

Biocontrol of Fusarium Stem Rot and Decline (FRD) with Trichoderma Biofungicide

2026 NSJV Tomato Meeting

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Trichoderma as biocontrol agents

- Frequently isolated from forest and agricultural soils – naturally occurring and culturable.
- Many species are able to form mutualistic relationships with plants.
- Serve as biocontrol agents against fungal diseases of plants.
- *T. harzianum*, *T. viride*, and *T. virens* as biofungicides

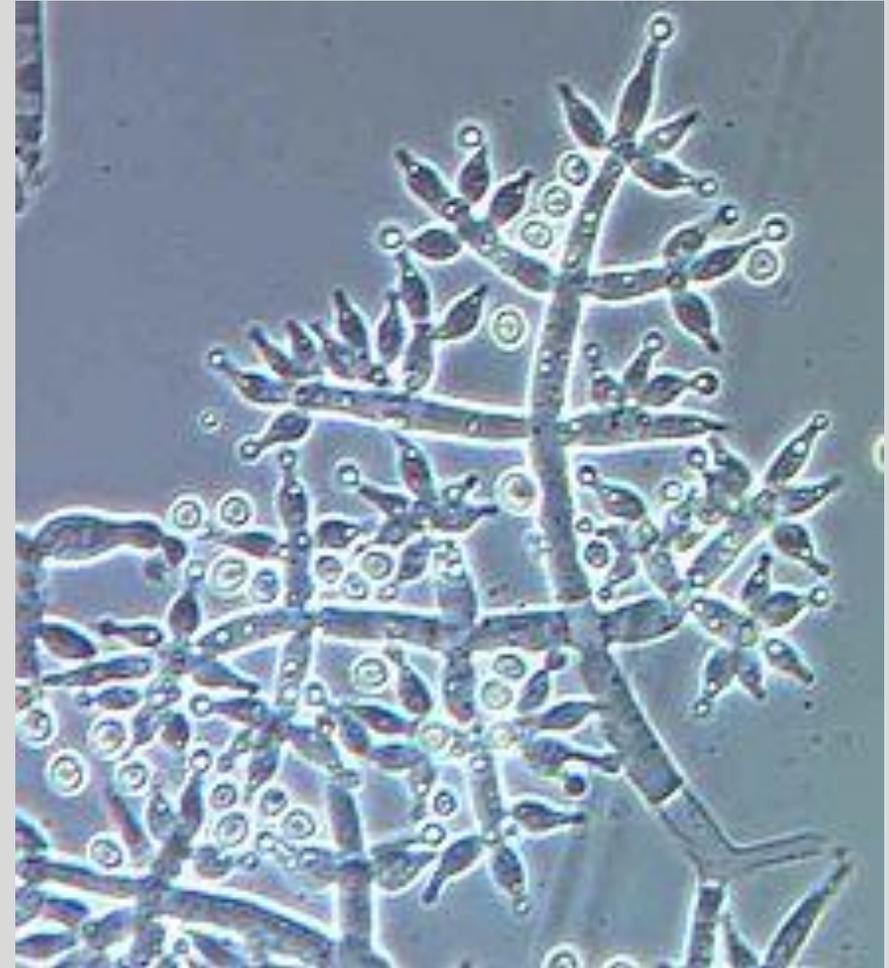


Trichoderma harzianum

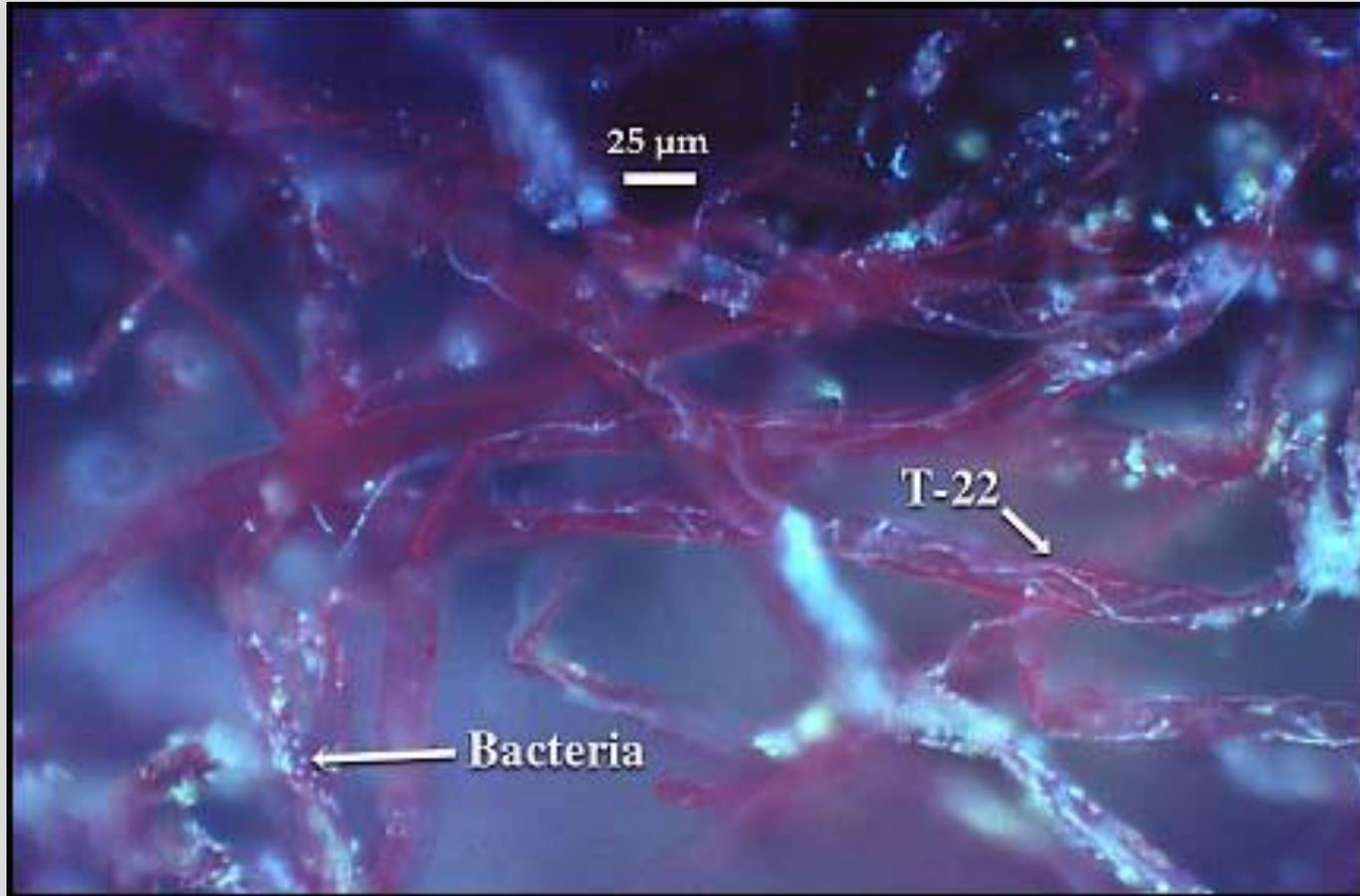
- Colonize plant roots and grow
- Attack, parasitize, and gain nutrition from other fungi
- Enhance plant and root growth
- *T. harzianum* strain T-22 – antibiosis, competition, induce resistance, inactivation



