixon site the AgriPlanter had more plants in gaps than all other planter types. However, as with planting skips, there were few gaps greater than 2 plants wide (less than 1 per 1000 feet). At the Clarksburg site, an irrigation issue led to a patchier stand in some rows, increasing the number of skips in all planter types. There were no differences among planters types at this site.

Yield and quality

Neither total nor paid yield differed among the four planter types at any of the three sites (Figure 4). At the Winters site, there was a slight tendency for the Futura rows to have fewer greens (p=0.08); otherwise, there were no significant fruit quality differences among the planter types.

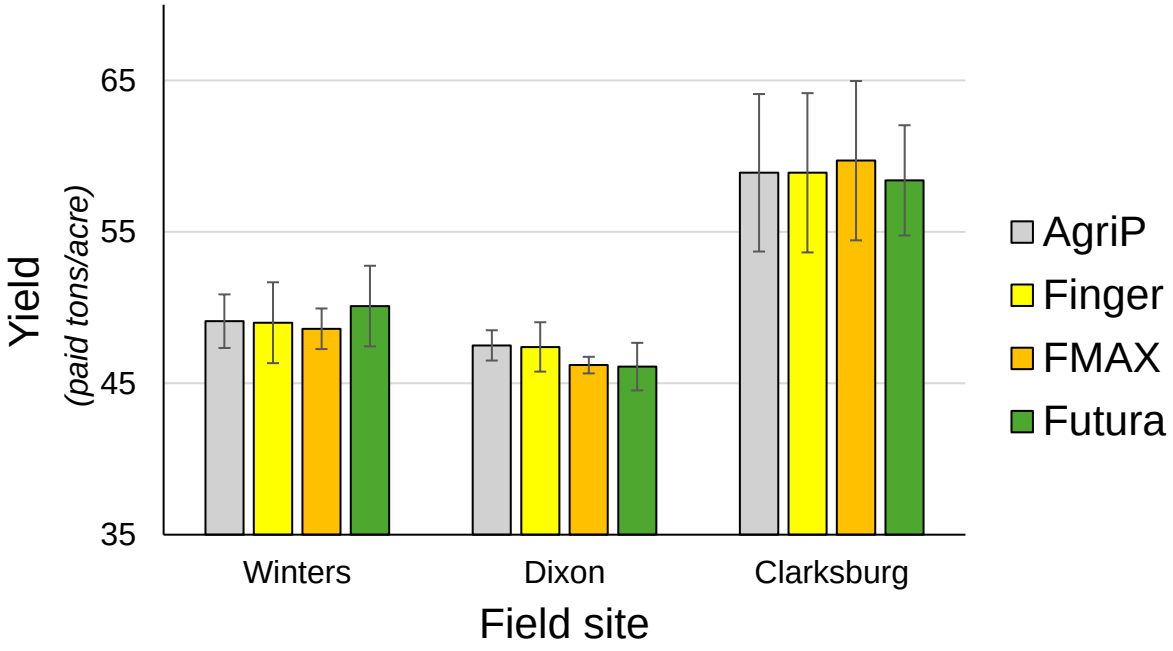

Figure 4. Average paid yields at the three field sites.

Yields and quality were obtained PTAB grades from the processor for each unmixed load from each replicate. Overall, the variation between fields (combined effect of variety, planting date, and other management and site-specific factors) and the variation between the replicates within a field were much greater than the differences between planters (Fig. 5). For example, in the Winters field, the first replicate (red dots) had issues with bindweed and decline which had a much stronger yield affect than planter type.

