Biocontrol of FRD with Trichoderma Biofungicide

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Three Trichoderma products x 5 tomato varieties

BioWorks®

ROOTSHIELD® *PLUS*+ WP

Biological Fungicide

OMRI LISTED For Organic Use

ACTIVE INGREDIENTS:
Trichoderma harzianum Rifai strain T-22*..... 1.15%
Trichoderma virens strain G-41** 0.61%
OTHER INGREDIENTS: 98.24%
TOTAL: 100.00%
*Contains at least 1.0 x 10^7 colony forming units per gram
**Contains at least 5.3 x 10^6 colony forming units per gram

KEEP OUT OF REACH OF CHILDREN
CAUTION

EPA Reg. No. 68539-9
EPA Est. No. 68539-NY-001
US Patent: US 9,681,668 B2

USER SAFETY RECOMMENDATIONS
Users should:
- Remove clothing/PPE immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Remove PPE immediately after handling this product. As soon as possible, wash thoroughly and change into clean clothing.

ENVIRONMENTAL HAZARDS
For terrestrial uses: Do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark. Do not contaminate water when disposing of equipment washwater or rinsate.

DIRECTIONS FOR USE

BioWorks®

ROOTSHIELD® WP

Biological Fungicide

OMRI LISTED For Organic Use

ACTIVE INGREDIENT:
Trichoderma harzianum Rifai strain T-22*..... 1.15%
OTHER INGREDIENTS: 98.85%
TOTAL: 100.00%
*Contains at least 1.0 x 10^7 colony forming units per gram of product.

KEEP OUT OF REACH OF CHILDREN
CAUTION

EPA Reg. No. 68539-7
EPA Est. No. 68539-NY-001
US Patent No.: 5,260,213
Net Contents: 1 lb, 3 lb, 30 lb

PRECAUTIONARY STATEMENTS
HAZARDS TO HUMANS AND DOMESTIC ANIMALS
CAUTION: Harmful if absorbed through skin, inhaled, or swallowed. Causes moderate eye irritation. Avoid contact with skin, eyes or clothing. Avoid breathing dust. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum, using tobacco or using the toilet. Remove and wash contaminated clothing before reuse.

PERSONAL PROTECTIVE EQUIPMENT (PPE)
Applicators and other handlers must wear:
- Protective eyewear
- Long-sleeved shirt and long pants
- Waterproof gloves

Koppert

TRIANUM®-P

Biological Fungicide

ACTIVE INGREDIENT
Trichoderma harzianum Rifai strain T-22* 3.65%
OTHER INGREDIENTS 96.35%
TOTAL 100.00%
*Contains at least $1.0x10^7$ colony forming units per g of product.

KEEP OUT OF REACH OF CHILDREN
CAUTION

EPA Reg. No. 89635-3 **EPA Est. No.** 63119-NLD-001
PRODUCT NUMBER 12903 **BATCH NUMBER** See packaging (10)
NET WEIGHT 1.1 lbs (500 g) **EXPIRATION DATE** See Packaging (17) as YYMMDD

- **HM5522**
- **H1996**
- **H2016**
- **SVTM9016**
- **HM8237**

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1	RS-WP+	HM5522
2		HM8237
3		SVTM9016
4		H1996
5		H2016
6	RS-WP	HM5522
7		HM8237
8		SVTM9016
9		H1996
10		H2016
11	Tria-P	HM5522
12		HM8237
13		SVTM9016
14		H1996
15		H2016
16	Check	HM5522
17		HM8237
18		SVTM9016
19		H1996
20		H2016

