

POTATO (*Solanum tuberosum* L. 'Snowden')

Pink rot; *Phytophthora erythroseptica*
 Pythium leak; *Pythium ultimum*
 Late blight; *Phytophthora infestans*

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Evaluation of fungicides as soil applications at planting and foliar applications for pink rot and Pythium leak control, 2002.

Soil was inoculated with mefenoxam-sensitive *Pythium ultimum* and *Phytophthora erythroseptica* at the Michigan State University Botany Farm, East Lansing, MI on 11 May 2000 and again on 17 May 2001; no further inoculum was applied in 2002. Potatoes (cut seed) were planted at the Michigan State University Botany Farm, East Lansing, MI on 17 May into four-row by 50-ft plots (34-in. row spacing) replicated three times in a randomized complete block design. The four-row beds were separated by a five-foot unplanted row. Plots were irrigated at planting and soil moisture was monitored with tensiometers. Water was applied as needed with seep-hose to maintain soil moisture at a minimum of 80% field capacity. After desiccation, plots were continuously watered to encourage tuber disease development caused by the inoculated pathogens. Plots were hilled immediately before foliar sprays began. Fungicides were applied in-furrow at planting at a rate of 5 gal/A (40 p.s.i.) applied at a rate using the conversion factor: Band rate per acre = [Band width (inches)/Row spacing (inches)] * Broadcast Rate per Acre. Thereafter fungicide treatments were applied as scheduled and late blight prevention maintenance treatments of Previcur 6SC 1.2 pt/A were applied weekly from 5 Jun to 15 Aug (10 applications) with an ATV rear-mounted R&D spray boom delivering 25 gal/A (80 p.s.i.) and using three XR11003VS nozzles per row. Weeds were controlled by hilling and with Dual 8E (2 pt/A on 28 May) and Poast (1.5 pt/A on 17 Jul). Insects were controlled with Admire 2F (20 fl oz/A at planting on 17 May) and Sevin 80S (1.25 lb on 1 and 17 Jul). Plots were rated visually for percent emergence and percent canopy closure from planting to full emergence and full canopy closure respectively and a relative rate of development was calculated for both emergence and canopy formation. Prior to application of fungicides on 19 Jun, five plants were harvested from each replicate and the number of tubers greater than 0.25" (any plane) per plant was counted. Harvests were repeated on 16 Jul (Harvest 2); 14 Aug (Harvest 3) and 11 Sep (Harvest 4) and tuber number and percent of tubers with symptoms of pink rot and/or Pythium leak were assessed. Symptomatic tubers were tested with *Phytophthora* and *Pythium* specific ELISA assays. Tuber number per plant and percentage of tubers per four-plant sample were compared using two-way ANOVA for comparison of treatments at individual harvest dates and two-way repeated measures ANOVA were used to compare if the metrics changed between harvests. Vines were killed with Reglone 2EC (1 pt/A on 15 Aug). Plots (50-ft row) were harvested on 11 Sep and individual treatments were weighed and graded (tubers less than 2.5 in width in any plane were discarded and only total marketable yield was reported). A further sub sample of 10 tubers per plot were challenge inoculated with each of *Pythium ultimum*, *Phytophthora erythroseptica*, *Phytophthora infestans* (all mefenoxam-sensitive isolates) or a sterile rye agar core by placing an 1/8" diameter core, taken from an axenic culture of each pathogen grown on rye agar, on the surface of the tuber at its apical end. The core was covered with a 1/4" diameter Eppendorf tube, the lid of which was cut off and dipped in petroleum jelly to adhere the tube to the tuber surface, to ensure a humid microenvironment. Tubers were cut open 28 days after inoculation and the percentage of tubers with symptoms of the diseases were calculated.

