The WG CENTER for Innovation & Technology™

WESTERN GROWERS
CASE STUDY

CARBON ROBOTICS

Published March 2024

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FIGURE OUT THE **FINANCIALS FOR YOUR FARM**

If you'd like to do the math for any automation equipment or technology on your farm, please contact the **Innovation Team** at **innovation@wga.com**.

We can provide you with Excel templates and we're also hiring interns that we can pair you with to help you conduct an ROI analysis and calculate your costs vs. savings.

About the Technology:
AN INDUSTRY-FIRST INNOVATION

Carbon Robotics LaserWeeder

CARBON ROBOTICS

The LaserWeeder is a first-of-its-kind, commercially available technology to use lasers for terminating weeds. The 20-foot-wide implement is equipped with 30 carbon dioxide lasers — capable of firing every 50 milliseconds — along with high-resolution cameras and Machine Learning/Deep Learning (ML/DL) technologies, to identify and differentiate between crops and weeds. Operated with an iPad, anything not identified as the keeper plant is shot with a laser and killed at the meristem. The LaserWeeder can be used for weed control in over 100 specialty conventional and organic row crops and has a lifespan of 7-10 years.

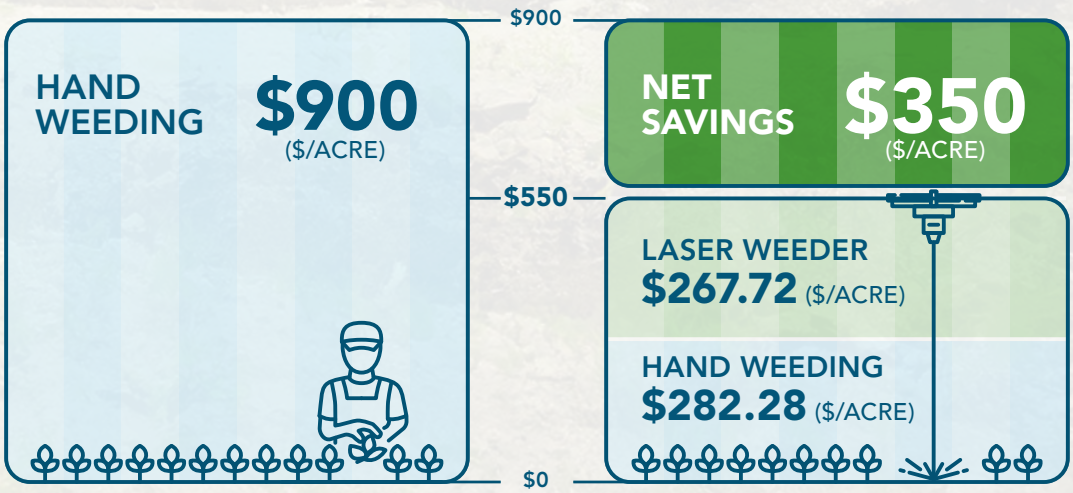
Specialty Row Crop Farms
CUT WEEDING COSTS BY ~40% WITH LASER WEEDING

After one year of running Carbon Robotics' LaserWeeder implement, Braga Fresh and Triangle Farms were able to save significantly on their hand-weeding costs.

In this case study, we'll look at how laser weeding impacted both operations, and the annual savings the farms will realize after a 5-year depreciation schedule, if they continue operating the LaserWeeder on the same crops and acreage.

BASE ON THE FOLLOWING CROPS:

Spinach, Cilantro, Arugula, Swiss Chard, Baby Kale, Red Spring Mix, Green Spring Mix, Mizuna.



Source: Based on Braga Fresh provided data.

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Braga Fresh is a third-generation family farm that grows over 30,000 acres of organic and conventional specialty row crops throughout California, Arizona, New Mexico, and Mexico.

Primarily growing organic baby leaf crops, they don't have any options for crop protection products, so eliminating weeds prior to the LaserWeeder was completely done by hand. Braga Fresh accomplished this with three crews of 25 employees. It would take them an average 90 minutes per acre at an average cost of $900 per acre.

"Hand weeding is a very tedious and hard job, and trying to find labor to help us get that done is getting harder every year," says Kyle Harmon, Director of Farming. "Having large organic acres, we needed to find a solution to help us be more efficient."

Carbon Robotics' LaserWeeder was the first viable solution Harmon saw on the market that could control weeds in high-density organic crops, so Braga Fresh decided to run some trials with it. The results left them impressed.