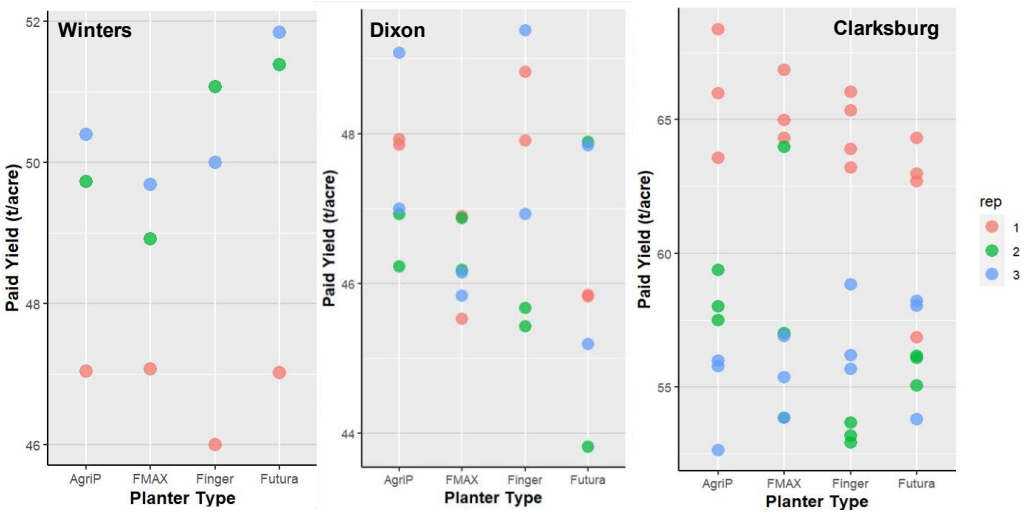

Figure 5. Yields for each planter, separated by replicate. Each dot represents a load (or the average of 2 or more loads, for the Winters site).

There were no differences among planter types in fruit quality or cull percentages.

IV. Cost comparison

In the second part of this study, a combination of observations from the trial and interviews with equipment distributors, growers and custom planters is employed to do a cost-benefit analysis for the different planter types.

Table 1. Planter speed, crew size, and calculated acres per man-hour as observed in the field trials

	AgriP 3-row	Futura 3-row	FMAX 3-row	Finger 3-row
Speed (mph; measured from 2 passes, 1 turn)	1.4 - 2.8	1.0 - 1.3	0.79 - 1.1	0.8 - 1.4
Crew size*	2 - 3	2	5 - 6	8 – 10
Acres/ man-hr (active time)**	1.3 - 2.5	0.9 - 1.3	0.3 - 0.4	0.2

* As observed at field trials. Not including water truck and forklift operators

** Calculated using observed crew size, pass length, and measured speed over 2 passes and one turn (3 replicates in 3 fields, n=9).

Table 2. Estimated costs, from grower & distributor interviews. ***Costs reflect only those directly associated with the machine itself, not the full cost of the planting operation.*** *Calculations exclude forklift/water truck operator.*

		AgriP 3-row	Futura 3-row	FMAX 3-row	Finger 3-row
	Acres per shift (seasonal avg)*	16 – 30	10 – 20	10 - 11	11 - 12
	Shift length (hr)	10 – 12	8	8 - 8.5	8 - 8.5
	Acres/ man-hr (seasonal avg)**	0.5 - 0.9	0.4 - 0.8	0.2 - 0.3	0.1 - 0.2
	Avg crew wage($/hr)***	$80	$80	$137	$205
	Avg labor cost ($/acre)	$29 – 44	$32 – 43	$100 - 117	$137 - 145
	Estimated diesel cost ($/acre)[$]	$5.44 - $7.25	$7.16	$4.63	$3.86
	Estimated maintenance cost ($/acre)[$$]	$3.00	$5.10	$4.50	$7.00
	Total average running costs ($/acre)	**$45.85**	**$49.76**	**$117.63**	**$151.86**
Cost per acre (5-year depreciation schedule)	Example purchase price	$352,000	$198,000	$63,000	$7500 (used)
	1000 acre/yr	$116.25	$89.36	$130.23	$153.36
	1500 acre/yr	$92.78	$76.16	$126.03	$152.86
	2000 acre/yr	$81.05	$69.56	$123.93	$152.61

*Grower and distributor-reported seasonal estimate (integrates breaks, cleaning, maintenance)

** Calculated using grower estimates of daily acreage, crew size, and shift length; not including water truck/forklift
Assumes 3 crew on automated planters

*** Calculated using averages of grower-reported wages for farm and contract labor
(Contract wage: base: $16; supervisor: $18; contract fee: 42%. Farm wage: base: $19, machine-operator: $22; benefits: 35%)