Taking 35 days after planting (DAP) as a key reference point, no fungicide applied in-furrow delayed emergence in comparison with treatments that were not applied in-furrow in terms of the RAUEPC. Canopy formation (RAUCDC) was not affected by any in-furrow application of any fungicide. The in-furrow applications of fungicides were not phytotoxic. At harvest 1, prior to applications of foliar fungicides, there were about 10.3 ± 0.91 ($n = 300$ plants) tubers per plant (greater than 0.25" any plane) and no significant differences between any treatments. The total number of tubers decreased in all treatments to 6.2 ± 0.71 , 5.8 ± 1.00 and 4.5 ± 0.66 after harvests 1, 2 and 3, respectively ($n = 300$ plants, average of all treatments), but there were no significant differences between treatments at harvests 2 to 4. At the final harvest (h4), all treatments except 10 and 17 had significantly more tubers than the untreated control. Tuber number decline was compared within treatments. There was a significant decline in tuber number in all treatments from harvest 1 to 4. There was generally no significant difference between harvest 2 and 3 for any treatment and treatments 3, 4, 6, 7, 8, 9, 11 and 19 did not significantly decline in tuber number between harvests 2 and 4. The percentage incidence of tubers with symptoms of pink rot or Pythium leak increased to harvest 3 then decreased at harvest 4 in all treatments. The untreated control had significantly more diseased tubers than all other treatments at harvests 2 and 3 but not at harvest 1 or 4. At harvest 2, treatment 5 had significantly more diseased tubers than treatments 1, 7, 9, 10, 11, 12, 13, 14, 15 and 18 but was not significantly different from any other treatment. At harvest 3, treatments 8 and 12 had significantly fewer diseased tubers than treatments 3 and 17 but were not significantly different from any other treatment. Percent incidence of diseased tubers was compared within treatments. A significant increase in percentage diseased tubers at harvest three occurred in treatments 1, 4, 7, 9, 10, 11, 14, 15, 16, 17 and 18. The high incidence of diseased tubers at harvest 3 and subsequent decline at harvest 4 may have been a result of complete deterioration of infected tubers between the two harvests. Although a significant increase in incidence of

diseased tubers was reported at harvest 3 within treatments, the overall incidence [average of the h1 - 4 within treatments, Table 2)] was numerically lower than the non-treated control for all treatments. All treatments had significantly greater marketable and total yield than the nontreated control (Table 3). Treatments 10, 17 and 18 had significantly lower marketable yield than treatments with yield greater than 212 cwt/A. Treatment 10 and 17 had significantly lower total yield than treatments with yield greater than 283 cwt/A. Some disease developed in tubers challenge inoculated with each of *Pythium ultimum*, *Phytophthora erythroseptica*, *Phytophthora infestans* but no treatments had significantly different percentage incidence of diseased tubers in comparison with the nontreated control for any of the pathogens (Table 4).

Mefenoxam-based products generally reduced the amount of tuber disease and tuber loss regardless of application timing or formulation type. Other products also reduced the amount of tuber loss and incidence of tuber disease. Tuber loss and incidence of tuber disease even in the best treatments in this trial, under highly conducive conditions for development of *Pythium* leak and pink rot, was still high with up to 60% tuber loss resulting in low yields. The use of mefenoxam not indeed any product for control of *Pythium* leak and pink rot under highly conducive conditions remains an issue and recommendations for application of any products aimed at controlling these diseases remains speculative..

Table 1.