	Bed 1	Bed 2	Bed 3	Bed 4	Bed 5	Bed 6	Bed 7	Bed 8	Bed 9	Bed 10	Bed 11	Bed 12	Bed 13	Bed 14	Bed 15	Bed 16	Bed 17	Bed 18	Bed 19	Bed 20	
70 ft	8237 (#12)	1996 (#14)	9016 (#13)	2016 (#15)	5522 (#11)	1996 (#4)	8237 (#2)	2016 (#5)	9016 (#3)	5522 (#1)	1996 (#9)	9016 (#8)	5522 (#6)	2016 (#10)	8237 (#7)	2016 (#20)	5522 (#16)	9016 (#18)	1996 (#19)	8237 (#17)	Rep 4
5 ft	Tria-P					RS-WP+					RS-WP					Check					
70 ft	8237 (#12)	9016 (#13)	1996 (#14)	2016 (#15)	5522 (#11)	9016 (#3)	8237 (#2)	1996 (#4)	5522 (#1)	2016 (#5)	8237 (#17)	5522 (#16)	1996 (#19)	2016 (#20)	9016 (#18)	9016 (#8)	8237 (#7)	2016 (#10)	5522 (#6)	1996 (#9)	Rep 3
5 ft	Tria-P					RS-WP+					Check					RS-WP					
70 ft	9016 (#18)	2016 (#20)	5522 (#16)	8237 (#17)	1996 (#19)	2016 (#10)	5522 (#6)	1996 (#9)	9016 (#8)	8237 (#7)	9016 (#13)	2016 (#15)	5522 (#11)	8237 (#12)	1996 (#14)	8237 (#2)	5522 (#1)	9016 (#3)	2016 (#5)	1996 (#4)	Rep 2
5 ft	Check					RS-WP					Tria-P					RS-WP+					
70 ft	2016 (#5)	8237 (#2)	9016 (#3)	1996 (#4)	5522 (#1)	8237 (#17)	1996 (#19)	9016 (#18)	2016 (#20)	5522 (#16)	1996 (#14)	9016 (#13)	2016 (#15)	8237 (#12)	5522 (#11)	5522 (#6)	2016 (#10)	1996 (#9)	8237 (#7)	9016 (#8)	Rep 1
60 ft	RS-WP+					Check					Tria-P					RS-WP					

- **Application through tray drenching for three times in the greenhouse.**
- **Split plot design with 4 replications, Crows Landing, Transplanted on 5/1/2025.**
- **(3 products + 1 non-inoculated control) x 5 varieties x 4 reps = 80 plots (70’ long each).**
- **Harvested on 9/9/2025.**

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FRD Pathogen Confirmation

DIAGNOSTIC REPORT

VEGETABLE & FIELD CROPS
COOPERATIVE EXTENSION
UNIVERSITY OF CALIFORNIA

Grower/PCA name	Perez Farm
Identifying information (field, sample #, etc)	CTRI FRD CV trial Plots 26, 31, 36, 56
Crop & variety	Tomato (HM5522, F2)
Date submitted	9/9/25
Swett Lab sample #	1652025
Advisor tentative diagnosis / notes	FRD, Fusarium Wilt
Diagnosis:	-Fusarium wilt caused by *Fusarium oxysporum* f. sp. *lycopersici* -Fusarium stem rot and decline (FRD) caused by *Fusarium noneumartii*
Notes:	• There were 5 plants. Plants came from 4 different plots

DIAGNOSTIC REPORT

VEGETABLE & FIELD CROPS
COOPERATIVE EXTENSION
UNIVERSITY OF CALIFORNIA

Grower/PCA name	Perez Farm
Identifying information (field, sample #, etc)	CTRI FRD CV trial Plots 24, 79
Crop & variety	Tomato (H1996, F3)
Date submitted	9/9/25
Swett Lab sample #	1652025
Advisor tentative diagnosis / notes	FRD, Fusarium Wilt
Diagnosis:	Fusarium stem rot and decline (FRD) caused by *Fusarium martii*

Percent Canopy Coverage/NDVI

- Variety played a more significant role in affecting canopy coverage than Trichoderma products.
- Vine coverage/NDVI dramatically decreased when closer to harvest for HM5522 and H1996

Table 1. Percent vine canopy coverage for each variety.