LASER WEEDING BY THE NUMBERS: COSTS AND SAVINGS

- Braga Fresh ran two LaserWeeders to cover 4,700 acres, or 2,350 acres per machine, of high-density organic crops: spinach, cilantro, arugula, swiss chard, baby kale, red and green spring mixes, and mizuna. All numbers presented below are based on one machine.
- Braga Fresh purchased the LaserWeeder for $1.2 million, which on a 5-year depreciation schedule over 2,350 acres annually breaks down to a per-acre cost of $102.13. Braga Fresh uses two operators to run the machine, and with the additional expenses of hardware and Over-The-Air (OTA) service, tractor, fuel, and logistical operations, it costs a total $267.72 per acre to run the implement (see Table 1 for complete breakdown of costs). Running the machine an average 18 hours a day, 6 days a week, Braga Fresh is able to cover an average 0.8 acres per hour.
- Braga Fresh found the LaserWeeder to be very effective at killing weeds and volunteer crops like baby lettuces. Harmon says some of the crawling weeds, like goosefoot, can be tougher to control because it has multiple growing points. But of the typical weeds they encounter in the Salinas Valley — purslane, malva and lambsquarter — it successfully terminated.
- Initially the LaserWeeder was accidentally shooting Braga Fresh's arugula crop because of how different each arugula variety can look at different growth stages. But it only took a day and half for Carbon Robotics to identify the arugula varieties Braga Fresh was growing to update their model. Harmon says Carbon Robotics is

> *"The amount of information is almost unlimited at this point. Now we're just trying to figure out how to use it all."*
>
> — Kyle Harmon, Braga Fresh, Director of Farming

continuing to update their models faster — usually within a few hours; at most 24 hours — especially as more customers use the machine.

- The LaserWeeder does not kill every weed, so Braga Fresh still had to do some follow-up hand weeding. But now they only need three crews of 18, allowing them to reallocate the other 21 employees to other critical farmwork like harvest, a task they were experiencing a labor shortage on. The hand-weeding crews can now go through the fields at a rate of 12-15 minutes per acre (4-5 acres per hour) after the LaserWeeder pass, whereas it used to take an average 90 minutes to weed one acre without the LaserWeeder. As a result, Braga Fresh reduced their per-acre hand-weeding costs to $282.28. This brings their total per-acre weeding costs to $550 an acre, for a per-acre net savings of $350 compared to hand-weeding alone.
- Across 2,350 acres, one LaserWeeder brings an annual weeding cost savings of $822,500, a 39% reduction over hand-weeding alone. Continued operational costs after the depreciation of the implement and tractor are predicted to be $148.14 (see Table 3), which will decrease weeding costs to $430.42 per acre, for a per-acre net savings of $469.58 (see Table 4).

ADJUSTING MANAGEMENT FOR LASER WEEDING

Adding the LaserWeeders did require some changes to farm practices.

"If you get to a field too early, you can sink because the machines are heavy.[1] But if you get there too late, the weeds are too big and the lasers cannot kill them," Harmon says. "Getting in the field 7-10 days after germination is ideal because it'll give you the most efficient kill."

They've now staggered their planting out to ensure they're not planting too much on the same day, otherwise the LaserWeeder would not be able to get to enough acres at the ideal time. They also break bottoms a day earlier, to make sure their furrows are going to be firm enough to handle the weight.

"It took us a little bit to figure those things out," Harmon says. "But once we got that dialed in, we just hit the ground running."

DATA COLLECTION AND CUSTOMER SUPPORT

Now Braga Fresh is starting to figure out how to tap into an additional benefit of the LaserWeeder: data.

The LaserWeeder provides its customers with the number of weeds shot, weeds seen, weeds skipped, stand counts, averaging spacing for plants, plants per acre, and heat maps, so they can see where their weed hotspots are. This has allowed Braga Fresh to do things like an extra pre-irrigation to germinate the weeds before they run the LaserWeeder, so they're now seeing a population decrease in their weed seedbank.

"The amount of information is almost unlimited at this point," Harmon says. "Now we're just trying to figure out how to use it all."

In addition to its weed-killing abilities and data collection, Braga Fresh has been impressed with Carbon Robotics' customer support. Harmon says they've been proactive in working with their customer base to see how else they can help them, and they're very reliable whenever Braga Fresh runs into a problem, whether it's over the phone or coming out to the field.

"The customer service has been unparalleled," Harmon says.

1. The combined weight of the LaserWeeder and tractor is over 20,000 pounds. Carbon Robotics does offer the Track LaserWeeder for better weight distribution and to help reduce compaction at an additional cost.

