

Influence of Fungicides and Biological Controls on Potato Diseases and Yukon Gold Yield and Quality

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Introduction: Effective disease management is critical to maximizing potato yield, potato quality, and grower profitability. In this study we investigated chemical and non-chemical disease controls and the integration of control methods for control of *Rhizoctonia solani* (black scurf), *Colletotrichum coccodes* (black dot), and *Verticillium dahlia* (Verticillium wilt). The study involved two separate trials conducted in 2011. One trial evaluated treatments applied to a potato crop grown in soil that was not fumigated prior to planting. The other trial was conducted in a field that was fumigated with metam sodium (Vapam) in fall 2010 and evaluated a sub-set of the same treatments. Harvest data included tuber yield, tuber size, potato grade, and tuber external and internal quality. Disease evaluations for *Rhizoctonia*, *Colletotrichum*, and *Verticillium* were conducted during the growing season and post-harvest. No fungicides besides those listed in the treatment list were applied to the study site.

General Study Information:

Location:	IREC, Tulelake, CA
Soil Type:	Tulebasin mucky silty clay loam with 4.5% organic matter
Planting Date:	No fumigation (non-vapam) trial- May 16, 2011; Fall Vapam trial- May 28, 2011
Vine Kill Date:	No fumigation trial- September 14, 2011; Fall Vapam trial- September 15, 2011
Days to Vine Kill:	No fumigation trial- 121 days; Fall Vapam trial- 110 days
Harvest Date:	No fumigation trial- October 3rd, 2011; Fall Vapam trial- October 13, 2011
Irrigation:	Solid-set sprinklers
Plot Size:	2 rows (6 ft) wide by 30ft long; (10 ft of plot length was used for destructive in-season sampling) (20 ft of plot length was harvested for yield)
In-Row Spacing:	9.1 inches
Row Spacing:	36 inches
Number of Reps:	6 replications
Fertilizer per acre:	202lbs N - 80lbs P ₂ O ₅ - 48lbs K ₂ O - 10lbs S
Herbicides:	Matrix and metribuzin
Insecticides:	Movento and Coragen

Treatments and Application Timings are detailed in Table 1.

Results

Several treatments increased total tuber yield, US No. 1 yield, pack-out revenue, and potato stand compared to the untreated control in the non-vapam trial (Table 2). Compost + compost tea treatments (trts 6 & 7) and the standard fungicide treatment including Maxim and Quadris (trt 12) had the highest total yield and pack-out revenue. These same treatments plus the Vertisan fungicide treatments (trts 9 & 10), Serenade treatments (trts 3 & 8), and Actinovate (trt 5) had the highest total US No. 1 yield. In the Vapam trial, compost + compost tea treatments produced the highest total yield, US No. 1 yield, and pack-out revenue (Table 2).

Treatments had a significant influence on Verticillium wilt and *Rhizoctonia* symptoms in the non-vapam trial (Table 3). Potato vines treated with picoxstrobil (trt 11) showed less Verticillium wilt symptoms on the foliage compared to the untreated control. The compost + compost tea treatment (trt 6) had a lower percentage of belowground stems with *Rhizoctonia* lesions compared to the untreated control. *Rhizoctonia* lesion severity on belowground stems and stolons was less in compost + compost tea treatments (trts 6 & 7), the Vertisan applied in-furrow and 9 weeks after planting treatment (trt 10), the picoxstrobil treatment (trt 11), and the standard fungicide treatment including Maxim and Quadris (trt 12). All biological and fungicide treatments reduced percent coverage of *Rhizoctonia* (black scurf) on tubers, albeit black scurf coverage averaged below 5% in all treatments including the untreated control.

In the Vapam-treated trial, compost + compost tea reduced the incidence of Verticillium wilt symptoms on potato vines and *Rhizoctonia* lesion severity on belowground stems and stolons compared to Vapam alone (Table 3). Serenade + Tenet also decreased *Rhizoctonia* lesion severity on belowground stems and stolons. All treatments decreased the percent coverage of black scurf on tubers, but similar to the non-Vapam trial, black scurf coverage was low in all treatments (Table 3).