T. Harzianum t22, source: jgi.doe.gov



Ways of delivering Trichoderma to plants

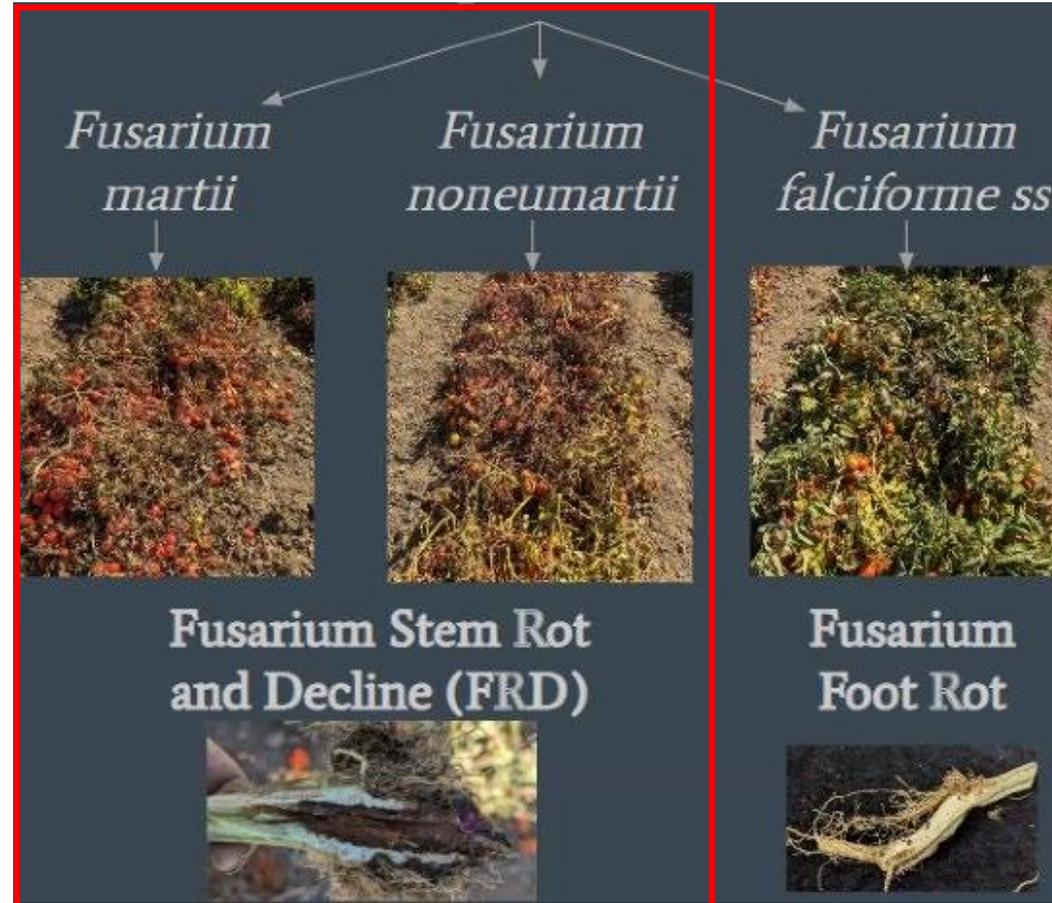


- Seed treatment
- Seedling drench/root ball soaking
- Root colonization through field drenching
- Drip line chemigation

Presence of root and moisture

Colonization of sweet corn root hairs through seed treatment by strain of *T. harzianum* T22 (Harman, 2000. Plant Disease).

Previously called *Fusarium falciforme*, now it is identified to have three species including *Fusarium stem rot and decline (FRD)*, caused by *fusarium martii* and *fusarium noneumartii*.