Variety/Date	May 3	June 3	June 26	July 8	July 24	August 8	August 22	Sept. 7
HM5522	27.5	68.5	82.3	90.1	73.8	65.3*	53.0*	41.9*
HM8237	28.9	72.0	83.3	91.2	78.9	74.2	65.3	52.1
STVM9016	24.2	64.9	84.4	90.6	79.9	75.2	65.9	51.5
H1996	24.9	62.4	81.3	89.3	75.3	68.6	56.4*	42.3*
H2016	22.4	60.4	80.9	89.1	75.5	69.9	60.1	49.2

*indicates that the % canopy coverage is significantly lower than SVTM9016 and HM8237 at $P < 0.05$.

Percentage of plants with FRD symptoms and advanced vine decline

- HM5522 had the biggest % plants with FRD symptoms followed by H1996 and H2016.
- HM5522 had a much higher rate of plants showing advanced decline than all other varieties.
- FRD symptoms: plants with all levels of FRD infection (mild - death).
- Advanced vine decline: dead plants or plants nearly death, meaning hardly any living tissues can be found

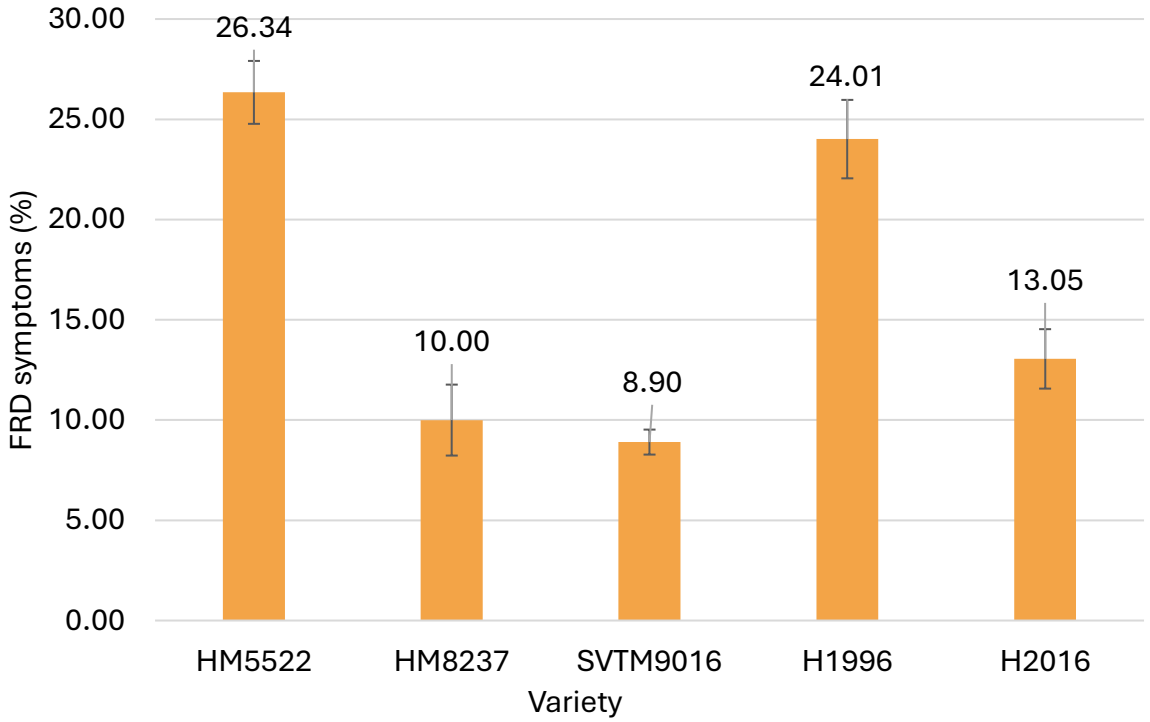


Figure 1A. Average percentage of plants with FRD symptoms for each variety.

