

Evaluation of novel fungicide seed treatments in combination with management practices for the control of seed-borne diseases of potato.

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Figure 1. *Fusarium* seed piece decay and sprout rot, caused by *Fusarium sambucinum*, results in delayed or non-emergence of plants and leads to poor and uneven stands with weakened plants.

Fungicide treatment and rate/100g seed ¹	Inoculation ²	Storage type ³	Diseased sprouts (%)	Incidence of seed piece decay (%) ⁴	Seed piece decay (%) ⁵
None	-	A	32.8 defg ^a	35.0 defg	5.1 e
		B	37.5 defg	25.0 fg	4.6 e
		C	27.7 fg	57.5 bcde	14.0 e
	+	A	89.4 a	97.5 a	68.9 ab
		B	96.9 a	100 a	85.1 a
		C	91.2 a	97.5 a	60.4 bc
Serenade Max (250g)	-	A	45.0 cdefg	40.0 cdefg	8.5 e
		B	42.4 defg	45.0 cdef	11.6 e
		C	35.6 defg	42.5 cdefg	6.9 e
	+	A	47.2 cdef	30.0 bcde	43.5 cd
		B	66.1 bc	77.5 ab	55.5 bc
		C	53.4 cde	45.0 cdef	40.0 cd
T-22 Planter Box (125g)	-	A	33.5 defg	27.5 fg	15.0 e
		B	37.5 defg	32.5 defg	11.0 e
		C	41.6 defg	30.0 efg	11.9 e
	+	A	54.0 cd	57.5 bcde	40.8 cd
		B	84.2 ab	67.5 bc	52.5 bc
		C	65.4 bc	60.0 bcd	43.8 cd
Maxim MZ (500g)	-	A	31.2 efg	15.0 g	3.4 e
		B	33.0 defg	40.0 cdefg	6.9 e
		C	30.1 fg	27.5 fg	6.9 e
	+	A	33.4 defg	32.5 defg	4.9 e
		B	38.2 defg	30.0 efg	22.8 de
		C	24.4 g	22.5 fg	4.1 e

Table 1. Effect of storage method, seed treatment application and inoculation with *Fusarium sambucinum* on sprout development, and sprout and seed piece health of potatoes stored for 14 days in controlled environments after the scheduled time of planting.



Figure 2. Seed pieces infected with *Fusarium sambucinum*. (a) A seed piece showing severe seed piece decay. A dry necrotic cavity is lined with clumps of white to orange mycelia. (b) A seed piece cut in half showing internal dry rot (DR) in the tuber tissue and sprout rot in the sprout (S). (c) Close-up of the sprout shown in (b) illustrating the brown necrosis of the sprout spreading out from the tuber tissue into the sprout which is characteristic of sprout rot.

Fungicide treatment and rate/100g seed ¹	Inoculation ²	Storage type ³	RAUEPC (%) ⁴	Final plant stand (%) ⁵	Diseased stems (%) ⁶
None	-	A	15.5 a ^a	89.2 abc	20.7 a
		B	14.7 abcd	85.8 abc	20.8 a
		C	6.5 g	44.2 d	37.8 a
	+	A	14.4 abcde	84.2 abc	24.3 a
		B	11.5 abcdefg	70.0 abcd	33.2 a
		C	8.2 efg	52.5 cd	34.5 a
Serenade Max (250g)	-	A	14.7 abcd	86.7 abc	13.2 a
		B	14.8 abcd	85.0 abc	24.3 a
		C	8.6 defg	58.3 bcd	24.1 a
	+	A	13.4 abcdef	80.0 abcd	24.5 a
		B	9.1 bcdefg	52.5 cd	27.1 a
		C	8.8 cdefg	58.3 bcd	31.2 a
T-22 Planter Box (125g)	-	A	15.1 abc	88.3 abc	31.2 a
		B	14.4 abcde	85.0 abc	41.8 a
		C	14.3 abcde	85.8 abc	34.8 a
	+	A	15.4 ab	91.7 ab	24.1 a
		B	12.6 abcdefg	75.8 abcd	36.0 a
		C	7.5 fg	51.7 cd	29.7 a
Maxim MZ (500g)	-	A	17.0 a	98.3 a	28.0 a
		B	15.8 a	94.2 ab	20.9 a
		C	13.7 abcdef	83.3 abc	35.5 a
	+	A	16.1 a	94.2 ab	26.9 a
		B	15.0 abc	86.7 abc	11.5 a
		C	11.2 abcdefg	71.7 abcd	12.6 a

Table 4. Effect of timing of seed treatment application and inoculation with *Fusarium sambucinum* on emergence, final plant stand, and number of diseased stems of potato.

Introduction

Seedborne diseases of potato represent a significant constraint to potato production in the United States. Pathogens such as *Phytophthora infestans* (late blight) and *Fusarium sambucinum* (Fusarium dry rot) are major pathogens of potato, affecting tubers in storage and seed tubers and sprouts after planting. In severe outbreaks, the pathogens may kill developing sprouts outright, resulting in delayed or non-emergence. Reduction in crop vigor then results from expenditure of seed energy used to produce secondary or tertiary sprouts to compensate for damage to primary sprouts. The use of an effective seed treatment in combination with good management practices during cutting and seed storage prior to planting is essential to reducing late blight and Fusarium dry rot, as well as secondary bacterial soft rot in cut seed prior to planting. This project sought to evaluate two new biofungicides (*Bacillus subtilis* Serenade Max; *Trichoderma harzianum*, T-22 PlanterBox) and a reduced risk fungicide (fludioxonil+mancozeb, Maxim MZ) for control of seedborne diseases, and to determine the best conditions to store seed after cutting and treating.