Photos from B. Aegerter and C. Swett

BP115	VFFFNptsw*	117	F3, EFH	MED/LG	-	-	5.37	4.36	EARLY
BP116	VFFFNptsw*	117	F3, EFH	MED/LG	-	-	5.34	3.76	EARLY
BP91	VFFFNptsw*	118	F3, EFH	LARGE	4	5.03	MED/HIGH	INTER	INTER
BP110	VFFFNptsw*	123	F3, EFH	MED/LG	-	-	HIGH	THIN	THIN
BP125	VFFFNptsw*	125	F3, EFH	LARGE	-	-	MED	INTER	INTER

HM.CLAUSE / HARRIS MORAN

HM7103	VFFntsw*	116	EFH	MED/LG	20,900	5.23	5.48	5.28	EARLY
HMC0371	VFFFNtswFrMV	117	F3, Fr, MV	MED/LG	2	5.40	5.55	4.13	EARLY
HM5511	VFFFNtswFrMV	118	F3, Fr, MV	LARGE	2,913	5.38	HIGH	THIN	THIN
HM5522	VFFntswFr	122	Fr	LARGE	25,701	5.66	5.76	4.35	INTER
HM8163	VFFntsw	122	-	MED/LG	6,658	5.70	5.80	3.99	PEAR
HM8507	VFFFNtswFr	122	F3, Fr	MED/LG	494	5.53	5.74	4.55	PEAR
HM9905	VFFN*	122	EFH	MED	51	4.70	MED	INTER	INTER
HM3887	VFFNptsw	123	-	LARGE	828	5.16	MED/HIGH	INTER	INTER
HM8268	VFFFNtsw	123	F3	MED/LG	15,012	5.36	5.53	4.04	INTER
HM5235	VFFFNptsw	124	F3	LARGE	2,789	5.16	MED/HIGH	INTER	INTER
HM58841	VFFntsw*	124	EFH	LARGE	31,292	5.24	5.61	3.30	INTER
HM7885	VFN*	124	EFH	MED/LG	168	4.52	MED	THICK	PEAR
HM3888	VFFNptsw*	125	EFH	LARGE	100	5.36	MED/HIGH	INTER	INTER
HM4521	VFFNptsw*	125	EFH	LARGE	15,429	5.28	5.44	3.57	INTER
HM8237	VFFFNtswFrMV*	126	F3, Fr, EFH, MV	LARGE	41,053	5.13	5.37	3.67	INTER

KRAFT HEINZ COMPANY / HEINZSEED

H1015	VFFNP*	114	EFS™	MED	941	5.06	MED/HIGH	INTER	EARLY
H2354	VFFFNtswFr	119	F3, Fr	MED/LG	7	5.06	5.46	4.47	INTER
H1293	VFFNptsw	120	-	MED/LG	97	5.33	HIGH	INTER	PEAR
H2128	VFFFNptsw	121	F3	MED/LG	311	5.40	5.33	3.68	PEAR
H5608	VFFNptsw	121	-	LARGE	8,398	4.97	5.02	2.18	THICK
H1776	VFFNptsw*	122	EFS™	MED/LG	87	4.81	5.29	2.35	THICK
H2355	FFFntswFr	122	F3, Fr	LARGE	4	5.40	5.65	4.82	THIN
H1991	VFFFNptsw	124	F3	MED/LG	3,177	5.10	MED	THICK	THICK
H2010	VFFFNtsw*	124	F3, EFS™	MED/LG	5,016	5.04	5.31	3.70	INTER
H2012	VFFFNtsw*	124	F3, EFS™	MED/LG	4,514	5.31	5.38	3.29	INTER
H1662	VFFFNptswLV	125	F3, LV	LARGE	9,773	5.06	5.09	1.95	THICK
H1996	VFFFNtsw*	125	F3, EFS™	MED/LG	26,889	4.97	5.11	2.26	THICK
H2016	VFFFNptsw	127	F3	MED/LG	15,439	4.92	4.96	1.90	THICK
H2365	VFFFNptswFr*	127	F3, Fr, EFS™	MED/LG	5	4.74	5.03	2.07	THICK
H5508	VFFntsw*	128	EFS™	MED	1,374	4.82	MED	THICK	THICK
H8504	VFFNP*	130	EFS™	MED/LG	-	-	MED	THICK	THICK
H2479	VFFFNtsw	116	F3	MED/LG	-	-	MED	THICK	EARLY
H2476	VFFFNtswFr	125	F3, Fr	MED/LG	-	-	5.54	4.08	INTER
H2374	VFFFNptswFr	127	F3, Fr	MED/LG	7	4.77	MED	THICK	THICK
H2485	VFFFNtswFr	128	F3, Fr	MED/LG	-	-	MED	THICK	THICK

Unlike Fusarium wilt and other common diseases, there are currently no resistant varieties to FRD.



Besides screening varieties for natural tolerance, we want to know if biocontrol could offer some preventive effects.

■ = Trial Varieties V = Verticillium Wilt F3 = Fusarium Wilt, Races 1, 2 & 3 Fr = Fusarium Crown Rot N = Root Knot
 * = EFS™, EFH Lab Data from 31 Common Locations, AgSeeds Quality Lab Viscosity = Predicted Paste Bostw

Three Trichoderma products x 5 tomato varieties



ROOTSHIELD® PLUS⁺ WP

Biological Fungicide



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 10⁷ colony forming units per gram

**Contains at least 5.3 x 10⁶ colony forming units per gram

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

This combination of Federal Labels may be used on this product in a

**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



ROOTSHIELD® WP

Biological Fungicide



ACTIVE INGREDIENT:

Trichoderma harzianum Rifai strain T-22* 1.15%

OTHER INGREDIENTS: 98.85%

TOTAL: 100.00%

*Contains at least 1.0 x 10⁷ colony forming units per gram of product.