Treatment and rate/acre	% final ^z	Emergence and Canopy development	
		RAUEPC ^y	RAUCDC ^x
1 Ridomil Gold 4EC 0.1 pt (A) ^w	91.4	0.33	0.20
2 Ridomil Gold 4EC 0.1 pt (A)			
Ridomil Gold Bravo 6WP 2.0 lb (D)	95.6	0.36	0.19
3 Ridomil Gold Bravo 6WP 2.0 lb (D,F)	96.4	0.36	0.20
4 Ridomil Gold Bravo 6WP 2.0 lb (F,H)	93.3	0.38	0.19
5 Ultra Flourish 2EC 0.2 pt (A)	93.3	0.35	0.20
6 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A)	93.1	0.39	0.20
7 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A)			
Fluorinil 76.4WP 2.0 lb (D)	94.4	0.35	0.21
8 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A)			
Fluorinil 76.4WP 2.0 lb (D,F)	90.0	0.38	0.19
9 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A)			
Phostrol 4SC 4.0 pt (D); 6.0 pt (F)	90.0	0.35	0.20
10 Gavel 75WDG 0.48 lb (A); 2.0 lb (B,C,F,H)	93.9	0.36	0.19
11 Messenger 3WDG 0.1 lb (A); 0.28 lb (D,F,H)	89.4	0.37	0.20
12 Ridomil Gold 4EC 0.1 pt + Messenger 3WDG 0.1 lb (A)	91.9	0.38	0.20
13 Ultra Flourish 2EC 0.2 pt (A)	94.4	0.37	0.21
14 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt +			
Acrobat 50WP 0.08 lb(A)	93.3	0.37	0.20
15 Acrobat 50WP 0.08 lb (A)	92.2	0.38	0.20
16 Headsup 3WDG 0.1 lb (A); 0.28 lb (D,F,H)	93.9	0.36	0.21
17 Summerdale I + II RATE 1 (A)	91.9	0.38	0.20
18 Summerdale I + II RATE 2 (A)	92.2	0.37	0.19
19 Summerdale I + II RATE 3 (A)	91.7	0.38	0.19
20 Untreated	96.7	0.38	0.19
sem P = 0.05 ^w	1.9	0.013	0.008

^z Percent emergence calculated as percent of maximum possible emergence in 2 x 50' rows.

^y Relative Area Under the Emergence Progress Curve from planting until 95% emergence [35 days after planting (dap)] in untreated control (max = 1).

^x Relative Area Under the Canopy Development Curve from planting until 100% canopy cover (53 dap) in untreated control (max = 1).

^w Application dates: A= 17 May (in-furrow at planting, Band rate per acre = [Band width (inches)/Row spacing (inches)] * Broadcast Rate per Acre) in 5 gal water/A; (foliar applications B - K), B= 5 Jun; C= 12 Jun; D= 19 Jun; E= 3 Jul; F= 17 Jul; G= 4 Aug; H= 15 Aug.

^u Standard error of mean included if no significant difference was calculated in ANOVA.