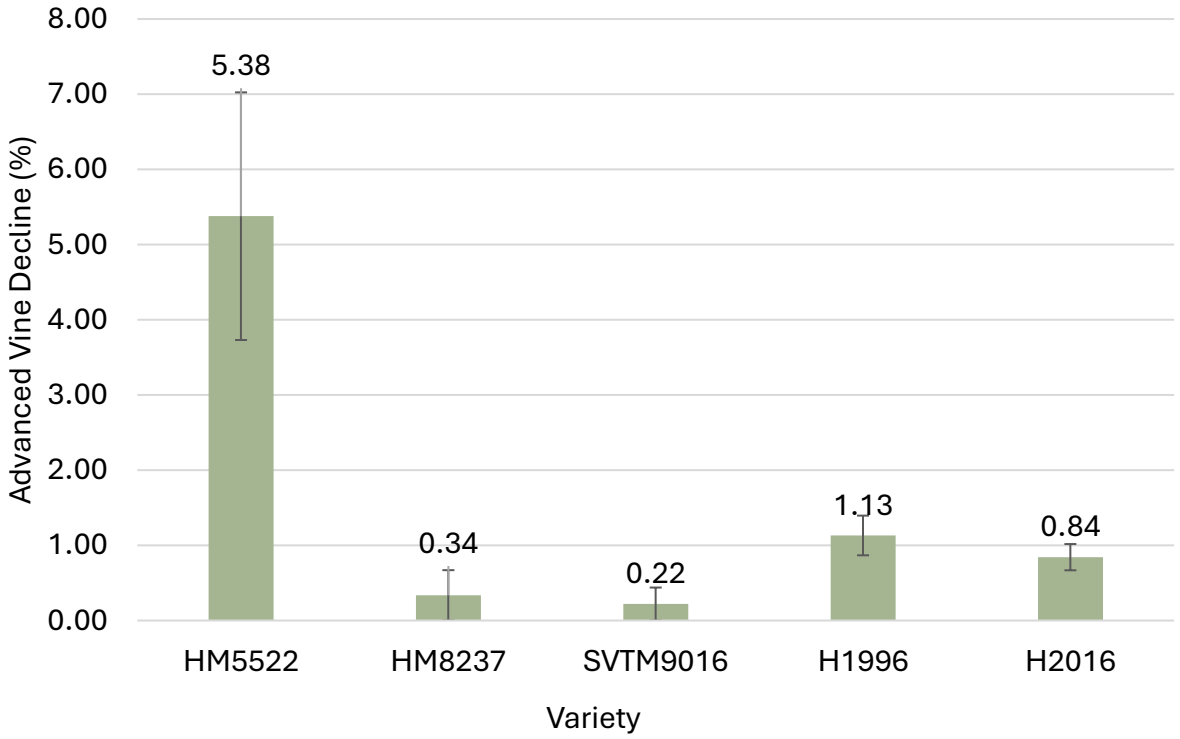


Figure 1B. Average percentage of plants with advanced vine decline for each variety.

Percentage of plants with FRD symptoms and advanced vine decline

- The overall Trichoderma product effect was less remarkable than variety.
- Inoculation of Trichoderma products did not reduce the FRD symptoms compared to the non-inoculated control, even though the percentage of plants with advanced vine decline showed a significant decrease over the control.