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

**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



TRIANUM®-P

Biological Fungicide

ACTIVE INGREDIENT

Trichoderma harzianum Rifai strain T-22* 3.65%

OTHER INGREDIENTS 96.35%

TOTAL 100.00%

*Contains at least 1.0x10⁷ 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

6	1	RS-WP+	HM5522	70 ft	8237	1996	9016	2016	5522	1996	8237	2016	9016	5522	1996	9016	5522	9016	1996	8237	Rep 4				
7	2		HM8237		(#12)	(#14)	(#13)	(#15)	(#11)	(#4)	(#2)	(#5)	(#3)	(#1)	(#9)	(#8)	(#6)	(#10)	(#7)	(#20)		(#16)	(#18)	(#19)	(#17)
8	3		SVTM9016		Tria-P																				
9	4		H1996		RS-WP+					RS-WP					Check										
10	5		H2016		8237 9016 1996 2016 5522 9016 8237 1996 5522 2016 8237 5522 1996 2016 9016 9016 8237 2016 5522 1996																				
11	6	RS-WP	HM5522	70 ft	8237	9016	1996	2016	5522	9016	8237	1996	5522	2016	8237	5522	1996	2016	9016	9016	8237	2016	5522	1996	Rep 3
12	7		HM8237		(#12)	(#13)	(#14)	(#15)	(#11)	(#3)	(#2)	(#4)	(#1)	(#5)	(#17)	(#16)	(#19)	(#20)	(#18)	(#8)	(#7)	(#10)	(#6)	(#9)	
13	8		SVTM9016		Tria-P																				
14	9		H1996		RS-WP+					Check					RS-WP										
15	10		H2016		9016 2016 5522 8237 1996 2016 5522 1996 9016 8237 9016 2016 5522 8237 1996 8237 5522 9016 2016 1996																				
16	11	Tria-P	HM5522	70 ft	9016	2016	5522	8237	1996	2016	5522	1996	9016	8237	9016	2016	5522	8237	1996	8237	5522	9016	2016	1996	Rep 2
17	12		HM8237		(#18)	(#20)	(#16)	(#17)	(#19)	(#10)	(#6)	(#9)	(#8)	(#7)	(#13)	(#15)	(#11)	(#12)	(#14)	(#2)	(#1)	(#3)	(#5)	(#4)	
18	13		SVTM9016		Check																				
19	14		H1996		Check					RS-WP					Tria-P					RS-WP+					
20	15		H2016		2016 8237 9016 1996 5522 8237 1996 9016 2016 5522 1996 9016 2016 8237 5522 5522 2016 1996 8237 9016																				
21	16	Check	HM5522	70 ft	2016	8237	9016	1996	5522	8237	1996	9016	2016	5522	1996	9016	2016	8237	5522	5522	2016	1996	8237	9016	Rep 1
22	17		HM8237		(#5)	(#2)	(#3)	(#4)	(#1)	(#17)	(#19)	(#18)	(#20)	(#16)	(#14)	(#13)	(#15)	(#12)	(#11)	(#6)	(#10)	(#9)	(#7)	(#8)	
23	18		SVTM9016		RS-WP+																				
24	19		H1996		Check					Tria-P					RS-WP										
25	20		H2016		2016 8237 9016 1996 5522 8237 1996 9016 2016 5522 1996 9016 2016 8237 5522 5522 2016 1996 8237 9016																				
26																									
27																									
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31																									
32																									
					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	

- 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.

