

## **SECTION 1**

**Project title:** Increasing Automation of Weed and Sucker Control

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**New Research**  **Continued Research**

**Viticulture**  **Enology**

**Amount Requested** \$ 17,764.75

## **SECTION 2**

**Summary Impact Statement:** This project evaluated the performance and safety of a precision Weed-IT™ sprayer integrated with a Bonsai Amiga autonomous platform for grape sucker control.

The autonomous system provided effective and consistent sucker control comparable to or exceeding a conventional application, without negatively affecting grape yield or vine health.

While operational speed and tank capacity remain constraints, the technology demonstrates strong potential to improve efficiency, reduce operator variability, and advance precision management in specialty crops. Although pesticide exposure is still associated with mixing, loading, and cleanout, the autonomous system eliminates the need for an operator during application, potentially reducing overall applicator exposure relative to conventional spraying

systems.

These results are being leveraged to secure additional research funding through the Cornell Future of American Agriculture Initiative, which supports projects with practical, tangible benefits for farmers across New York and beyond by harnessing science and technology to strengthen U.S. agriculture and the broader economy.

Objectives: This project addresses two of the New York Wine & Grape Foundation's (NYWGF) priorities.

*Floor and weed management: Develop and evaluate vineyard floor and weed management strategies to reduce energy and herbicide use.*

*Mechanization and precision agriculture: Identify opportunities for vineyard management mechanization and application of precision agriculture technology with a particular emphasis on development of labor saving and affordable canopy management equipment.*

The 2025 project expanded upon previous years' efforts. Specifically, the goal was to evaluate the performance and safety of the Weed-It sprayer mounted on a Bonsai Amiga robotic platform for fully autonomous weed and sucker control.

Activities/Methods: Crop management practices such as pruning, training, and suckering are critical for maintaining vine health, vigor, and grape yield and quality. Grapevine suckers are non-fruit-bearing shoots that emerge near the base of the trunk and compete with productive tissues for water and nutrients while contributing little to overall canopy photosynthesis as shading increases. As a result, early-season sucker removal is a standard practice to reduce competition, limit pest and disease pressure, improve vineyard floor management, and facilitate harvest. Manual removal is labor-intensive and costly, while mechanical approaches can risk vine injury. Chemical suckering is efficient but may lead to unnecessary herbicide use when suckers are absent and can increase the risk of off-target injury if not properly managed.

Precision sprayers provide a targeted alternative for managing unwanted vegetation by using sensors to detect and treat plant tissue in real time, enabling site-specific herbicide applications that improve efficiency, reduce input costs, and minimize off-target impacts. The Weed-IT™ system ([Fruit growing and orchards | WEED-IT precision spraying](#)) uses chlorophyll detection to identify green tissue and activate nozzles only where vegetation is present, eliminating the need for crop-weed discrimination and allowing operation at faster speeds. This approach is particularly well-suited for trellised grape systems, where desirable canopy tissues are spatially separated from unwanted suckers along the trunk.

Across 2022–2024 trials in Concord and Cabernet Franc vineyards, an ATV-mounted Weed-IT™ system effectively controlled grape suckers, achieving 83–96% biomass reduction at 28 days after treatment. Performance was comparable to or better than conventional spray wand and manual removal methods, demonstrating the system's potential as an efficient and scalable tool for vineyard sucker management ([NYWGF-FY24-25-Final-Report-Sosnoskie.pdf](#))

When mounted on the Amiga robotic platform (a compact, electric, semi-autonomous field robot designed for specialty crop systems, [Equipment - Bonsai Robotics](#)) the Weed-IT™ system can

be deployed with high precision and minimal operator input. The Amiga's lightweight design can reduce soil compaction, while its modular framework allows integration of implements such as precision sprayers. Together, this combination provides a cost-effective approach to vineyard management by enabling targeted applications, reducing labor requirements, and improving overall production sustainability.

New York (NY) trials took place at the Cornell Lake Erie Research and Extension Laboratory (CLEREL) located in Portland, NY (42°22'N, 79°29'W). Soil at the site is a Chenango gravelly loam (loamy-skeletal, mixed, superactive, mesic Typic Dystrudepts) with 50% sand, 35% silt, 15% clay, 3.3% organic matter and soil pH averaging 6.2. Trials were conducted in a rainfed block of Concord grapes established in 2015. Rows within the block were spaced 2.6 m apart with 2.4 m vine spacing.

