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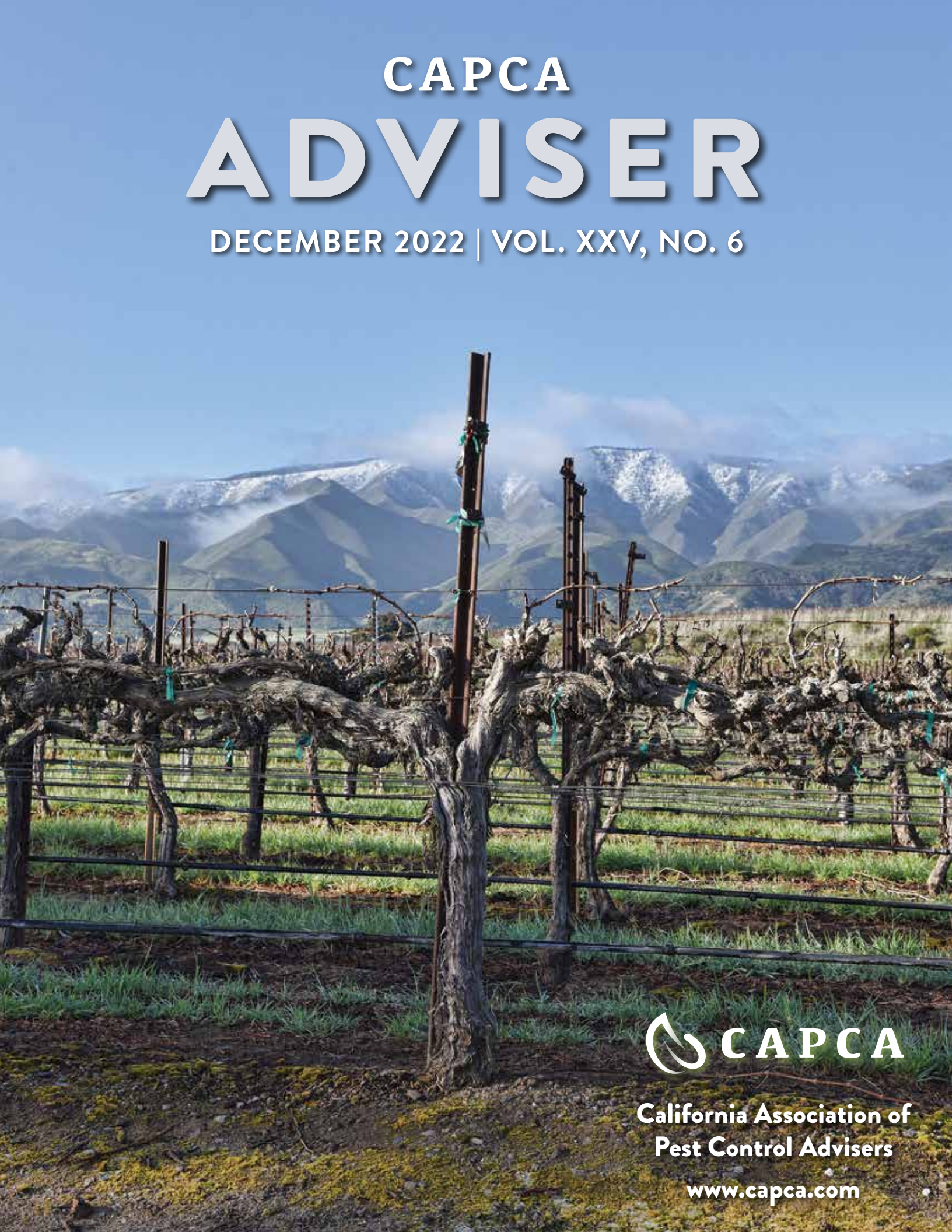

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California Association of Pest Control Advisers

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CONTENTS

CAPCA
AT THE CENTER OF PLANT HEALTH

Management of watermelon productivity and plant health using grafting and Trichoderma-containing biofungicide