[$] Calculated using grower reported diesel usage (per hour or per acre), California 5-yr average diesel cost of $4.63/gal

[$$] As reported by Ray Yeung (AgriPlanter, FMAX, Finger) and Todd Diederich and Brad Strock (Futura)

Table 3: Operational case studies from two custom planting operations (MTD Transplanting & Kubo Yeung Farms)

		Futura (3 row)	AgriPlanter (3-row)	FMAX (3-row)	Finger planter (3-row)
Purchase & equipment	Purchase costs	$198,000 (includes training)	$335,811 - $368,195 (lower costs for purchases Jan-May; includes training)	$63,000	~$7500 at auction.
	Weight	4500-4600 lb	~7500 lb	~3000 lb	~3000 lb single-line, 4500 lb double-line
	Tractor needs	70-90 hp, 540 PTO and 3-point hitch	160-175 hp; PTO depends on what grower wants to carry for water (200 for 1000 gal)	125 hp	125 hp
	Additional equipment	Common add-ons include rubber rollers to promote good soil-plug contact, custom built bin rack	Requires a variable-rate GPS, pressure washer for regular cleaning, appropriate pump	Quick hitch	
	Updates	Most updates are to the software, and the cost to the consumer is minimal	Currently supplied at-cost through distributer		
Speed & labor	Crew size	2-4 (1 driver, 1 crew on own farm; more if using for custom planting)	3 (driver, 2 on machine)	5.5 (1 driver, 3 contract labor planting, 1 supervisor. Mechanic, half-time)	8.5 (1 driving, six contract labor planting, 1 supervisor. Mechanic, half-time)
	Acres / day	10-20 acres per 8-hr day	16-20 acres per 10-hr day	10-11 acres per 8-hr day	11-12 acres/8-hr day
	Acres/ man-hr	0.4 - 0.8 (assumes 3-man crew)	0.5 - 0.7 (assumes 3-man crew)	0.2 - 0.3	0.18 - 0.19
	Avg labor cost/acre	$44/acre	$41/acre	$109/acre	$142/acre
	Reasons for a slower day	Higher planting density, short field length	Cracked/broken trays. When they first started the average was closer to 13-15 acres per day, but speed has increased as they learn how to run it better, make adjustments	Tall, tangled plants; poor plant quality	The machine rarely has problems; the more important issue is managing the people and cars
Inputs & maintenance	Diesel (estimated)	Diesel use estimated about 1.5 gal/acre (~4-4.5 gal/hr). Hauled by 90 hp tractor.	Diesel use estimated 22-25 gal/day; 1.2-1.5 gal/acre at 16-20 acre/day. Hauled by 160 hp tractor.	Estimated diesel use is about 0.95 gal/acre; hauled by 125 hp tractor.	Estimated diesel use is about 0.8 gal/acre; hauled by 125 hp tractor.
	Seasonal maintenance	~$5 per acre. Replacement shoes are the only regular wear item, at $320 per row, replaced about every 200 acres	~ $3.00/acre . Bearings, belts are regular replacement items. Shoes are about $400/row, replaced about every 2500 acres	~ $4-5/acre; shoes are regular replacement items	~$7/acre (rubber plant holders, chains, fingers, shoes, guides, wheels)
	Service visits	Service visits are $130-$180 per hour, but they have not had any issues yet that can't be fixed with a phone call	The distributer comes to do the winterazation, at a charge of $200/hr. The bill for a major servicing, after around 5000 acres of use, was $5000-$6000	Service visits haven't been needed	Service visits haven't been needed

A SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis to capture less quantifiable issues. This analysis summarizes internal (strengths, weaknesses) and external (opportunities, threats) factors which may positively and negatively affect machine's success

Agriplanter:

Strengths:
Highest measured speed of all planters in this study, lowest per-acre operational cost (particularly for the 5-bed model). High speed also means fewer engine-hours on the tractor. Low labor requirement, good customer support, uses standard trays. May require less water than finger planter. Rapidly developing technology; updates made available at cost to existing customers. High degree of adjustability (specialized expertise is needed and there's a learning curve, but distributer willing to work closely with the grower).