FRD Pathogen Confirmation

DIAGNOSTIC REPORT

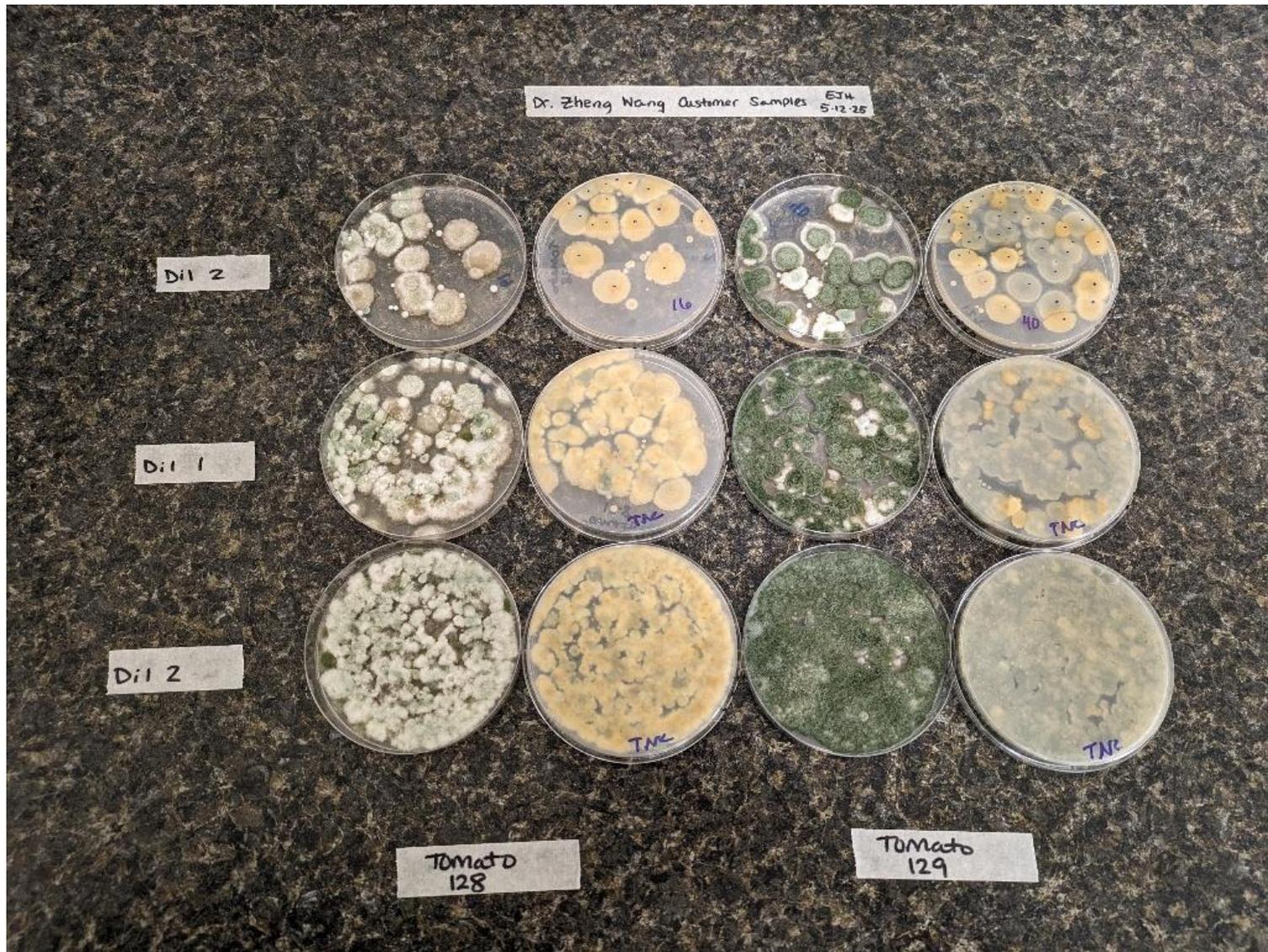
VEGETABLE & FIELD CROPS
COOPERATIVE EXTENSION
UNIVERSITY OF CALIFORNIA

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 <i>Fusarium oxysporum</i> f. sp. <i>lycopersici</i> -Fusarium stem rot and decline (FRD) caused by <i>Fusarium noneumartii</i>
Notes:	<ul style="list-style-type: none">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 <i>Fusarium martii</i>



Root zone soil incubation to confirm colonization (May 12, 2025)

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

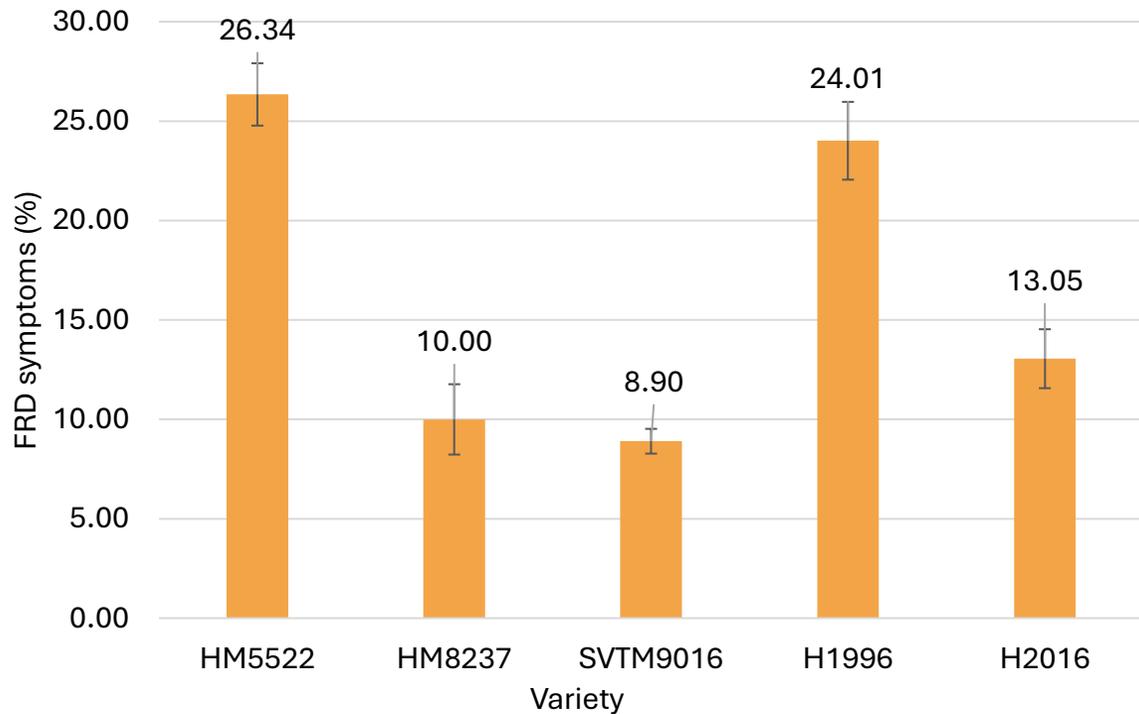


Figure 1A. Average percentage of plants with FRD symptoms for each variety.