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Research background

Although disease resistant commercial cultivars become more available, soil-borne pathogens such as Verticillium wilt (*Verticillium dahliae*), remain the top threatening diseases to California's watermelon production, resulting in continuously increased use of soil fumigants to treat the pathogens in watermelon fields. Worse, with more watermelon being planted early in the season for an early market presence, reports of infection of other soil-borne diseases which usually favor cooler and wetter soil conditions and were not commonly found on watermelon increased. Therefore, watermelon growers need to implement more environmentally sustainable and productive farming methods to sustain fruit yield and manage disease problems to cope with the more restrictive regulations of minimizing environmental threats. Watermelon grafting and biological pesticide are such methods aiming to enhance yield and safeguard plant health while securing soil and water quality. While there is a lack of studies from California, tremendous amount of research studies in other parts of the U.S. and the world has demonstrated multiple economic and horticultural benefits of using grafted watermelon plants with multi-pathogen resistant rootstocks and applying Trichoderma-containing biofungicide regarding yield enhancement, soil-borne disease prevention, and environmental protection. In 2021, we launched a project funded by the California Department of Pesticide Regulation to evaluate the potential of reducing soil fumigation in California's seedless watermelon production using grafting and Trichoderma-based biofungicides.

Project setup

A field trial was conducted in the summer of 2022 on a commercial watermelon field in the northern San Joaquin Valley. Three watermelon rootstocks (Cobalt, RS841, and Flexifort) were grafted onto a field scion, Summer Breeze, by a local greenhouse. The study was designed to also include two ways of inoculating two Trichoderma-based biofungicides. First, two fifths of the grafted and non-grafted transplants were inoculated with two different Trichoderma-containing biofungicides by soaking the root balls into the solutions a day before transplanting (May 18, 2022). Active ingredients of the products are *Trichoderma harzianum* Rifai T-22 and *T. virens* G-41. Both strains are naturally occurring fungi that are used as microbial biocontrol agents to prevent crops and seeds from various fungal pathogens. The trial was mechanically transplanted on May 19 and 20, 2022. Each treatment row is 60 feet long containing ten grafted or non-grafted plants and three grafted and non-grafted pollinizers. The second way of inoculation was then performed on June 18 and July 22, 2022 (30 and 64 days after transplanting) by chemigating both products through the drip system at a rate of 2 lbs./acre to another two fifths of the plants in the field (Figure 1). All treatments were replicated four times.

Data collection

Vine collapse. Vine collapse in each treatment row was visually assessed on July 7, July 27, and August 4. The assessment was based on a 1-5 scale, where 1 was rated as no vine collapse found in a given row; 2 as up to 25% of the vines collapsed; 3 as vine infection up to 50%; 4 as collapse symptoms up to 75%; 5 being collapse observed for the entire treatment row.

FIG. 1. Chemigation of Trichoderma-containing biofungicides into watermelon rows. Photo taken on June 18, 2022 (30 days after transplanting).

PROTASSIUM+®

UNDERSTANDING SALINE SOILS FOR OPTIMAL GROWTH AND YIELD

For growers in the West, the effect of soil salinity on crops is a justifiable concern. In areas of saline soils, the ability for plant roots to absorb water and nutrients can become limited. This can result in smaller or fewer leaves, shorter stature, reduced root length and mass, decreased yields and possibly plant death. Plants in the emergence and seedling stages are more susceptible to plant failure in saline soils than a more mature plant. The degree to which growth is stunted by salinity differs greatly with species and, to a lesser extent, varieties within a species. It is important to understand how and where saline soils can occur, the usefulness of soil testing and how to provide nutrition to crops in saline soils.

Regions Susceptible to Salt Buildup

Salt accumulates in soil over time, occurring from both natural and human-caused events such as mineral weathering, fertilizer applications, irrigation practices, precipitation or drought. Arid or semi-arid regions (including deficit irrigated areas) typically contain soils with an excessive accumulation of soluble salts, caused by a lack of rainfall or water movement preventing salts from leaching out of the plant root zone. Soil salinity may also be impacted by irrigation water that contains soluble salts leaving excess salt deposits behind after evaporation. Salinity build-up in soil is typically measured by laboratory analysis of a soil sample, and periodic soil tests are needed to ensure proper management of saline soils.

Applying Fertilizers in Saline Soils

When salts concentrate at higher levels in soil, the use of low salt index fertilizers is critical. Fertilizers with a higher salt index can create an area of high osmotic pressure near plant roots, causing moisture to be drawn from the plant and leaving unwanted salt behind. Plant root tips injured because of excess salts in the soil become unable to absorb water and essential nutrients.