Funding MPIC and Industry

Table 2

Treatment and rate/acre	Tuber number per plant ^z								Tubers with Pythium and/or Pink Rot (%) ^z				average harvest 1 to 4 (standard error)					
	harvest 1 ^z		harvest 2		harvest 3		harvest 4		harvest 1		harvest 2			harvest 3		harvest 4		
1 Ridomil Gold 4EC 0.1 pt (A) ^x	10.5 a ^w	A ^y	6.2 a	B	5.4 a	B	4.2 ab	C	0.0 a	B	1.3 c	B	12.7bcd	A	1.4 a	B	3.9	5.95
2 Ridomil Gold 4EC 0.1 pt (A)																		
Ridomil Gold Bravo 6WP 2.0 lb (D)	9.5 a	A	6.0 a	B	6.3 a	B	4.2 ab	C	3.7 a	A	6.2 bc	A	9.7 cd	A	1.2 a	A	5.2	3.64
3 Ridomil Gold Bravo 6WP 2.0 lb (D,F)	9.7 a	A	6.4 a	B	5.5 a	B	4.6 ab	B	13.4a	A	0.0 bc	A	9.3 cd	A	1.4 a	A	6.0	6.40
4 Ridomil Gold Bravo 6WP 2.0 lb (F,H)	10.3 a	A	6.5 a	B	5.3 a	BC	4.9 a	C	0.0 a	B	2.7 bc	B	14.6bc	A	1.5 a	B	4.7	6.69
5 Ultra Flourish 2EC 0.2 pt (A)	10.9 a	A	7.0 a	B	6.8 a	BC	4.5 ab	C	0.0 a	A	7.7 b	A	8.2 cd	A	1.5 a	A	4.4	4.22
6 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A)	9.9 a	A	6.3 a	B	6.4 a	B	5.1 a	B	0.0 a	A	2.5 bc	A	12.7bcd	A	1.6 a	A	4.2	5.74
7 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A)																		
Fluorinil 76.4WP 2.0 lb (D)	10.2 a	A	6.0 a	B	5.6 a	B	5.1 a	B	0.0 a	B	0.0 c	B	9.2 cd	A	2.1 a	B	2.8	4.36
8 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A)																		
Fluorinil 76.4WP 2.0 lb (D,F)	10.3 a	A	5.8 a	B	5.3 a	B	5.0 a	B	3.7 a	A	1.5 bc	A	4.8 d	A	1.4 a	A	2.9	1.67
9 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A)																		
Phostrol 4SC 4.0 pt (D); 6.0 pt (F)	11.4 a	A	6.0 a	B	5.3 a	B	4.7 a	B	5.6 a	AB	0.0 c	B	12.6bcd	A	1.4 a	B	4.9	5.64
10 Gavel 75WDG 0.48 lb (A); 2.0 lb (B,C,F,H)	10.3 a	A	5.8 a	B	6.3 a	B	3.9 bc	C	6.4 a	AB	0.0 c	C	8.3 cd	A	2.3 a	BC	4.2	3.78
11 Messenger 3WDG 0.1 lb (A); 0.28 lb (D,F,H)	10.5 a	A	6.2 a	B	6.8 a	B	4.4 ab	B	3.5 a	A	0.0 c	A	5.3 cd	A	2.1 a	A	2.7	2.25
12 Ridomil Gold 4EC 0.1 pt + Messenger 3WDG 0.1 lb (A)	9.8 a	A	7.2 a	B	6.3 a	BC	4.6 ab	C	0.0 a	C	0.0 c	C	3.9 d	A	1.9 a	B	1.5	1.88
13 Ultra Flourish 2EC 0.2 pt (A)	9.8 a	A	6.2 a	B	6.5 a	B	4.6 ab	C	0.0 a	B	0.0 c	B	5.0 d	A	1.7 a	B	1.7	2.36
14 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt +																		
Acrobat 50WP 0.08 lb(A)	10.9 a	A	6.1 a	B	6.3 a	B	4.4 ab	C	3.1 a	A	1.5 bc	A	6.4 cd	A	1.0 a	A	3.0	2.43
15 Acrobat 50WP 0.08 lb (A)	10.0 a	A	6.4 a	B	5.3 a	C	4.8 a	C	3.2 a	B	1.2 c	B	10.7cd	A	2.1 a	B	4.3	4.35
16 Headsup 3WDG 0.1 lb (A); 0.28 lb (D,F,H)	11.0 a	A	6.1 a	BC	6.7 a	B	4.8 a	C	0.0 a	B	0.0 c	B	9.1 cd	A	2.1 a	B	2.8	4.30
17 Summerdale I + II RATE 1 (A)	11.0 a	A	6.4 a	B	4.8 a	BC	3.8 bc	C	0.0 a	B	2.7 bc	B	20.4b	A	1.5 a	B	6.1	9.55
18 Summerdale I + II RATE 2 (A)	10.3 a	A	6.4 a	B	6.0 a	B	4.3 ab	C	0.0 a	B	0.0 c	B	11.3bcd	A	1.0 a	B	3.1	5.49
19 Summerdale I + II RATE 3 (A)	10.4 a	A	5.5 a	B	5.1 a	B	4.7 a	B	0.0 a	B	3.1 bc	B	13.3bcd	A	1.7 a	B	4.5	5.98
20 Untreated	10.1 a	A	5.5 a	B	4.3 a	BC	3.0 c	BC	6.9 a	A	15.5 a	A	30.8 a	A	3.0 a	A	14.1	12.3
sem P = 0.05 ^u	0.49		0.41		0.54				2.21								0.58	