Applications (June 2<sup>nd</sup>) were made to suckers that were 6 to 24 inches in length with 3 to 10 flat leaves. Hand-wand applications of carfentrazone (Aim EC at 2 oz/A) were performed using an ATV-mounted Fimco 15-gal sprayer equipped with a HighFlo 1.2 GPM pump operated at 60 psi. The hand wand was adjustable and set to deliver a spray pattern of appropriate width with a coarse droplet size. Targeted treatments (also Aim EC at 2 oz/A) were applied using the WEED-IT™ system mounted on an autonomous Bonsai Amiga platform (Figure 1). The WEED-IT™ unit (Rometron B.V., Steenderen, The Netherlands) uses fluorescence technology for chlorophyll detection. The system emits blue light (450 to 500 nm), which is absorbed by chlorophyll and re-emitted as near-infrared light through a process known as chlorophyll fluorescence. The WEED-IT™ sensor detects this near-infrared signal to distinguish living plant tissue from the surrounding soil or non-vegetative surfaces. The unit consists of four independent photodetectors that control four TG-3.5 spray nozzles (TeeJet Technologies, Glendale Heights, IL, USA). When plant tissue is detected within a given zone, the corresponding nozzle activates to apply a targeted dose of herbicide.

With respect to autonomous Amiga programming, we have developed and deployed a hardware and software integrated framework for autonomous navigation in the vineyard. The hardware system includes a multiband global positioning system (GPS) with real time kinematics (RTK) correction (Reach RS3, Emlid Tech Kft., Budapest, Hungary), a high precision inertial measurement unit (IMU, HWT 905, WitMotion Co., Ltd, Shenzhen, Guangdong, China), a microcontroller (Feather M4 CAN, Adafruit Industries LLC, New York, US), and an embedded computer (Raspberry Pi 5, Raspberry Pi Holdings plc, Cambridge, England, UK). The microcontroller provides low-level control by directly interfacing with the robot motor controllers to read motor status and send control commands. The embedded computer provides high-level control by aggregating and processing robot position, heading, and motor encoder readouts to generate motor control sequences that achieve navigation goals specified by a human operator.

The software system is structured as a layered stack of modules that convert sensing data into control commands for autonomous navigation. The base layer hosts dedicated sensor interface modules responsible for collecting raw measurements from the GPS and IMU devices. These modules parse sensor specific messages and publish standardized outputs, along with lightweight monitoring modules that continuously evaluate sensor validity and publish quality indicators. A state construction layer is implemented to transform positioning data across coordinate systems and perform pose assembly. Absolute position and orientation are explicitly combined at the robot level to construct a planar navigation state in a fixed local reference frame. This state is published as odometry and serves as the sole pose reference for all

downstream navigation and control components. The navigation layer includes a waypoint management module that organizes waypoints into a navigation sequence and a control module that generates motor commands based on the published odometry and the current target waypoint. A proportional integral derivative (PID) controller is employed within this control module. Before transmitting commands to the robot motor controller, a safety layer incorporates additional operational signals, including emergency stop and manual teleoperation inputs, to enable human intervention and prevent potential damage to the robot and surrounding environment. Once the commands pass the safety checks, they are forwarded to the robot motors through the microcontroller, where platform-agnostic velocity commands are translated into platform-specific control messages for execution. This software design enables transparent inspection of system behavior, straightforward debugging, and predictable operation under degraded sensing or communication conditions.

In practice, a human operator first collects a set of waypoints with corresponding GPS coordinates and saves them in a comma separated value (CSV) file. The operator then uploads the CSV file to the embedded computer for execution. Once autonomous navigation is initiated, the robot follows the waypoints sequentially, stops at the final waypoint, and awaits further operator commands. During navigation, if the GPS signal is lost or data quality degrades beyond an acceptable threshold, the system pauses execution and waits for signal recovery based on a predefined timeout. If the signal does not recover to a satisfactory level within this period, the navigation process is terminated and human intervention is requested to ensure operational safety.

Results/Progress/Next steps: Sucker control (necrosis of green tissue) differed between methods on all evaluation dates ( $P < 0.0001$ ; Table 1, Figures 2 and 3)). The Weed-IT™ sprayer mounted on an autonomous Amiga robot consistently provided greater sucker control than the ATV-based hand wand approach, achieving 96%, 92%, and 88% control on June 12, June 21, and June 29, respectively. In contrast, the ATV hand wand treatment resulted in 86%, 81%, and 76% sucker control on those same dates. By the end of June, the Concord canopy was sufficiently developed that no further applications could be made under the vines.

Perennial weeds (horsenettle (*Solanum carolinense* L.) and milkweed (*Asclepias syriaca* L.)) were also present in the plots and were also treated manually and autonomously. Unlike sucker control, weed cover did not differ between treatments at any evaluation timing ( $P = 0.2828$  to  $0.5463$ ; Table 2). Weed cover increased over time for both treatments, ranging from 4.3% to 9.4% for the hand wand treatment and 5.2% to 11.2% for the Weed-IT™ spray system between June 12 and June 29. While the aboveground portions of the treated weeds were burned by herbicide applications, the plants quickly started to regrow from underground root reserves.