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> — Kyle Harmon, Braga Fresh, Director of Farming

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Table 1. Braga Fresh's Costs for Running One LaserWeeder (Assumes a 5-year depreciation schedule)

	$/ACRE	HARD COSTS
Implement	$102.13*	$1,200,000
Hardware & Over the Air (OTA) Service	$37.45	$88,000
Tractor	$17.45	$205,000
Fuel	$20.57	4.6 gal/hr at $5/gal
Operators (Loaded) (2x)	$70.12	2 operators at $25/hr
Logistical Operations (moving)	$20.00	Trucks, Trailers, Etc.
TOTAL PER ACRE COST =	**$267.72**	

Table 2. Organic Crops Braga Fresh Weeded with LaserWeeder

Spinach	**Baby Kale**
Cilantro	**Red Spring Mix**
Arugula	**Green Spring Mix**
Swiss Chard	**Mizuna**

Table 3. Braga Fresh's Expected Post 5-Year Depreciation Costs

Hardware & Over the Air (OTA) Service	$37.45	$88,000
Fuel	$20.57	4.6 gal/hr at $5/gal
Operators (Loaded) (2x)	$70.12	2 operators at $25/hr
Logistical Operations (moving)	$20.00	Trucks, Trailers, Etc.
TOTAL PER ACRE COST =	**$148.14**	

Table 4. Braga Fresh's Pre- vs. Post 5-Year Depreciation Costs

	HAND WEEDING COST ($/ACRE)	LASER WEEDER COST ($/ACRE)	TOTAL COMBINED WEEDING COSTS ($/ACRE)	NET SAVINGS ($/ACRE) From Domestic Only Hand Weeding Labor
Pre-Depreciation Costs	$282.28	$267.72	$550.00	$350.00
Post-Depreciation Costs	$282.28	$148.14	$430.42	$469.58

*Set to a 5-year depreciation schedule

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Triangle Farms is a 10,000-acre conventional and organic specialty crop farm based in Salinas, Calif. It is part of the JVSmith Company, which has a total of 40,000 acres across farms throughout California, Arizona, Colorado, New Mexico and Mexico.

Prior to the LaserWeeder, Triangle Farms relied on H-2A labor provided by a labor contractor for hand weeding. They were leveraging a substantial number of people to hand weed and certain crops, like their organic baby leaf and carrots, needed to be weeded multiple times. This resulted in very high hand-weeding costs, ranging from $500 to $1,800 per acre, depending on the crop (see Table 5). With labor availability and costs going up 7-15% year-over-year, Triangle Farms was seeking any possible solution.

JVSmith purchased two LaserWeeders to run on their organic carrots, onions, spinach, salanova oakleaf lettuce, arugula, and direct-seeded romaine lettuce acres for farms in California, Colorado and Arizona. For this case study, the ROI analysis was conducted only on the acres in the Salinas Valley, where the LaserWeeder was used February through September. In those eight months, Triangle Farms not only reduced their weeding expenses with the LaserWeeder, but they also improved yield and reduced their weed seedbank.

LASER WEEDING BY THE NUMBERS: COSTS AND SAVINGS

- Triangle Farms looked at how one LaserWeeder impacted their weeding costs and savings for 1,108 acres of organic spinach, salanova oakleaf lettuce, arugula, and direct-seeded romaine lettuce
- The annual cost of running a LaserWeeder over 1,108 acres on a 5-year depreciation schedule averages out to $216.61. Triangle Farms leases the John Deere tractor used to run the implement for $2,500 a month, for a per-acre expense of $27.07. Triangle Farms also runs a 3-person crew for the LaserWeeder: two operators, which are H-2A labor they've trained, along with a supervisor. Taking these costs along with fuel, hardware and Over-The-Air (OTA) service plans, and logistical operations (see Table 6), comes to a total cost of $448.73 per acre to operate the LaserWeeder. Triangle Farms is able to cover approximately 0.7 acres per hour with the LaserWeeder, running an average of 18 hours of coverage per day, 6 days a week.
- Running the LaserWeeder reduced Triangle Farms' contracted H-2A hand-weeding costs to $135 per acre on organic spinach and $120 on organic salanova oakleaf lettuce, for a per-acre savings of $416.27 and $1,231.27, respectively. They did not need any additional hand weeding completed on organic arugula after running the LaserWeeder while

> *"You're not only buying the equipment, you're buying the experience, you're buying the support."*
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> — Josh Roberts, Triangle Farms, Former President

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doing their food safety inspection pass, which saved them $251.27 per acre. Josh Roberts, former president of Triangle Farms, says this is because it only takes 18-24 days to harvest arugula, so the crop was able to outgrow any remaining weeds after one pass with the LaserWeeder.