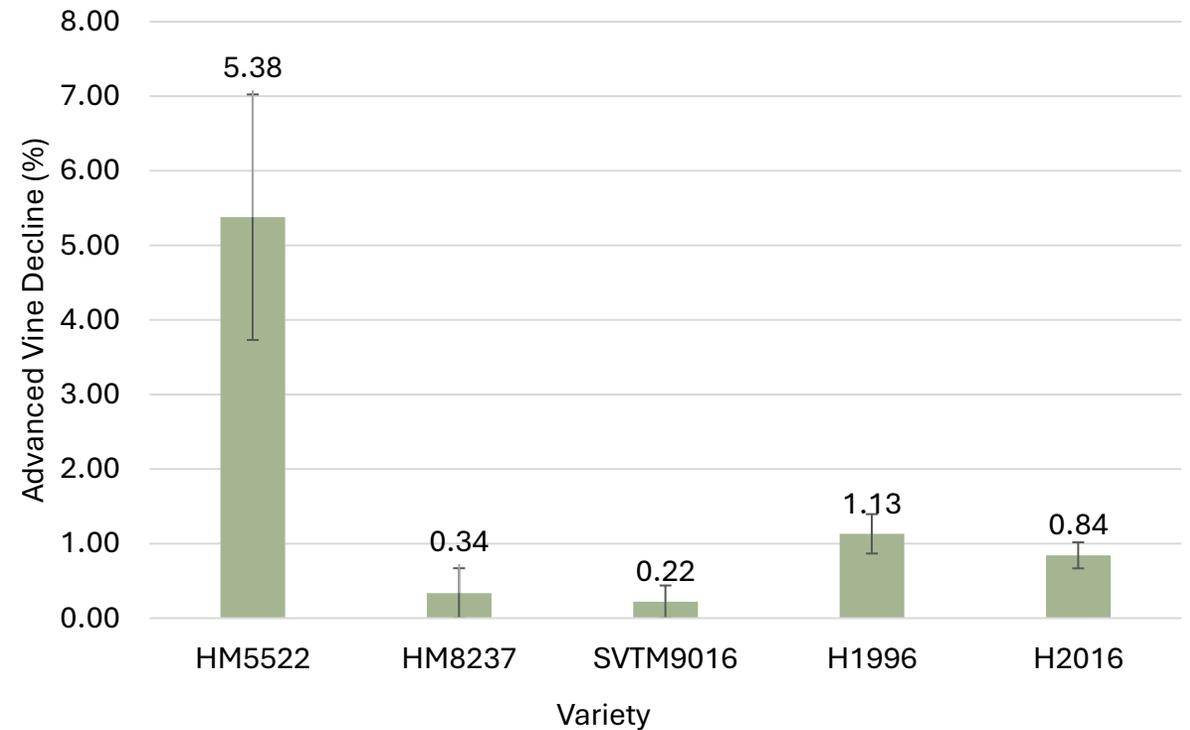


Figure 1B. Average percentage of plants with advanced vine decline for each variety.

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.

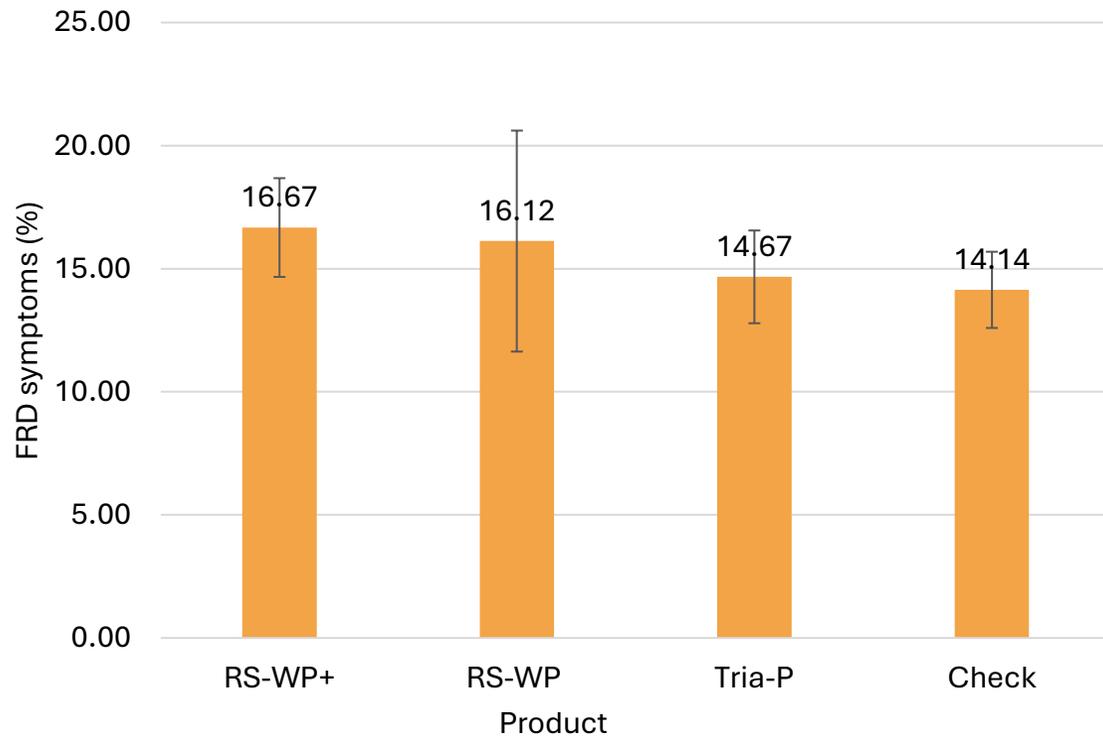


Figure 2A. Product effects on the average percentage of plants with FRD symptoms.