^z Five plants were selected at random from outside rows of each treatment plot on 18 Jun (Harvest 1, 1 day prior to application of foliar fungicide on 19 Jun); 16 Jul (Harvest 2); 14 Aug (Harvest 3) and 11 Sep (Harvest 4), tuber number and percent of tubers with symptoms of pink rot and/or Pythium leak were assessed. Symptomatic tubers were tested with Phytophthora and Pythium specific ELISA assays.

^y Total and marketable yield (cwt/A), tubers >2.5" width in any plane (estimated from 2 x 50ft row).

^x Application dates: A= 17 May (in-furrow at planting, Band rate per acre = [Band width (inches)/Row spacing (inches)] * Broadcast Rate per Acre) in 5 gal water/A; (foliar applications B - K), B= 5 Jun; C= 12 Jun; D= 19 Jun; E= 3 Jul; F= 17 Jul; G= 4 Aug; H= 15 Aug.

^w Values followed by the same lower case letter are not significantly different for treatment comparisons at P = 0.05 (Tukey Multiple Comparison).

^y Values followed by the same upper case letter are not significantly different for harvest comparisons at P = 0.05 (Tukey Multiple Comparison); analyses completed after significant interactions computed in comparison s of tuber number and percent incidence of diseased tubers using a two-way repeated measures ANOVA.

^u Standard error of mean included if no significant difference was calculated in ANOVA.

Table 3.

Treatment and rate/acre	Market-able		Yield cwt/A ^z	
				Total
1 Ridomil Gold 4EC 0.1 pt (A) ^y	226	ab ^x	254	ab
2 Ridomil Gold 4EC 0.1 pt (A) Ridomil Gold Bravo 6WP 2.0 lb (D)	212	ab	253	ab
3 Ridomil Gold Bravo 6WP 2.0 lb (D,F)	228	ab	278	ab
4 Ridomil Gold Bravo 6WP 2.0 lb (F,H)	248	a	296	a
5 Ultra Flourish 2EC 0.2 pt (A)	244	a	273	ab
6 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A)	254	a	303	a
7 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A) Fluorinil 76.4WP 2.0 lb (D)	261	a	304	a
8 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A) Fluorinil 76.4WP 2.0 lb (D,F)	250	a	297	a
9 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A) Phostrol 4SC 4.0 pt (D); 6.0 pt (F)	235	a	284	a
10 Gavel 75WDG 0.48 lb (A); 2.0 lb (B,C,F,H)	198	b	235	bc
11 Messenger 3WDG 0.1 lb (A); 0.28 lb (D,F,H)	216	ab	267	ab
12 Ridomil Gold 4EC 0.1 pt + Messenger 3WDG 0.1 lb (A)	239	a	278	ab
13 Ultra Flourish 2EC 0.2 pt (A)	232	ab	279	ab
14 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt + Acrobat 50WP 0.08 lb(A)	220	ab	264	ab
15 Acrobat 50WP 0.08 lb (A)	239	a	288	a
16 Headsup 3WDG 0.1 lb (A); 0.28 lb (D,F,H)	236	a	288	a
17 Summerdale I + II RATE 1 (A)	181	bc	226	bc
18 Summerdale I + II RATE 2 (A)	205	b	255	ab
19 Summerdale I + II RATE 3 (A)	224	ab	283	a
20 Untreated	146	c	183	c

^z Total and marketable yield (cwt/A), tubers >2.5" width in any plane (estimated from 2 x 50ft row).