No injury (whether via direct tissue contact or spray drift) was observed in the grape canopy for either treatment at any time (data not shown). Grapevine canopy NDVI values differed between treatments early in the season but converged as the season progressed (Table 3). On June 2 and June 11, NDVI was greater in the Weed-IT™ sprayer mounted on an Autonomous Amiga robot treatment (0.608 and 0.672, respectively) compared to the ATV-based hand wand treatment (0.583 and 0.653;  $P = 0.0419$ ). However, these early-season differences were small and inconsistent over time, suggesting limited biological relevance. No differences were detected on May 15 or after June 11 ( $P = 0.5416$ ), with NDVI values increasing similarly across treatments through August and reaching peak values of approximately 0.85 by August 21.

Grape yield did not differ between sucker control methods ( $P = 0.8301$ ; Table 4). Yields were comparable between treatments, with 6.82 tons/acre for the hand wand treatment and 6.85 tons/acre for the Weed-IT™ sprayer mounted on an Autonomous Amiga robot.

The autonomous Bonsai Amiga–mounted Weed-IT™ sucker control operation was slower than ATV-based spraying. Both systems required pesticide mixing, loading, and cleanout; the smaller tank capacity of the Weed-IT™ system may necessitate more frequent handling and refilling to cover an equivalent vineyard area, particularly compared to ATV or tractor mounted sprayers. Yet, because the system operates autonomously, it removes the need for a continuous operator/applicator in the field during application, resulting in reduced overall human exposure to pesticides. The robotic platform required upfront time for initial programming and route development. However, once programmed, the system can repeat operations with a high degree of consistency and presumed fidelity, thereby reducing operator variability across passes.

Bonsai Robotics is actively advancing automation in specialty crop systems through partnerships with industry leaders. Recent announcements highlight commercial integrations of the Amiga platform with Weed-IT™ sprayers, underscoring continued progress toward scalable, autonomous weeding and spraying solutions (<https://www.globalagtechinitiative.com/in-field-technologies/robotics-automation/bonsai-robotics-showcases-new-autonomous-weeding-and-spraying-solutions-on-amiga-platform-at-world-ag-expo/>) (Figures 4 and 5).

Technology Transfer Plan: Precision spray results were presented, virtually, to employees of the Environmental Protection Agency (EPA) on March 4<sup>th</sup> as part of the WSSA Seminar Series. Internationally, the trial was discussed at the Inaugural Canadian Ag Robotics and AI Summit in London, Ontario, on March 26<sup>th</sup> ([Canadian AgRobotics & AI Summit | Join the Future of Agriculture — Ag Robotics Working Group](#)). Results will also be shared at the Southeastern Ag Specialty Crop Tech Conference ([Southeastern Specialty Crop Technology Conference](#)) May 5 and 6 in Tifton, GA. Results from this precision spray research have been incorporated into guest lectures for undergraduate students at Cornell University, Rutgers University, and Finger Lakes Community College, enhancing student exposure to emerging vineyard automation technologies. Findings will also be shared at upcoming summer extension events hosted at AgriTech and CLEREL to engage growers and industry stakeholders. In addition, these results are currently being prepared for manuscript submission to the American Journal of Enology and Viticulture. Broader dissemination is ongoing through online outreach via Dr. Sosnoskie's LinkedIn page.

Attachments:

**Table 1.** Temporal sucker control (%) as affected by control method in Portland, NY, 2025.

Suckering method	Jun. 12	Jun. 21	Jun. 29
	----- % -----		
ATV Hand Wand	86 b	81 b	76 b
WEED-IT AMIGA™	96 a	92 a	88 a
<b>p-value</b>	<b>&lt;0.0001</b>	<b>&lt;0.0001</b>	<b>&lt;0.0001</b>

<sup>a</sup>Means followed by the same letter within in a column are not significantly different based on Tukey's HSD test ( $\alpha = 0.05$ ).

**Table 2.** Temporal weed cover (%) as affected by sucker control method in Portland, NY, 2025.

Suckering method	Jun. 12	Jun. 21	Jun. 29
	----- % -----		
ATV Hand Wand	4.3	5.8	9.4
WEED-IT AMIGA™	5.2	7.5	11.2
<b>p-value</b>	<b>0.5463</b>	<b>0.3384</b>	<b>0.2828</b>

<sup>a</sup>Means followed by the same letter within in a column are not significantly different based on Tukey's HSD test ( $\alpha = 0.05$ ).

**Table 3.** Grapevine canopy normalized difference vegetation index (NDVI) as affected by sucker control method at Portland, NY, 2025.