Treatments did not influence black dot coverage on lower stems in either the non-Vapam or Vapam trial (Table 3). Treatments also did not influence black dot coverage on tubers in either trial, except for the 20 ton/acre compost treatment in the Vapam-treated trial which increased black dot coverage and severity on tubers compared to Vapam alone (Table 3).

In summary, select biological and fungicide treatments increased potato yield and pack-out revenue while decreasing disease symptoms. Compost + compost tea showed promise as an effective biological treatment as it increased potato yield and pack-out revenue while decreasing *Rhizoctonia* severity on belowground stems, stolons, and tubers compared to the untreated control. Additional research will be conducted next year to verify these results. We also plan to investigate individual components of the fungicide and biological treatments tested in 2011 including comparing compost to compost tea, individual fungicides, and fungicide and biological control application timings.

Table 1. 2011 Biological & Fungicide Disease Management Trials Treatments & Application Timings.

Non-Vapam Trial Treatment List			Foliar Treatment Application Times					
			5 WAP	2, 4, 6, 8, 10, & 12 weeks after emergence	6.5 WAP	9 WAP	12 WAP	13 WAP
Trt #	Product	Product Rate/A	Early Vegetative Growth	Late Vegetative Growth	Tuber Initiation	Tuber Bulking	Tuber Bulking	
1	Untreated Control							
2	Tenet (in furrow)	3 oz/1000 ft of row						
2	Tenet (foliar)	2.5 lb/A	X			X	X	
3	Serenade Soil (in furrow)	4qt/A						
3	Serenade Max (foliar)	2.5lb/A	X			X	X	
4	Superzyme (in furrow)	4qt/100 gallons						
4	Superzyme (foliar)	3 qt/100 gallons	X			X	X	
5	Actinovate (in furrow)	9 oz/A						
5	Actinovate (foliar)	9 oz/A	X			X	X	
6	Compost (pre-plant)	10 ton/A						
6	Compost Tea (in furrow)	10 gallons per acre						
6	Compost Tea (foliar)	5 gallons per acre		X				
6	Fish Plus Organic (foliar)	2.5 gallons per acre		X				
7	Compost (pre-plant)	10 tons/A						
7	MycoApply (seed dust)	1 lb/acre						
7	Biolife (in furrow)	1 pt/A						
7	Serenade Soil (in furrow)	4 qt/A						
7	Compost Tea (in furrow)	10 gallons per acre						
7	Compost Tea (foliar)	5 gallons per acre		X				
7	Fish Plus Organic (foliar)	2.5 gallons per acre		X				
8	Serenade Soil (in furrow)	4 qt/A						
8	Tenet (in furrow)	3 oz/1000 ft of row						
8	Serenade Max (foliar)	2.5 lb/A	X			X	X	
8	Tenet (foliar)	2.5 lb/A	X			X	X	
9	Penthiopyrad-Vertisan (in furrow)	1.6 fl oz/1000 ft of row						
10	Penthiopyrad-Vertisan (in furrow)	1.6 fl oz/1000 ft of row						
10	Penthiopyrad-Vertisan (foliar)	20 fl oz/A				X		
11	Picoxstrobin-Approach (in furrow)	1.3 fl oz/1000 ft of row						
12	Maxim 4FS*	0.08 oz/100 lbs of seed						
12	Quadris (in furrow)	0.6 fl. oz/1000 ft of row						
12	Quadris (foliar) 1st app.	12 fl. oz/A			X			
12	Endura (foliar) 2nd app.	8 oz/A				X		
12	Tanos (foliar) 3rd app.	8 oz/A					X	
13	Bioforge (seed piece trt)	4 oz per 100 lbs of seed	Seed treatment					
13	Calcium 5S (early emergence)	8 fl. oz/A	Emergence					
13	Rezist (early emergence)	4 fl oz/A						
13	N-Large (10 days after early emergence application)	1 fl oz/A	10 Days After Emergence Application					
13	5X (10 days after early emergence application)	8 fl oz/A						
13	BioForge (1 week after N-Large & 5X application)	16 fl. oz/A	1 Week After N-Large & 5X Application					
13	Nitro Plus 9 (2 weeks after Bioforge application)	5 gallons per acre	2 Weeks after BioForge Application					
13	Nitro Plus 9 (2 weeks after 1st Nitro application)	5 gallons per acre	2 Weeks after 1st Nitro Plus 9 Application					
13	Sugar Mover (3 weeks before vine kill)	4 pts/A	3 Weeks before vine kill					