Plant growth in saline and water stress conditions is influenced by the ability of the plant to regulate potassium/sodium ratio in the plant tissues. The severity of detrimental effects of sodium are greater under low potassium concentrations, and plants having efficient activity of potassium transporters are better able to maintain optimal levels of potassium required for normal growth. Applying a potassium fertilizer with a low salt index is a sound management practice to achieve optimal crop growth and yields.

Table 1. A comparison of the salt index per unit of K_2O of all major potassium sources.

Potassium Fertilizers	Salt Index	Salt Index Per Unit of K_2O
Potassium sulfate/SOP (0-0-50 17S)	42.6	0.852
Potassium nitrate/NOK (13-0-46)	69.5	1.219
Potassium chloride/MOP (0-0-60)	116.2	1.936
Potassium sulfate-magnesia/SOP-M (0-0-22 11Mg, 22S)	43.4	1.971
Potassium thiosulfate/KTS (0-0-25 17S)	68.0	2.720

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Protassium+ (0-0-50 17S) high-quality sulfate of potash (SOP) delivers 50% potassium and 17% sulfur with low chloride and **the lowest salt index per unit of K_2O of all major potassium sources** (Table 1). When compared with other low-chloride potassium fertilizers, Protassium+ SOP offers a better cost value per unit of K_2O. Protassium+ products are mined and manufactured by Compass Minerals through methods that promote sustainability and minimize environmental impacts. Organic forms of Protassium+ SOP are CDFA and OMRI certified.

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COMPASS MINERALS

Canopy coverage. Canopy coverage was measured starting on June 10 until August 4, 2022 at an approximate 7-day interval using the Canopeo App (https://canopeoapp.com/#/login, developed by the Oklahoma State University). When scanning with the smartphone, the camera was paralleled to the ground and kept a height of 30 inches between the phone and the top watermelon canopy.

Yield and fruit quality. The trial was harvested three times on August 9, 16, and 24, respectively. All mature melons from each treatment row were cut by the grower's crew. Fruits were then counted, and the average fruit weight was collected from representatively selected five fruits. In the first harvest, two melons were selected from the group of five within a treatment row and taken back to the lab for quality measurements, including fruit length, width, rind thickness, total soluble solid (°Brix), and flesh firmness.

Results

Vine health assessment and canopy coverage. Overall, the effects of grafting on preventing vine collapse and maintaining ground coverage were much stronger than the effects of using both biological fungicides. For the non-grafted watermelon plants, receiving the inoculation of biofungicide regardless of application method had very little impact on reducing vine collapse. However, vine collapse was significantly reduced for grafted plants even without inoculation of any product (Figures 2 and 3). In the meantime, the synergistic effects of grafting and biofungicide provided some but limited benefits to plant health compared to the single factor of grafting (Figures 4 and 5).

Fruit yield and quality. The cumulative yield followed the similar trend as the vine collapse. The overall effect of