^y Application dates: A= 17 May (in-furrow at planting, Band rate per acre = [Band width (inches)/Row spacing (inches)] * Broadcast Rate per Acre) in 5 gal water/A; (foliar applications B - K), B= 5 Jun; C= 12 Jun; D= 19 Jun; E= 3 Jul; F= 17 Jul; G= 4 Aug; H= 15 Aug.

^x Values followed by the same lower case letter are not significantly different for treatment comparisons at P = 0.05 (Tukey Multiple Comparison).

Table 3.

Treatment and rate/acre	Percent tubers with disease symptoms after challenge inoculation ^z		
	Late blight <i>P. infestans</i>	Pink rot <i>P. erythroseptica</i>	Pythium leak <i>Pythium ultimum</i>
1 Ridomil Gold 4EC 0.1 pt (A) ^y	6.7	6.7	3.3
2 Ridomil Gold 4EC 0.1 pt (A) Ridomil Gold Bravo 6WP 2.0 lb (D)	6.7	10.0	3.3
3 Ridomil Gold Bravo 6WP 2.0 lb (D,F)	6.7	10.0	6.7
4 Ridomil Gold Bravo 6WP 2.0 lb (F,H)	3.3	10.0	0.0
5 Ultra Flourish 2EC 0.2 pt (A)	6.7	6.7	0.0
6 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A)	6.7	6.7	6.7
7 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A) Fluorinil 76.4WP 2.0 lb (D)	6.7	6.7	3.3
8 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A) Fluorinil 76.4WP 2.0 lb (D,F)	13.3	13.3	10.0
9 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt (A) Phostrol 4SC 4.0 pt (D); 6.0 pt (F)	3.3	10.0	3.3
10 Gavel 75WDG 0.48 lb (A); 2.0 lb (B,C,F,H)	13.3	13.3	10.0
11 Messenger 3WDG 0.1 lb (A); 0.28 lb (D,F,H)	3.3	10.0	3.3
12 Ridomil Gold 4EC 0.1 pt + Messenger 3WDG 0.1 lb (A)	6.7	6.7	3.3
13 Ultra Flourish 2EC 0.2 pt (A)	10.0	10.0	10.0
14 Ultra Flourish 2EC 0.2 pt + Phostrol 4SC 1.44 pt + Acrobat 50WP 0.08 lb(A)	10.0	13.3	6.7
15 Acrobat 50WP 0.08 lb (A)	6.7	6.7	3.3
16 Headsup 3WDG 0.1 lb (A); 0.28 lb (D,F,H)	6.7	6.7	3.3
17 Summerdale I + II RATE 1 (A)	6.7	10.0	3.3
18 Summerdale I + II RATE 2 (A)	13.3	13.3	6.7
19 Summerdale I + II RATE 3 (A)	6.7	6.7	6.7
20 Untreated	10.0	16.7	10.0
sem P = 0.05 ^x	3.66	4.02	3.28

^z Sub samples of 10 tubers per plot were challenge inoculated with each of *Phytophthora infestans*, *Phytophthora erythroseptica* and *Pythium ultimum* (all mefenoxam-sensitive isolates) or a sterile rye agar core by placing an 1/8" diameter core, taken from an axenic culture of each pathogen grown on rye agar, on the surface of the tuber at its apical end. The core was covered with a 1/4" diameter Eppendorf tube, the lid of which was cut off and dipped in petroleum jelly to adhere the tube to the tuber surface, to ensure a humid microenvironment. Tubers were cut open 28 days after inoculation and the percentage of tubers with symptoms of the diseases were calculated.

^y Application dates: A= 17 May (in-furrow at planting, Band rate per acre = [Band width (inches)/Row spacing (inches)] * Broadcast Rate per Acre) in 5 gal water/A; (foliar applications B - K), B= 5 Jun; C= 12 Jun; D= 19 Jun; E= 3 Jul; F= 17 Jul; G= 4 Aug; H= 15 Aug.

^x Inclusion of the sem (P=0.05) indicated that there was no significant difference among treatments.