Vapam Trial Treatment List (Vapam applied in fall 2010 at 47 gal/A via rototill incorporation)			Foliar Treatment Application Times					
			5 WAP	2, 4, 6, 8, 10, & 12 weeks after emergence	6.5 WAP	9 WAP	12 WAP	13 WAP
Trt #	Product	Product Rate/A	Early Vegetative Growth	Late Vegetative Growth	Tuber Initiation	Tuber Bulking	Tuber Bulking	
1	Untreated Vapam Control							
2	Serenade Soil (in furrow)	4 qt/A						
2	Tenet (in furrow)	3 oz/1000 ft of row						
2	Serenade Max (foliar)	2.5 lb/A	X			X	X	
2	Tenet (foliar)	2.5 lb/A	X			X	X	
3	Penthiopyrad-Vertisan (in furrow)	1.6 fl oz/1000 ft of row						
3	Penthiopyrad-Vertisan (foliar)	20 fl oz/A				X		
4	Compost (pre-plant)	10 tons/A						
4	Compost Tea (in furrow)	10 gallons per acre						
4	Compost Tea (foliar)	5 gallons per acre	X	X				
4	Fish Plus Organic (foliar)	2.5 gallons per acre	X	X				
5	Compost (pre-plant)	20 ton/A						
5	Compost Tea (foliar)	5 gallons per acre	X	X				
5	Fish Plus Organic (foliar)	2.5 gallons per acre	X	X				

* Maxim 4FS was applied after potato seed was dusted with fir bark.

Design= Randomized Complete Block- 6 replications

In-furrow treatments applied at 18 GPA via 8002 flat-fan nozzle after the seed piece was placed in-furrow and before seed furrow closure.

Postemergence foliar treatments were applied via a CO2 Backpack sprayer at 20 GPA.

The entire trial area was fertilized with split applications of nitrogen totaling 200 lbs N/A along P, K, & S fertilizer at planting to match soil test recommendations.

Table 2. Influence of Fungicides and Biological Products on Yukon Gold Tuber Yield, Size, Performance, and Residual Soil Nitrate and Ammonium at IREC in 2011.

Trt#	Treatment Name- Non Vapam Study Treatments	Tuber Yield (cwt/A)										Avg Tuber	Pack-out Revenue \$/A ²	Residual Soil NO ₃ + NH ₄
		U.S. No. 1's (cwt)							Culls	Plants / Plot ¹	Tubers / Plant			
		Total	10-14oz	6-10oz	4-6oz	<4oz	>14oz	& 2's						
1	Untreated control	343	70	184	89	59	24	12	437	69.4	6.9	6.0	\$5,053	24.4
2	Tenet (<i>Trichoderma asperellum</i> , <i>Trichoderma gamsii</i>)	337	73	169	95	62	17	19	435	71.3	6.8	5.9	\$4,890	n/a
3	Serenade (<i>Bacillus subtilis</i> QST 713)	376	87	196	93	62	14	13	465	72.8	6.9	6.2	\$5,360	n/a
8	Serenade + Tenet	369	76	204	89	57	20	16	462	73.2	6.9	6.2	\$5,270	n/a
4	Superzyme (<i>Bacillus</i> , <i>Pseudomonas putida</i> , and <i>Trichoderma</i> spp.)	364	97	178	89	56	28	17	465	70.8	6.8	6.3	\$5,296	n/a
5	Actinovate (<i>Streptomyces lydicus</i>)	368	91	189	89	57	30	14	469	73.5	7.0	6.2	\$5,391	n/a
6	Compost + compost tea + Fish Plus Organic	386	107	192	87	52	52	14	504	72.8	7.6	6.6	\$5,803	22.1
7	Compost + MycoApply + compost tea + Serenade Soil + Biolife + Fish Plus Organic	390	94	197	99	63	36	16	505	70.6	6.8	6.2	\$5,792	19.9
9	Penthiopyrad (Vertisan) at planting (no foliar applications)	368	96	179	93	59	26	16	469	73.2	6.9	6.2	\$5,356	n/a
10	Penthiopyrad (Vertisan) at planting & Vertisan foliar 9 WAP	367	85	192	90	60	20	16	463	70.5	7.2	6.1	\$5,290	n/a
11	Picoxstrobin (Approach) at planting	335	81	176	78	61	28	26	450	70.2	6.9	6.2	\$4,958	n/a
12	Maxim + Quadris at planting & Quadris, Endura, Tanos rotation starting 6.5 WAP	389	112	186	92	59	32	15	495	72.3	7.2	6.3	\$5,686	n/a
13	Bioforge Program	329	76	158	95	68	23	22	442	66.2	7.5	5.9	\$4,936	26.6
95% confidence interval		23	15	17	NS	6	11	NS	30	2.2	0.4	0.3	\$379	NS