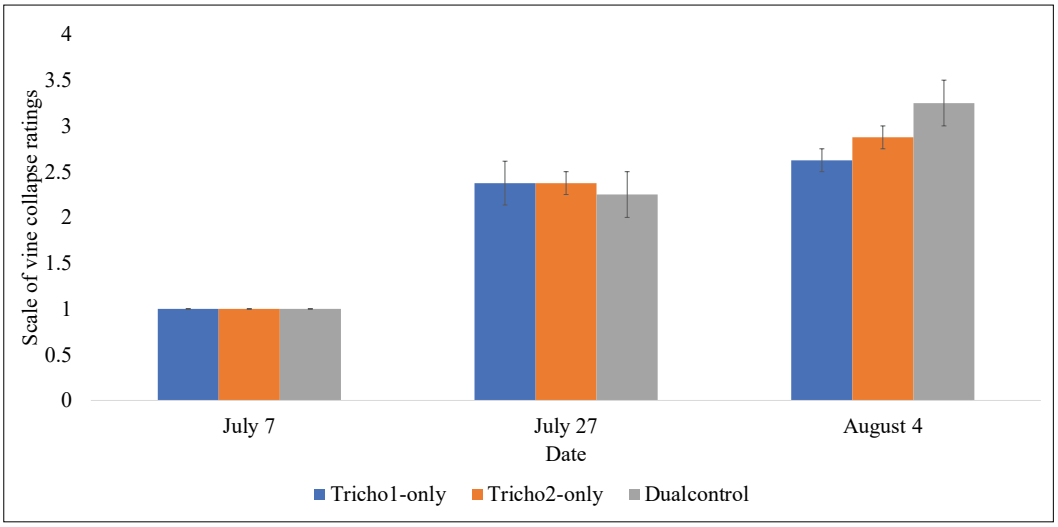

FIG. 2. Comparisons of vine collapse ratings between nongrafted watermelon plants that received the inoculation and those without any inoculation. Tricho1 and Tricho2 represent the two different Trichoderma products. Dualcontrol refers to non-inoculated, non-grafted plants.

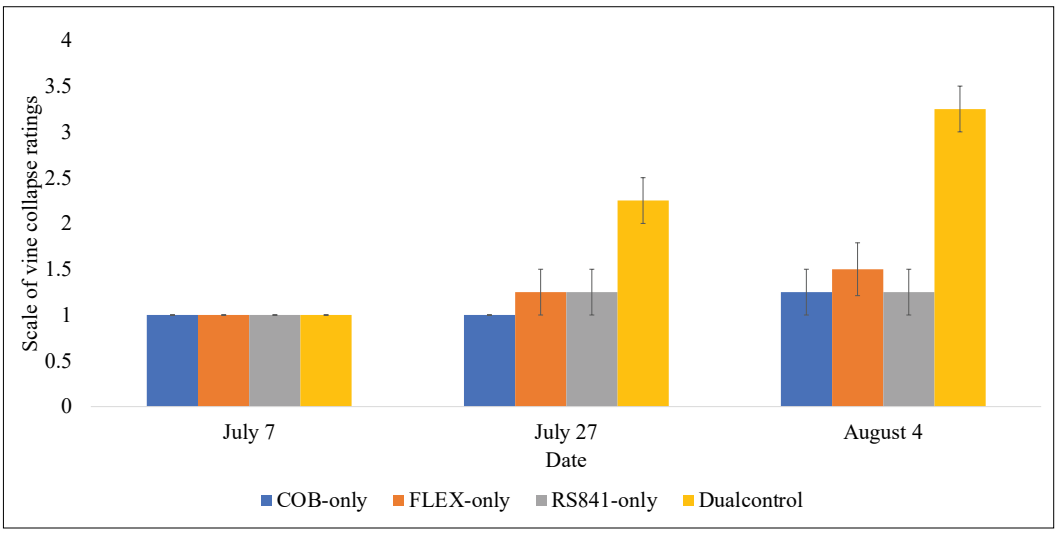

FIG. 3. Comparisons of vine collapse ratings between non-inoculated watermelon plants that were grafted with different rootstocks and the non-grafted control. COB, FLEX, and RS841 are the three rootstocks used in this project (Cobalt, Flexifort, and RS841). Dualcontrol refers to non-inoculated, non-grafted plants.

using biofungicide did not offer a greater watermelon yield compared to the control regardless of the application method (soaking vs. chemigation). Yield enhancement was well observed for plots using grafted watermelon plants (Table 1). For fruit quality from the first harvest, grafting also made much more significant impacts than biofungicide on fruit rind thickness and flesh firmness (Figures 6).

Disease diagnosis. Plants showing symptoms of vine collapse were excavated on August 20 and were shipped to Dr. Cassandra Swett's Fungal Pathology Lab at UC Davis for pathogen identification. Based on the symptomatology, initial diagnosis indicated that the primary diseases were *Fusarium falciforme* crown rot and Phytophthora crown and root rot. Both are soil-borne fungal pathogens, and further