Suckering method	May 15 <sup>a</sup>	Jun. 2	Jun. 11	Jun. 20	Jul. 7	Jul. 24	Aug. 11	Aug. 21
ATV Hand Wand	0.452	0.583 b	0.653 b	0.732	0.823	0.784	0.852	0.855
WEED-IT AMIGA™	0.427	0.608 a	0.672 a	0.738	0.829	0.778	0.850	0.859
<b>p-value</b>	<b>0.3428</b>	<b>0.0419</b>	<b>0.0374</b>	<b>0.5416</b>	<b>0.5764</b>	<b>0.5821</b>	<b>0.8138</b>	<b>0.5690</b>

<sup>a</sup>Means followed by the same letter within in a column are not significantly different based on Tukey's HSD test ( $\alpha = 0.05$ ).

**Table 4.** Grape yield response to sucker control method in Portland, NY, 2025.

Suckering method	Yield <sup>a</sup>
	Tons/acre
ATV Hand Wand	6.82
WEED-IT AMIGA™	6.85
<b>p-value</b>	<b>0.8301</b>

<sup>a</sup>Means followed by the same letter within in a column are not significantly different based on Tukey's HSD test ( $\alpha = 0.05$ ).

Figure 1. Cornell's autonomous Bonsai Amiga - Weed-IT™ spray system operating in a newly planted vineyard (2025) located at CLEREL in Portland, NY.



Figure 2. Hand wand sucker control (2025) in Concord grapes located at CLEREL in Portland, NY.



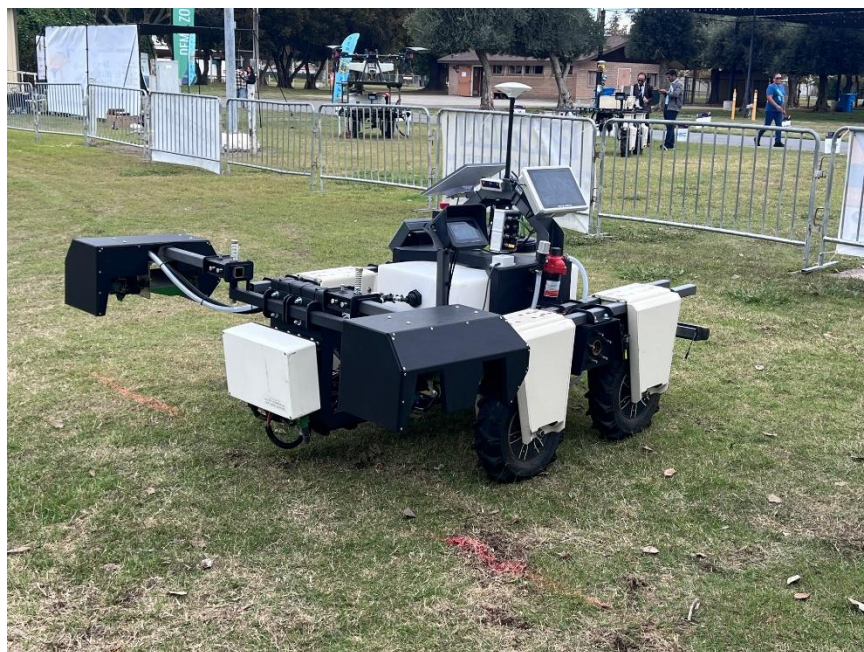
Figure 3. Bonsai Amiga - Weed-IT™ sucker control (2025) in Concord grapes located at CLEREL in Portland, NY.



Figure 4. Commercial Bonsai Amiga - Weed-IT™ spray system at the 2025 FIRA USA robotics showcase in Woodland, CA.



Figure 5. Commercial Bonsai Amiga - Weed-IT™ spray system at the 2025 FIRA USA robotics showcase in Woodland, CA.



### **SECTION 3**

Project objectives: This project aimed to evaluate a precision Weed-IT™ sprayer mounted on an autonomous Bonsai Amiga robot for vineyard sucker control.

Importance of research to the NY wine industry: Labor shortages, rising input costs, and the need to reduce herbicide use are major challenges for New York grape growers. This research explores a practical, scalable technology that can improve vineyard efficiency, maintain yield and vine health, and support more sustainable production systems.

Project Results/next steps: The autonomous Weed-IT™ system provided equal or better sucker control than conventional methods, with no impact on grape yield or vine injury. Fully autonomous spraying functioned effectively under the conditions of this study and offers the opportunity to reduce certain pesticide exposure pathways by removing the need for an applicator during treatment. Using our current setup, the autonomous Weed-IT™ system can require additional time for refilling due to its smaller tank size.

Beginning in 2026, we will evaluate the Amiga–Weed-IT™ system for autonomous weed and sucker control in a newly planted high-tech vineyard at CLEREL, with the goal of improving efficiency and scalability.