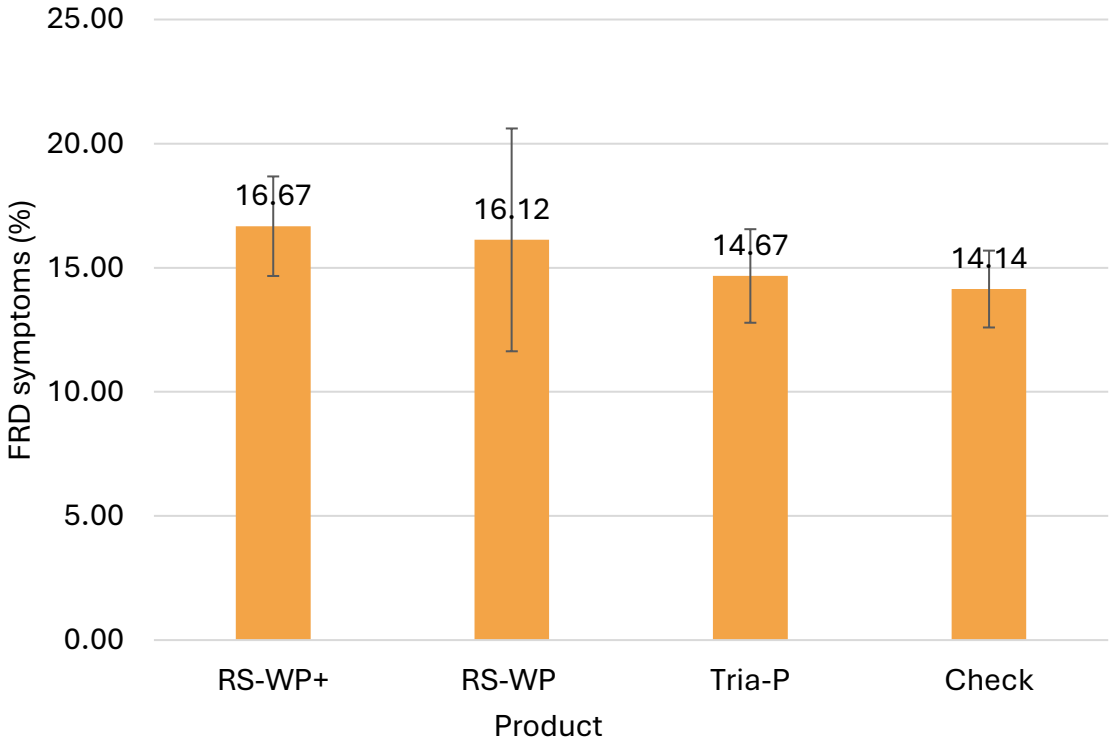


Figure 2A. Product effects on the average percentage of plants with FRD symptoms.

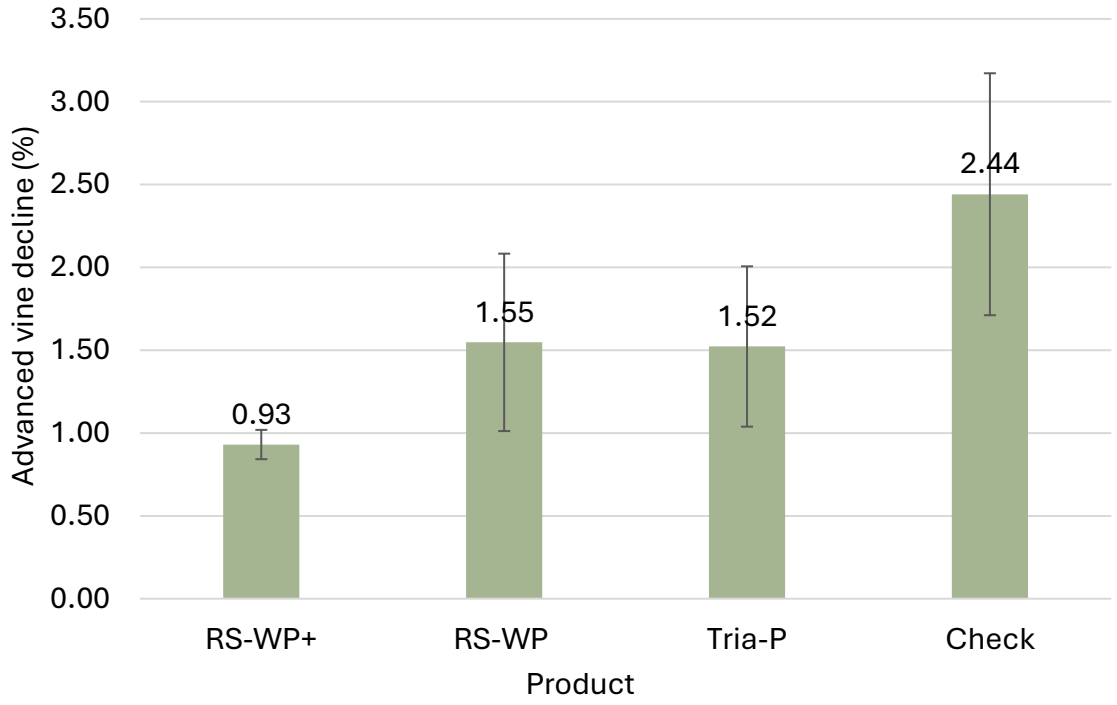


Figure 2B. Product effects on the average percentage of plants with advanced vine decline.