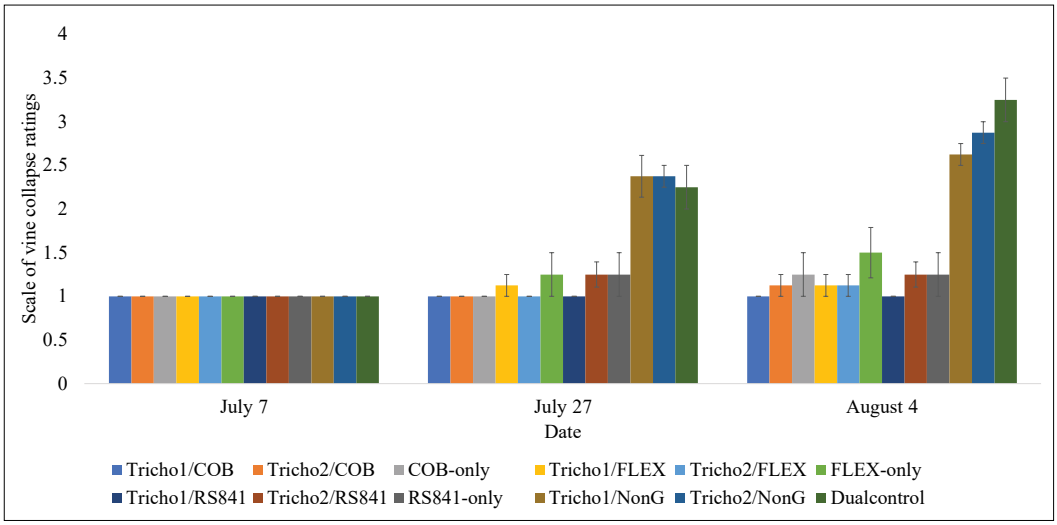

FIG. 4. Effect of the interaction of Trichoderma biofungicide and grafting on the vine collapse ratings. Tricho1 and Tricho2 represent the two different Trichoderma products. COB, FLEX, RS841, and NonG are the three rootstocks used in this project (Cobalt, Flexifort, and RS841) and non-grafted control. Dualcontrol refers to non-inoculated, non-grafted plants.

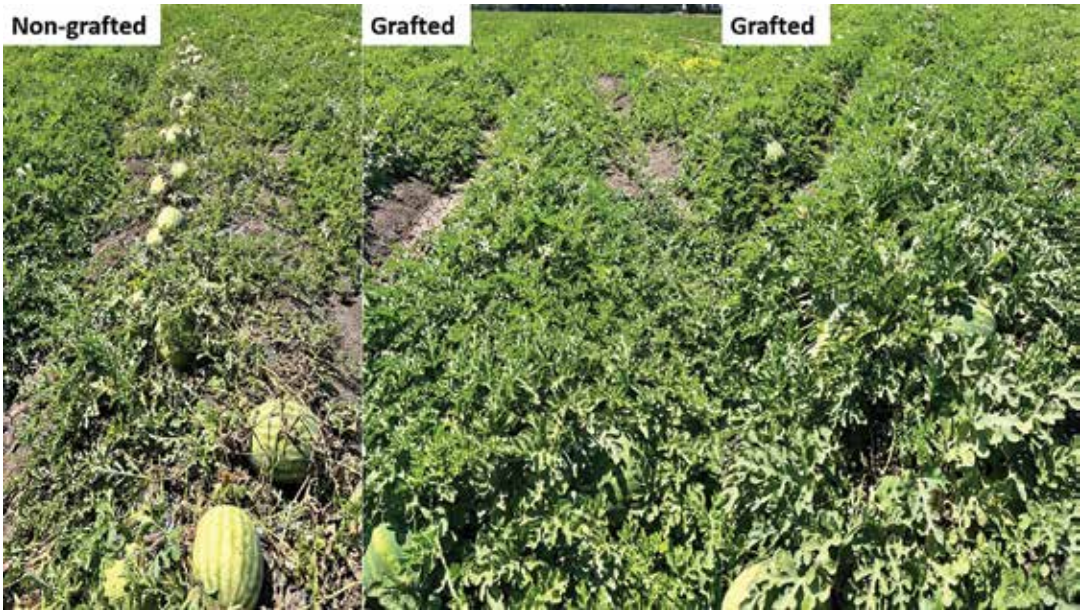

FIG. 5. Left: rows grown with non-grafted, non-inoculated plants; Middle: rows grown with grafted but non-inoculated plants; Right: rows grown with grafted and inoculated plants. Photo taken on August 2, 2022 (76 days after transplanting).

Table 1. Cumulative watermelon yields (tons per acre ± standard error) at each harvest when plants were inoculated with two Trichoderma biofungicides and grafted onto three rootstocks.