- Weeding on the organic romaine lettuce costs were $88.73 more per acre with the LaserWeeder than hand-weeding alone, but Roberts says this was due to thinning the romaine lettuce (see Table 7). The value of doing both thinning and weeding at the same time is something that is still being explored. Triangle Farms found that a Stout Smart Cultivator, which was purchased in 2019, as well as Farmwise's smart cultivating as a service, were more cost effective in removing weeds in their romaine lettuce.[2]
- Because they saw significant savings with the other crops, Triangle Farms still reduced their per-acre weeding costs across all four crops by $388.34, resulting in a total annual savings of $430,277.16, a 40% reduction compared to contracted H-2A labor alone.
- After the 5-year depreciation schedule, Triangle Farms' continued operational costs of running the LaserWeeder are predicted to reduce to $232.12 per acre (see Table 8), which will increase Triangle Farms' per-acre savings to $604.95.

YIELD IMPROVEMENTS & REDUCED SEEDBANK

The LaserWeeder's ability to eliminate weeds effectively has also allowed Triangle Farms to increase some of their yields, particularly with organic spinach and multi-leaf lettuces — usually around 10-15%, but sometimes as high as 50%.

Roberts says this yield increase comes in the form of recoverable product. Historically, some fields would have such a high amount of weeds, they would skip harvest and just disc the field, because it wasn't worth putting a hand crew in to weed.

The LaserWeeder has also helped yields because it causes less crop damage than hand-weeding. Now hand crews only go in the fields closer to harvest for final cleanup and food safety inspections, which is less invasive and a much faster process.

In addition to improving yields, Triangle Farms has seen a reduction in their weed seedbank, which was a big reason they opted for the LaserWeeder. Hand-weeding propagating weeds like purslane would not completely eliminate the weed, because of its ability to reroot. But the high-powered carbon dioxide lasers are able to completely destroy the weed seed and weed base.

"It was important for us to not only weed at a relatively low cost, but that we would improve our weed-to-plant ratio over time by reducing the weed seed count in the soil," Roberts says.

CUSTOMER SERVICE HELPS OVERCOME CHALLENGES

Like Braga Fresh, Triangle Farms also had to make some management changes to incorporate the LaserWeeder. Typically the farm would still be heavily irrigating when they would need to run it, but due to the size and weight of the machine, they needed to be strategic about when they water. Roberts notes this was more of a learning curve than a big challenge to overcome. The only other negative the farm has encountered is the travel speed of the implement. Roberts says in high-density crops it averages 1 acre per hour, while it can reach higher 3-4 acres an hour in other crops.[3]

"It was important for us to not only weed at a relatively low cost, but that we would improve our weed-to-plant ratio over time by reducing the weed seed count in the soil."

— Josh Roberts, Triangle Farms, Former President

Triangle Farms also has smaller fields and needed to figure out a way to transport the LaserWeeder. Carbon Robotics developed a custom trailer for that, which has proved very effective for Triangle Farms.[4]

Beyond those initial management adjustments, running the LaserWeeder has gone smoothly, and there's little training necessary on the operator side. "The UI (user interface) of the machine is so robust that it really doesn't take anything other than an operator to select what crops they're in and what their goal is [weeding or thinning]," Roberts says. "And it's multilingual."

Most importantly, Roberts was impressed with the level of support they received from Carbon Robotics and how they developed a solution that would work on different types of farms in various locations.

"You're not only buying the equipment, you're buying the experience, you're buying the support," he says. "I think that's probably more important than what the tool is, that you have the support behind it to really get the machine rolling, because time is the most important. Carbon Robotics is very unique in that respect."

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2. Western Growers plans to release a case study about Triangle Farms' experience with the Stout Smart Cultivator later in 2024.

3. The value proposition of the machine is justified when running in certain types of weeding densities and sizes. The higher the density of weeds in a field, the slower the LaserWeeder will run.

4. The LaserWeeder does not have folding wings that will allow it to remain attached to the tractor during transportation. Instead it must be disconnected from the tractor and placed onto a trailer. The custom trailer developed by Carbon Robotics allows for transportation with a ¾- or 1-ton pickup. Maneuvering the 20-foot-wide implement may also be a challenge for small farms or those with fences.

TRIANGLE FARMS DID NOT NEED ANY ADDITIONAL HAND WEEDING AFTER RUNNING THE LASERWEEDER ON THEIR ORGANIC ARUGULA,

SAVING THEM $251.27 PER ACRE.