Weaknesses:
Cracked trays greatly reduce speed and performance; also has some difficulty with non-uniform/ leggy/ saturated plants. Higher skip rate than other tested planters (however, likely doesn't affect tomato yields). High speed translates to a greater probability of long skips, though with an experienced crew these are less likely. Compared with other planters, not as adaptable to conditions of poor bed prep or non-level ground. Cannot change row configurations. Highest purchase price; large units also need powerful pump, tractor.

Opportunities:
Labor costs are likely to rise and availability to fall, labor savings therefore likely to increase rather than otherwise. As more growers acquire automated machines, nurseries are more likely to invest in providing plants that work well with them.

Threats:
Successful use depends on availability of appropriate plants/trays, good company support, and skilled, experienced operators. If these become less available, the planting speed will be slower and may do a poorer planting job.

Futura:

Strengths:
Combines low labor requirement with medium speed, lower cost than other automated planters available. Adaptable to many different crops. Lower number of skips and more even spacing than Agriplanter; if a roller is used, may be more adaptable to poor bed prep or less level conditions. Existing customers get updates as they become available. Does not require a pump. Narrower shoe may give better plug-soil contact and reduces early heat damage risk—not tested by this study, but did see some evidence in 2023 with the FMAX, which uses the same shoe.

Weaknesses:
Has difficulty with leggy plants. Not as fast as the Agriplanter, potentially translating to higher per-acre labor costs. A special shoe is needed, which may increase routine maintenance costs. In processing tomato, data suggests even spacing and low skip rate don't necessarily result in a yield advantage

Opportunities:
Labor costs likely to rise and availability to fall, labor savings therefore likely to increase rather than otherwise. As more growers acquire automated machines, nurseries are more likely to invest in providing plants that work well with them. If climate change increases risks of planting into hot weather, it's possible the narrower shoe and more targeted water delivery system could give an agronomic advantage. However, this needs to be tested.

Threats:
Successful use depends on availability of appropriate plants, good company support, and skilled, experienced operators. If for some reason these are not available it is less likely to succeed.

FMAX

Strengths:
Fewest skips of all planters tested. In the 2023 pilot trial FMAX rows had less heat damage than the other tested planters (finger and AgriPlanter), possibly due to narrow shoe which is designed to increase plug-soil contact and plug contact with transplant water. Adaptable to many crops, bed configurations, planting conditions. Can change plant spacing more quickly than the finger planter. Accommodates cracked trays. More output per person than finger planter, less training necessary, may need less water.

Weaknesses:
Slowest of the tested planters. Higher labor requirement than automated planters, requires contract labor. Does not perform well on hard clay soils. Less adaptable than the finger planter, requires better ground prep. Special shoes wear faster and increase maintenance costs.

Opportunities:
If incidence of hot weather during planting increases, it's possible the narrower shoe and more targeted water delivery system could give an agronomic advantage. However, this needs to be tested

Threats:
Increasing cost and decreasing availability of contract labor. Also, if more customers move to automated planters, which can't deal with non-uniform or leggy plants or cracked trays, it's possible nurseries will start assigning poorer quality plants to customers using non-automated planters

Finger

Strengths:
Most adaptable of all the planter types (e.g. if in-field adjustments are needed for planting depth). Least sensitive to hard or rocky soils, or poor bed prep or plant quality. Wide, robust shoe, wears less quickly than that of the FMAX. Used for many crop types, bed configurations, planting conditions. The machine is the least expensive to purchase.

Weaknesses:
Highest labor requirement of the tested planters; contract labor necessary. Labor has to be trained and skilled. Many people at planting leads to a lot of cars, traffic, and confusion, can also be a safety risk to the workers. Wide shoe may lead to poorer plug soil contact and pooling of transplant water at the bottom of the transplant furrow; meaning more water may be required. Relatively high maintenance cost, as cited in case study.