Product	First harvest	Second harvest	Third harvest
Tricho-1	29.0 ± 1.71 A	37.5 ± 1.94 A	39.2 ± 1.64 A
Tricho-2	29.4 ± 1.07 A	35.6 ± 0.95 A	37.6 ± 0.92 A
Control-1	28.3 ± 2.88 A	38.2 ± 1.68 A	39.6 ± 1.73 A
Rootstock			
COB	34.5 ± 1.49 A	45.0 ± 1.57 A	47.1 ± 1.40 A
FLEX	24.6 ± 2.24 B	32.4 ± 1.73 B	33.7 ± 1.74 B
RS841	32.8 ± 2.68 A	44.1 ± 2.97 A	47.0 ± 2.64 A
Control-2	24.2 ± 0.83 B	25.9 ± 0.86 C	26.8 ± 0.98 C

Tricho-1 and Tricho-2 represent the two different Trichoderma products.
COB, FLEX, and RS841 are the three rootstocks used in this project (Cobalt, Flexifort, and RS841).
Control-1 refers to the average cumulative yield from all non-inoculated watermelon plants.
Control-2 refers to the average cumulative yield from all non-grafted watermelon plants.
Cumulative yield values followed by different letters indicate a significant yield difference between treatments based on the Least Significant Difference at $P < 0.05$.

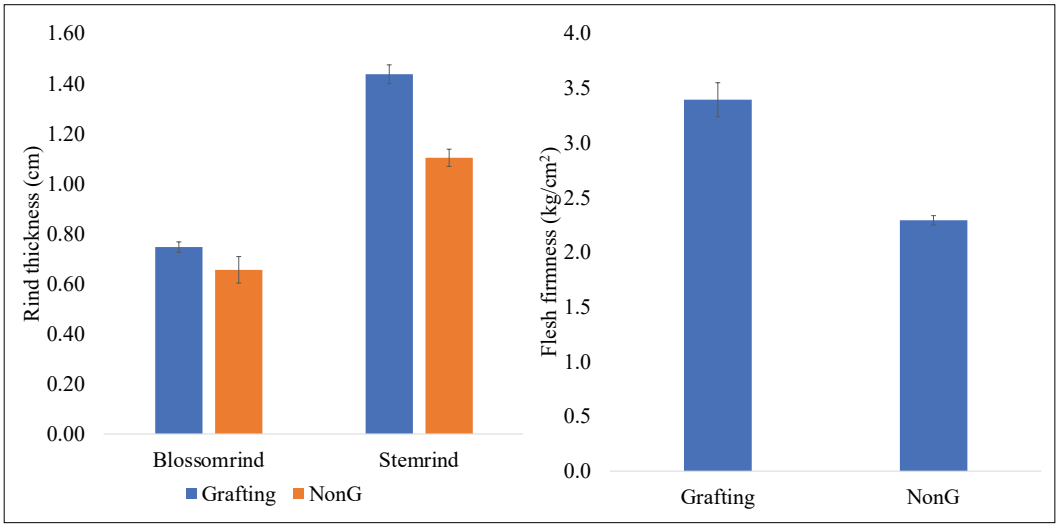

FIG. 6. Effects of grafting on rind thickness measured at the blossom end and stem end (Left) and flesh firmness (Right). NonG = non-grafted watermelons.

molecular confirmation is underway. More research is being conducted at Swett's lab to characterize the *F. falciforme* as a pathogen of diverse California crops, including watermelons.

Summary and take-home message

Grafting onto the hybrid squash rootstocks were tested to be an effective way to reduce the threat of soil fungal pathogens. However, the effects of applying biofungicides in the first-year trial did not stand out. First, the timing of chemigating these living microorganisms through drip lines is crucial. Trichoderma species will be unlikely to inoculate if crop roots are absent or low in volume at or below drip tapes. Therefore, applying these biofungicides before root grows down to the drip line could cause poor inoculation. Second, if chemigation occurs with an irrigation event, it is highly recommended that the chemigation begin at the last part (e.g., one third) of the irrigation depending on the duration. This can limit the length of flushing drip lines and prevent the microbes from draining before they inoculate roots. Root ball soaking seems impracticable for large-scale producers. The reason to include this application method is to test if it is an actionable way to massively inoculate roots before the plants are transplanted into the complex soil environment. In the future, watermelon growers may request the greenhouse to apply multiple times through overhead misting and tray drenching until the transplants are shipped. ■

Acknowledgments

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