Product performance on individual variety for the rate of FRD symptoms and advanced vine decline

- For the product effects on each variety in response to FRD, using Trichoderma biofungicide either showed a lower level of FRD symptoms or advanced vine decline for the “weaker” varieties (HM5522, H1996, and H2016) than the non-inoculated check.

Table 2. Percent of plants with FRD symptoms and advanced vine decline for each variety under different Trichoderma treatments.

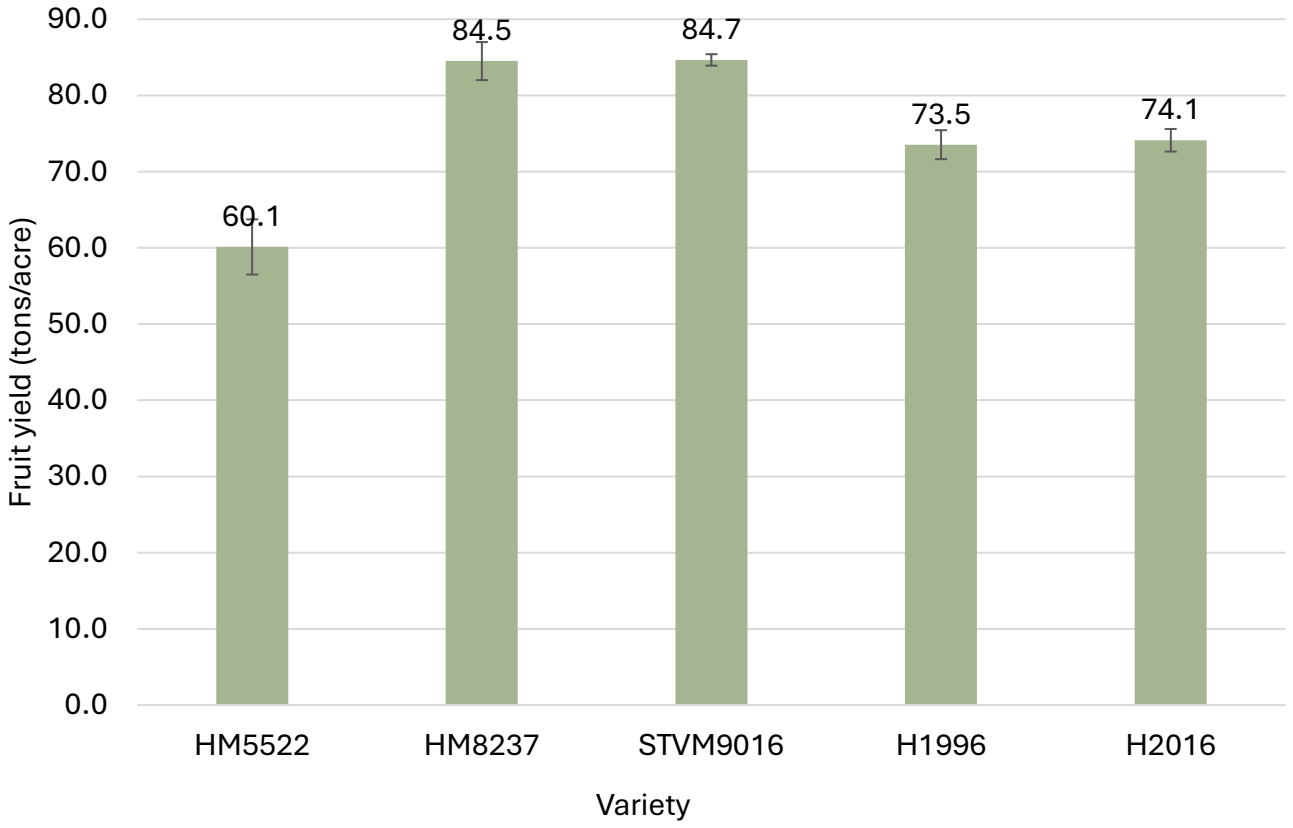
	HM5522		HM8237		SVTM9016		H1996		H2016	
	FRD symptoms*	AD-Vine decline**	FRD symptoms	AD-Vine decline	FRD symptoms	AD-Vine decline	FRD symptoms	AD-Vine decline	FRD symptoms	AD-Vine decline
RS-WP+	29.1%	2.5%	10.2%	0.8%	3.6%	0.4%	23.3%	1.3%	14.4%	0.4%
RS-WP	23.2%	4.8%	10.4%	0.5%	4.9%	0.4%	20.2%	1.6%	13.6%	0.4%
Tria-P	21.2%	6.0%	9.3%	0.4%	11.1%	0.3%	18.3%	0.4%	13.4%	1.3%
Check	31.9%	8.3%	10.1%	0.9%	16.0%	0.5%	34.3%	1.8%	12.8%	2.0%