Trt#	Treatment Name- Vapam Study Treatments (Do Not Compare with Non Vapam Study Results)	Total	10-14oz	6-10oz	4-6oz	<4oz	>14oz	& 2's	Culls	Plants / Plot ¹	Tubers / Plant	Avg Tuber	Pack-out Revenue \$/A ²	Residual Soil NO ₃ + NH ₄
1	Fall Vapam at 47 gal/A	305	107	145	53	29	84	32	450	63.2	5.9	8.0	\$4,857	24.5
2	Fall Vapam & Serenade + Tenet	315	123	142	50	32	73	30	450	61.8	6.0	8.0	\$4,890	n/a
3	Fall Vapam & Penthiopyrad (Vertisan) at planting & Vertisan foliar 9 WAP	285	95	144	46	35	72	31	423	62.8	5.8	7.7	\$4,553	n/a
4	Fall Vapam & compost 10 ton/A + compost tea + Fish Plus Organic	338	142	149	47	28	97	38	501	64.0	6.1	8.5	\$5,365	23.8
5	Fall Vapam & compost 20 ton/A & compost tea + Fish Plus Organic	338	134	161	44	25	140	31	534	60.7	6.5	9.0	\$5,887	n/a
95% confidence interval		22	14	NS	NS	NS	21	NS	30	NS	NS	0.4	\$434	NS

¹The seed spacing for this trial was 9.1 inches; 100% emergence = 79 plants per plot.

²Pack-out Revenue per Acre was calculated as follows: <4 oz to >14 oz size classes = \$12 per CWT; Culls and 2's = \$-5 per CWT

³Residual soil nitrate and ammonium (0-12 inch depth) was measured at harvest for select treatments. n/a = not available because treatments were not sampled for residual nitrate and ammonium.

Table 3. Influence of Fungicides and Biological Products on Yukon Gold Disease Ratings & Tuber Internal Characteristics at IREC in 2011.