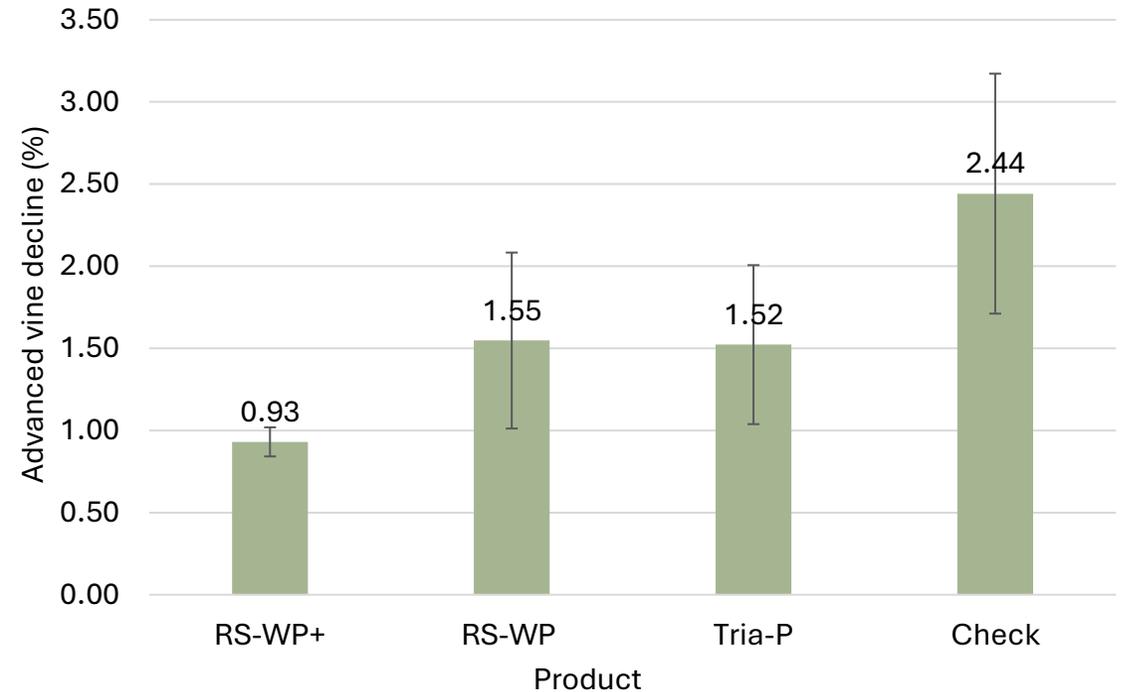


Figure 2B. Product effects on the average percentage of plants with advanced vine decline.

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.