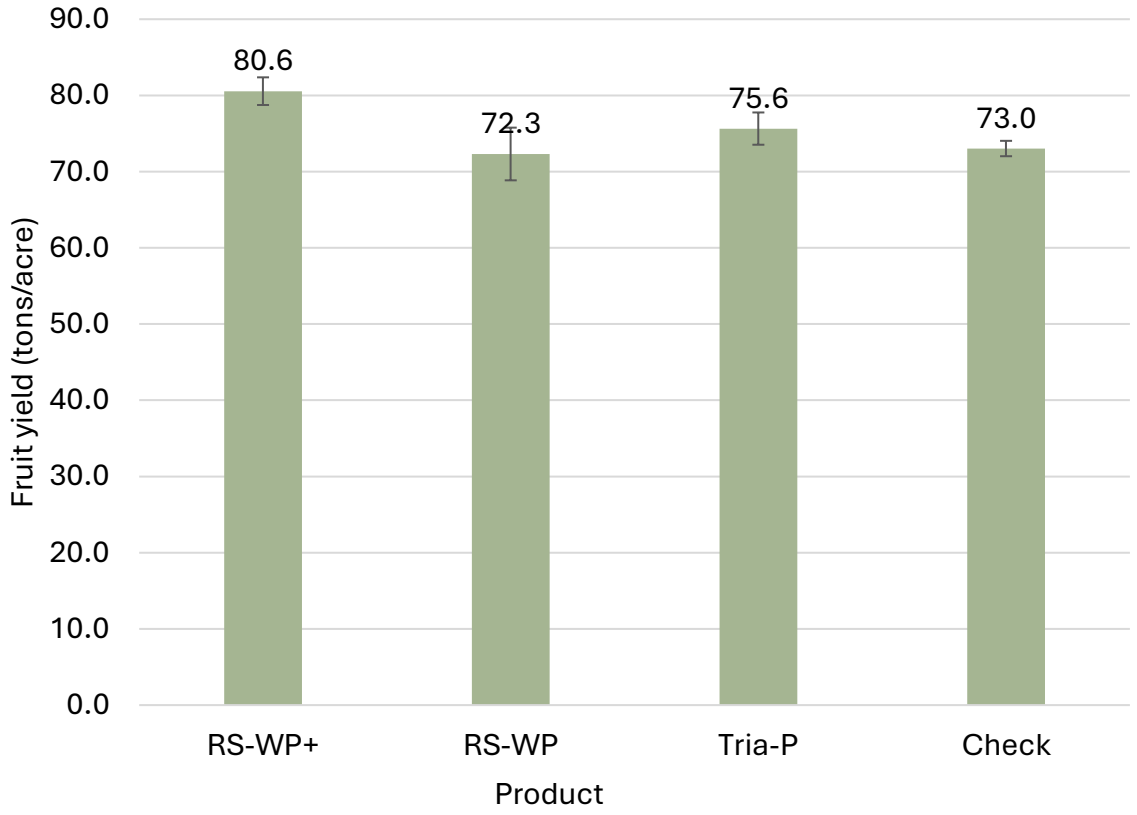
*FRD symptoms: plants with all levels of FRD infection (mild - death).