Trt#	Treatment Name- Non Vapam Study Treatments	Vert. Wilt Rating	End of Season Vine Vigor ²	Stolons with Rhizoc. Lesions %	Stems with Rhizoc. Lesions %	Stolon & Stem Rhizoc. Severity Rating ³	Avg Rhizoc. Coverage on Tubers %	Root Rhizoc. Severity Rating ⁴	Avg. Wt./ 10ft of Row (grams)	Avg Black Dot Coverage on Lower Stems %	Black Dot Coverage on Tubers %	Black Dot Severity Rating ⁵	Hollow Heart % ⁶	Tuber	
														End Stem Necrosis % ⁶	Vascular Discoloration % ⁶
1	Untreated control	7.2	2.2	29.4	54.0	2.6	4.0	4.52	342.2	39.0	16.8	3.2	0.1	18.2	5.8
2	Tenet (<i>Trichoderma asperellum</i> , <i>Trichoderma gamsii</i>)	7.6	2.2	17.5	70.3	3.0	2.8	4.76	353.2	39.2	17.5	3.2	2.3	7.2	0.6
3	Serenade (<i>Bacillus subtilis</i> QST 713)	7.0	2.5	44.1	52.0	3.0	2.7	4.74	384.6	35.1	15.9	3.2	0.4	18.3	4.8
8	Serenade + Tenet	7.5	2.0	49.7	49.3	3.0	1.9	4.75	297.4	44.2	16.3	3.2	0.0	12.1	2.7
4	Superzyme (<i>Bacillus</i> , <i>Pseudomonas putida</i> , and <i>Trichoderma</i> spp.)	7.0	3.0	32.5	48.3	2.7	2.2	4.75	328.8	33.5	17.4	3.4	0.0	18.3	3.3
5	Actinovate (<i>Streptomyces lydicus</i>)	7.2	2.8	21.7	47.2	2.8	2.4	4.75	363.5	40.9	16.6	3.3	3.3	8.3	3.3
6	Compost + compost tea + Fish Plus Organic	7.3	3.0	20.8	38.8	3.3	2.5	4.75	374.0	37.7	16.7	3.3	0.0	13.3	5.0
7	Compost + MycoApply + compost tea + Serenade Soil + Biolife + Fish Plus Organic	7.0	3.2	28.5	43.1	3.4	2.8	4.76	388.0	31.0	16.4	3.3	0.0	15.7	3.8
9	Penthiopyrad (Vertisan) at planting (no foliar applications)	7.5	2.5	44.8	62.5	2.7	2.3	4.75	371.3	36.9	22.7	3.0	0.0	10.0	5.0
10	Penthiopyrad (Vertisan) at planting & Vertisan foliar 9 WAP	6.8	2.7	34.8	41.0	3.5	2.8	4.75	333.6	42.6	15.8	3.2	2.6	19.8	0.5
11	Picoxstrobin (Approach) at planting	6.6	2.8	32.0	59.2	3.1	2.2	4.75	370.8	33.0	14.0	3.4	0.0	16.7	1.7
12	Maxim + Quadris at planting & Quadris, Endura, Tanos rotation starting 6.5 WAP	7.0	3.0	25.0	55.8	3.1	2.6	4.60	350.7	30.2	18.1	3.4	1.6	11.7	1.7
13	Bioforge Program	7.3	2.8	32.9	62.5	2.5	2.7	4.75	377.7	31.6	18.2	3.1	2.0	10.7	4.7
	95% confidence interval	0.5	NS	NS	15.0	0.6	1.1	0.14	NS	NS	NS	NS	NS	NS	NS

Trt# Treatment Name- Vapam Study Treatments (Do Not Compare with Non Vapam Study Results)															
1	Fall Vapam at 47 gal/A	7.1	2.7	35.1	57.7	2.6	3.5	4.68	399.7	42.8	7.2	3.9	4.7	8.8	1.5
2	Fall Vapam & Serenade + Tenet	7.0	3.3	25.0	46.0	3.6	1.8	4.75	393.6	42.2	9.2	3.8	3.3	3.3	3.3
3	Fall Vapam & Penthiopyrad (Vertisan) at planting & Vertisan foliar 9 WAP	6.8	3.2	32.3	57.2	3.1	2.1	4.75	415.2	40.6	9.9	3.8	1.7	8.3	5.0
4	Fall Vapam & compost 10 ton/A + compost tea + Fish Plus Organic	6.3	3.8	24.3	51.5	3.2	2.1	4.75	463.1	40.2	8.8	4.1	1.7	8.3	3.3
5	Fall Vapam & compost 20 ton/A & compost tea + Fish Plus Organic	6.3	4.9	23.0	54.8	3.9	1.7	4.77	568.4	31.4	13.0	3.4	0.0	23.6	0.0
	95% confidence interval	0.4	0.5	NS	NS	0.9	1.0	NS	48.4	NS	3.0	0.3	NS	6.6	NS

¹ = Verticillium Wilt Rating 0-9 scale, 0= 0 Symptoms, 1= Trace, 2= 1-5% of plants show symptoms of disease, 3= 5-10%, 4= 10-20%, 5= 20-40%, 6= 40-60%, 7= 60-75%, 8= 75-90%, 9= 90-100%

² = Vine Vigor Rating 1-10 scale, 10= highest vigor

³ = Rhizoctonia Severity Rating for Belowground Stems and Stolons (10ft of row) 1-5 scale, 5= no infection

⁴ = Rhizoctonia (black scurf) Severity Rating on Tuber Skin (10 tubers/ plot) 1-5 scale, 5= no infection

⁵ = Black Dot Severity Rating on Tuber Skin (10 tubers/ plot) 1-5 scale, 5= no infection

⁶ = 10 tubers evaluated from each plot (6-14 oz tubers)