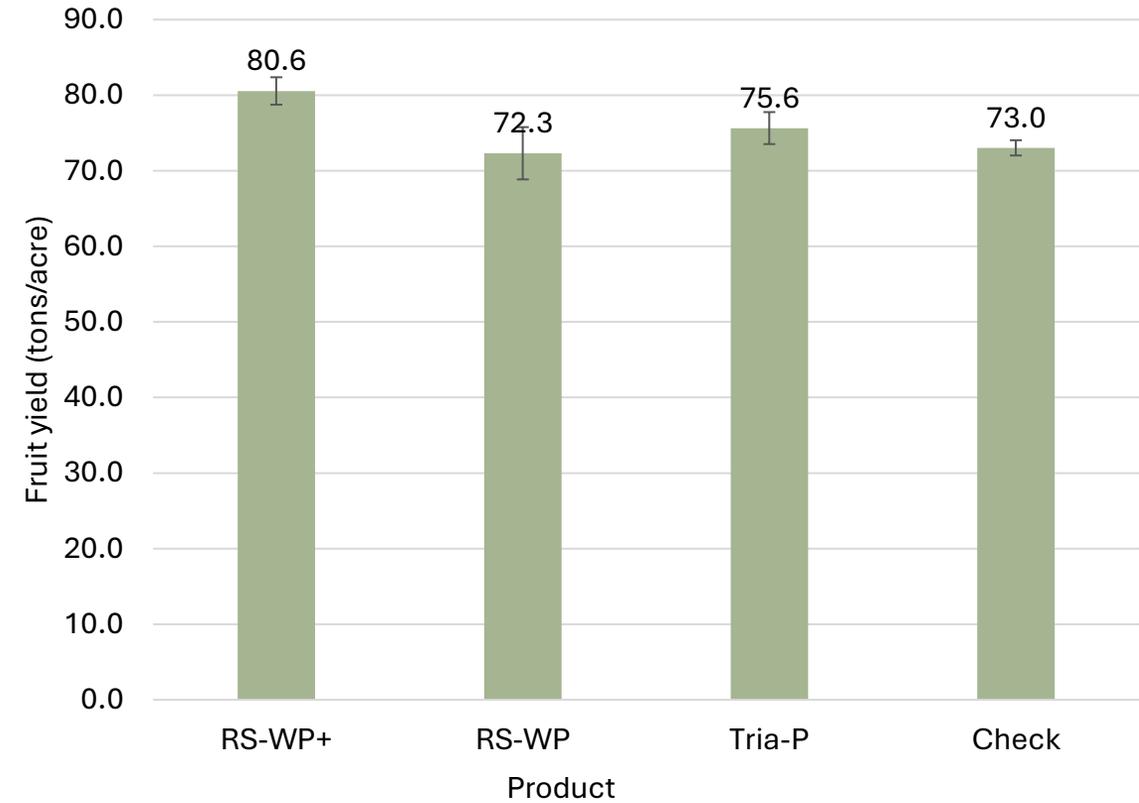
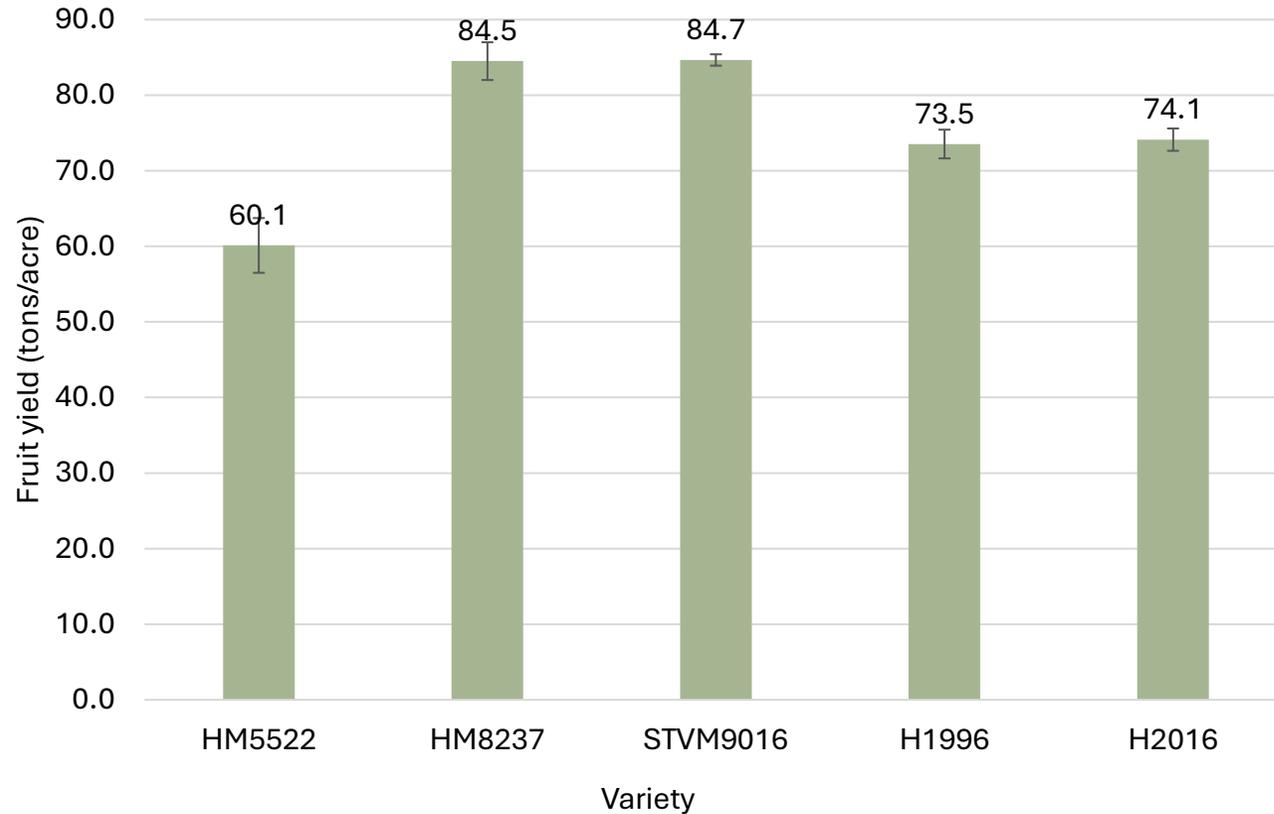
	HM5522		HM8237		SVTM9016		H1996		H2016	
	FRD symptoms*	AD-Vine decline**	FRD symptoms	AD-Vine decline						
RS-WP+	29.1%	2.5%	10.2%	0.8%	3.6%	0.4%	23.3%	1.3%	14.4%	0.4%
RS-WP	23.2%	4.8%	10.4%	0.5%	4.9%	0.4%	20.2%	1.6%	13.6%	0.4%
Tria-P	21.2%	6.0%	9.3%	0.4%	11.1%	0.3%	18.3%	0.4%	13.4%	1.3%
Check	31.9%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

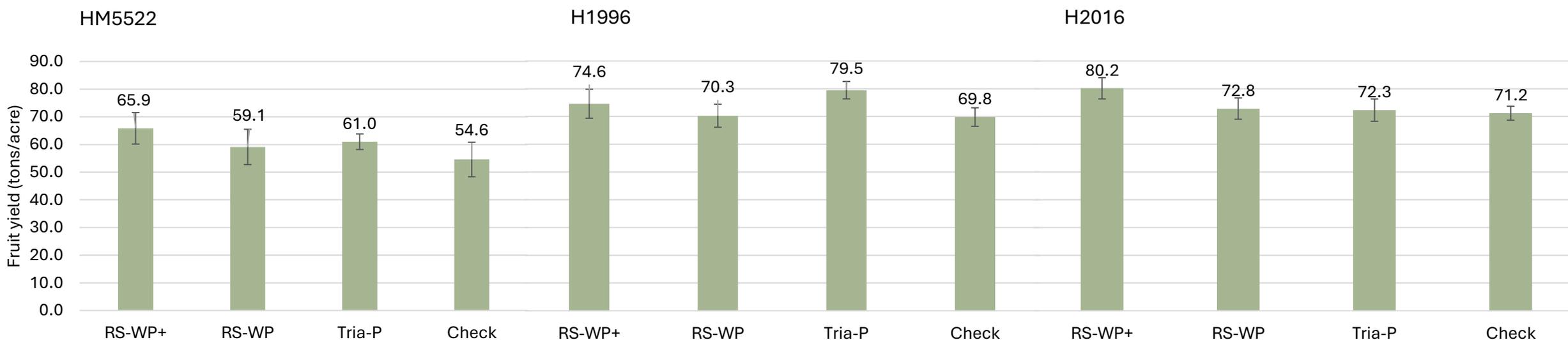


Figure 4A-4C. Effects of Trichoderma product on the yield of tomato varieties.

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
- Brenna Aegerter and Patricia Lazicki
- Perez Farm
- California Transplants
- BioWorks and Koppert
- Student and Staff Assistants
- CTRI