Opportunities:
As processing tomato production expands to areas where it's less typical (e.g. into Northern California, Washington), adaptability to non-ideal plant and soil conditions and utility for many vegetable transplants may be an advantage

Threats:
Increasing cost and decreasing availability of contract labor. Also, if more customers move to automated planters, which can't deal with non-uniform or leggy plants or cracked trays, it's possible nurseries will start assigning poorer quality plants to customers using non-automated planters

V. Conclusions

Trial results suggest that under a range of representative growing conditions for high-yielding processing tomato production in the southern Sacramento Valley, planter type is unlikely to influence fruit yield or quality. While the automated planters (especially the Agriplanter) have more frequent skips, they were small and rare enough that they didn't influence yields. However, while planting conditions were different in all three fields, it's important to note that:

1. Each machine was operated by a grower and planting crew experienced in its use
2. Apart from the high wind at the Dixon site, planting conditions were generally good (e.g. moderate temperatures, excellent bed prep, generally good quality transplants and trays.)
3. All three fields were flat, did not have major differences in soil type or drainage, and did not have any complicating surface conditions such as stones or undecomposed biomass.

It's possible that some of the planters would be more affected than others by having less experienced operators or more challenging planting conditions. For example, growers who have worked with the Agriplanter for a couple years report that cracked trays or uneven plant heights pose special challenges for the planter's automation. As a next step, I'll be compiling a list of factors especially likely to affect the performance of each planter type, as well as a rough cost-benefit analysis.

Costs and savings

Our cost example for the AgriPlanter is likely conservative, as the data comes from a business which mostly uses it in custom planting. This business normally runs AgriPlanter with a somewhat larger crew and more slowly than is typical (based on conversations with other AgriPlanter growers). On average for this business, the 3-row AgriPlanter saves around $106/acre in operational costs compared with the 3-row finger planter. Over 1500 acres/yr, at this rate the AgriPlanter would pay itself off in about 2.2 yr. (For comparison, another local grower who uses it calculated a savings of $230/acre in labor compared to his 2022 labor costs with the finger planter). Another local grower, who replaced two 5-row finger planters with a single 5-row AgriPlanter, reports spending $22,000 in parts and labor on planting in 2024. Compared with the calculated labor cost alone with the finger planters, this represents a savings of $237/acre. Assuming the same wages and crew size as that reported for the 3-row AgriPlanter, the savings of a Futura over a 3-row finger planter are calculated to be around $102/acre, which over 1500 acres would pay itself off in around 1.3 yr. This also may be conservative, as it is also based on data from a custom planting operation which uses larger crews for a custom planting job than is recommended for someone planting on their own farm.

Lifespan & resale value

There is insufficient data on the lifespan and resale value of the automated planters. The oldest Agriplanters in use in California were purchased in 2021. The AgriPlanter US distributor, Puehler Ag, reports that they are aware of a machine in Italy which has been running for 22 years. They estimate that an Agriplanter could be sold for about 25% of the original cost after 20 years of use with reasonable maintenance. Shoes, belts, and bearings all need regular replacement, and the hydraulic pump also will need replacement at some point. The US distributor for the Futura, MTD Transplanting, said it was difficult to give an estimate for the lifespan since the machines are rebuildable and repairable. They estimate that a major overhaul may be needed every 10 to 12 years on a planter doing 1000 acres per year, and that a used Futura would probably sell for about 60-70% of its original purchase price.

Other concerns: plant quality, training needs, machine weight, available configurations

For both automated planters, the distributors emphasize that success depends on good communication with the nursery. For both planters, tall and leggy plants and poor uniformity can lead to problems, and for the Agriplanter cracked and broken trays are also a major issue. These can lead to slower days and long skips. Both also noted that it's very important to have someone on the machine who is well-trained and

motivated to learn. Both Puehler Ag for AgriPlanter and MTD Transplanting for Futura offer staff trainings as part of the purchase price, as well as continuing support over the phone.

Automated planters are large, heavy machines, and the potential for delayed field entry or soil compaction was one of the initial concerns for their use. Weights are reported in Table 3. However, the users I spoke with report that the weight seems well-distributed and they have not had issues so far.

All planters were tested in the 3-row, single-line configuration, as all planters needed to be in the same configuration and this is the most common locally for the Agriplanter. However, for both Agriplanter and Futura other configurations (e.g. 5- or 6-row, double-line) can be requested.

Want more information?

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