**Advanced vine decline: dead plants or plants nearly death, meaning hardly any living tissues can be found.

Fruit yield

- Variety effects performed a much stronger impact than product on the yield.
- HM8237 and SVTM9016 which showed strong tolerance to FRD on protecting advanced vine decline also produced the highest yields compared to susceptible varieties, HM5522 and H1996, with significantly lower yields.





Figures 3A and 3B. Variety and Trichoderma product effects on the total fruit yield.

Product performance on individual variety for fruit yield

- HM5522 plants inoculated by RS-WP+, a two-species Trichoderma product, yielded almost 20% more than the non-inoculated control.
- For H1996 and H2016, inoculations of RS-WP+ and Tria-P boosted fruit yield by 10-15% on average compared to the non-inoculated control.

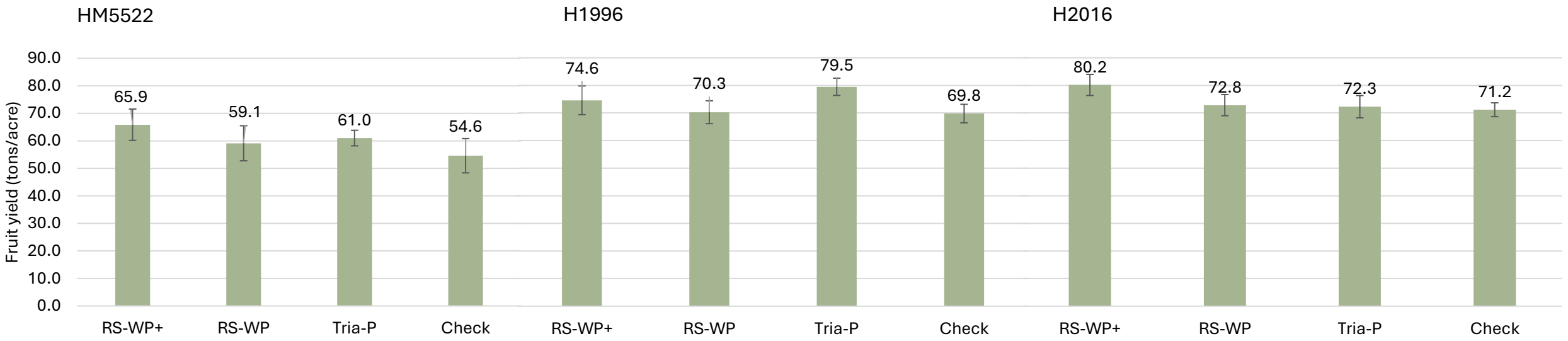


Figure 4A-4C. Effects of Trichoderma product on the yield of tomato varieties.

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Key take homes/What we found

- All applications were made when plants were in the greenhouse. We believe this is the most effective and reliable way to deliver Trichoderma inoculants to plant root systems.
- Fields with FRD are usually co-infested by Fusarium wilt or other soil-borne pathogens. Therefore, even though some F2 cultivars may provide better tolerance to FRD than the F3s, extra caution may be given to prevent F. wilt R3 when selecting varieties.
- Like many other biocontrol substances, Trichoderma products provide preventive function instead of directly killing pathogens. Therefore, applying before symptoms show up is important.
- Performance of Trichoderma products is strongly impacted by varieties.
- Varieties with EFH trait (SVTM9016, HM8237, and HM58841) could perform a strong natural tolerance to FRD as fruit may stay fresh longer for better marketable yields even when vines decline earlier due to FRD.
- Since most varieties probably produced historically high yields in 2025, we will repeat the trial in 2026 with the hope of an average year and yield performance.

Acknowledgement

- Swett Lab at UC Davis
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- BioWorks and Koppert
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- CTRI