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Table 5. Triangle Farms Pre-LaserWeeder Costs for Hand Weeding by Organic Crop

2022 USING ONLY CONTRACTED H-2A HAND LABOR			
CROP	ACRES PLANTED	CONTRACTED H-2A HAND WEEDING COST ($/ACRE)	TOTAL CONTRACTED H-2A HAND WEEDING COSTS
Organic Spinach	78	$1,000.00	$78,000.00
Organic Salanova Oakleaf Lettuce	350	$1,800.00	$630,000.00
Organic Arugula	80	$700.00	$56,000.00
Organic Romaine (Direct seed)	600	$500.00	$300,000.00
TOTALS =	**1,108**		**$1,064,000**

High Density Leafy Greens **Medium Density Vegetables**

Trailer developed by Carbon Robotics allows for transportation with a ¾- or 1-ton pickup. Maneuvering the 20-foot-wide implement may also be a challenge for small farms or those with fences.

Table 6. Triangle Farms Costs for Running One LaserWeeder (Assumes a 5-year depreciation schedule)

	$/ACRE	HARD COSTS
3-Bed Laser Weeding Implement	$216.61	$1,200,000 (Dep Over 5 Yrs on 1,108 Acres/Year)
Tractor	$27.07	JD 6-175 $2,500/month Lease on 1,108 Acres
Hardware + Over the Air (OTA) Service Plans	$74.91	$83,000 per Year
Fuel	$28.57	4.5 gal/hr @ $5/gal
Operators (Loaded) (2x)	$48.57	Qty: 2 Operators @ $24.29 ea
Supervisor (Loaded) (1x)	$33.00	
Logistical Operations (moving)	$20.00	Transport Trucks, Fuel etc
COST PER ACRE TO RUN LASERWEEDER =	**$448.73**	

Table 7. Triangle Farms Per-Acre Weeding Costs and Savings with LaserWeeder

Crop	Acres Planted	Contracted H-2A Hand Weeding Cost ($/Acre)	Laser Weeder Cost ($/Acre)	Total Combined Weeding Costs ($/Acre)	Net Savings ($/Acre) From Contracted H-2A Only Hand Weeding Labor	Total Weeding Costs Using the Carbon Robotics Laserweeder + Contracted H-2A Hand Labor
Spinach Organic)	78	$135.00	$448.73	$583.73	$416.27	$45,530.94
10-Line (oak & Salanova) (Organic)	350	$120.00	$448.73	$568.73	$1,231.27	$199,055.50
Arugula (Organic)	80	$0.00	$448.73	$448.73	$251.27	$35,898.40
Romaine (Direct seed) (Organic)	600	$140.00	$448.73	$588.73	-$88.73	$353,238.00
TOTALS =	**1,108**					**$633,722.84**

Table 8. Triangle Farms' Expected Post-Depreciation Costs

	$/ACRE	HARD COSTS
Tractor	$27.07	JD 6-175 $2,500/month Lease on 1,108 Acres
Hardware + Over the Air (OTA) Service Plans	$74.91	$83,000 per Year
Fuel	$28.57	4.5 gal/hr @ $5/gal
Operators (Loaded) (2x)	$48.57	Qty: 2 Operators @$24.29 ea per acre, per operator
Supervisor (Loaded) (1x)	$33.00	
Operations (moving)	$20.00	Transport Trucks, Fuel etc
COST PER ACRE TO RUN LASERWEEDER =	**$232.12**	

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Farmer Focus

This resource would not be available without the generous support of both time and resources from Josh Roberts, Former President of Triangle Farms, and Kyle Harmon, Director of Farming at Braga Fresh.

Both Josh and Kyle are instrumental in the advancement of agtech within the industry. Their and their organization's willingness to provide the financial data to create a first-of-its-kind resource for all companies interested in adopting agtech is a testament to the continued support Josh and Kyle give to others.

Western Growers is grateful for their help with this project. It wouldn't have been possible without them.

braga FRESH

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> *"The strength of this resource is in the grower data, and the only way to be able to share this is by creating relationships within the agricultural community over years. Ben Palone brings that invaluable contribution to the Western Growers team and this project. The WG Innovation team and I recognize the unique and special value Ben adds to this resource as well as the outlook of future progress-advancing projects like it."*
>
> — Walt Duflock, Western Growers, SVP of Innovation

For more information on this study or future studies, please contact the **Innovation Team** at **innovation@wga.com.**

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