Materials and Methods

- Experiments were carried out in Spring 2006 with potato cultivar "FL1879".
- Seed piece tubers free from disease were selected from certified seed crops grown in Michigan.
- Tubers were inoculated with solutions of sporangia/zoospores of *P. infestans* (late blight) and conidia of *F. sambucinum* (dry rot), prepared from cultures of the pathogens previously isolated from potato tubers in Michigan. All pathogens were grown on PDA for 10 days prior to preparation of inoculum solutions.
- Sporangia (*P. infestans*) and conidia (*F. sambucinum*) were harvested from the plates and concentrations, determined by hemacytometer, adjusted to about 1×10^3 sporangia, conidia/ml.
- A comparison between two simulations of cutting/treating/planting regimes were made; a) cutting and treating seed with a delay in planting of 10 days and b) cutting and treating on the day of planting. Controls included seed that was cut and inoculated with the pathogen and cut but not inoculated at each of the two cutting times.
- For each treatment, tubers were cut longitudinally in half with a sterile knife ensuring that viable sprouts were present on both halves. The cut seed pieces were then treated in one of three ways, 1) not inoculated, 2) inoculated with either *P. infestans* or *F. sambucinum* or 3) inoculated with one of the 2 pathogens and treated with one of the fungicide seed treatments (see above) at the manufacturers recommended rate. The non-inoculated treatments consisted of cut seed pieces sprayed with sterile distilled water only.
- Inoculated seed pieces were produced by spraying 200 ml of conidial/mycelial suspension (1×10^3 conidia/ml) over the entire cut surface to give a final dosage of about 1 ml per seed piece. Care was taken to limit inoculum spray to the cut surface only.
- The fungicidal seed treatments were applied to the cut seed pieces 30 minutes after inoculation using a Gustafson revolving drum seed treater.

Conclusions

Results of the *in vitro* experiments on the effectiveness of fungicidal seed treatments and different storage conditions prior to planting for controlling seed piece decay and sprout rot are shown in Tables 1 and 2. The results show that storage of seed pieces under sub-optimal conditions (at 25°C in the dark without ventilation) significantly increased the levels of seed piece decay and sprout rot (Tables 1, 2). In experiments inoculated with *F. sambucinum*, all treatments had significantly fewer diseased sprouts (sprout rot) and a lower incidence of seed piece decay than the inoculated/non-treated controls (positive controls). Seed treatment with the biofungicides Serenade Max, and T-22 Planter Box and storage under optimal conditions (between 12 and 18°C at 95% RH and with forced air ventilation at 5950 l min⁻¹) provided good control of sprout rot and seed piece decay caused by *F. sambucinum* (Table 1). In the late blight experiments treatment with the biofungicides significantly lowered the incidence of seed piece decay and the percentage of seed piece decay per tuber when seed pieces were stored under optimal conditions or treated on the day of planting (Table 2). The amount of seed piece decay in seed pieces treated with T-22 Planter Box and stored under optimal conditions was equivalent to that in treatments with Maxim MZ (Table 2). In treatments where the biofungicides were applied on the day of planting the amount of seed piece decay was not significantly different from the non-inoculated/non-treated control (negative control). Neither of the biofungicides or the commercial seed treatment Maxim MZ provided effective control of seed piece decay when the tubers were stored under sub-optimal conditions (Table 2).

Results of the *in vivo* field experiments to evaluate the agronomical effects of fungicidal seed treatments and storage conditions before planting on crop health are shown in Tables 4 and 5. In all experiments, treatment with the biofungicides did not significantly enhance the rate of emergence of sprouts (RAUEPC) or the final plant stand compared to the positive control (Tables 4, 5). In experiments inoculated with *F. sambucinum*, there were no significant differences between the two types of storage regime. However, in all treatments there was a lower rate of emergence and lower final plant stand in treatments treated and inoculated on the day of planting (Table 4). There were no significant differences between treatments in terms of the number of diseased stems. In late blight experiments (Table 5), the non-inoculated treatments where the biofungicides were applied on the day of planting showed a significant reduction in the rate of emergence and final plant stand, suggesting that the biofungicides may be having a phytotoxic effect on emerging sprouts (Table 5).

Footnotes for Tables

- Seed pieces were treated with the seed treatment 30 min after inoculation. All rates are manufacturers recommended rate.
- Seed pieces were inoculated with *Fusarium sambucinum* (Table 1) or *Phytophthora infestans* (Table 2) = "+"; seed pieces were not inoculated = "-"; seed pieces were inoculated immediately after cutting 14 days prior to planting.
- Storage types were: A, stored for 10 days before planting (DBP) under optimal conditions (12 - 18°C at 95% RH with forced air ventilation at 5950 l min⁻¹); B, stored for 10 DBP under poor conditions (25°C in dark with no ventilation); C, treated and inoculated on the day of planting.
- Incidence of seed piece decay was calculated as the mean number of seed pieces showing symptoms of Fusarium dry rot (Table 1) or late blight (Table 2).
- Seed piece decay was calculated as the percentage volume of decay per tuber.
- RAUEPC, relative area under the plant emergence progress curve, calculated from the day of planting to full emergence 28 days after planting (max = 100).
- Final plant stand, was expressed as the percentage of emerged plants divided by the expected number based on the planting rate.
- Diseased stems, the number of stems showing symptoms of vascular wilt when cut open.
- Numbers followed by the same letter within a column are not significantly different at $P = 0.05$ (Tukey multiple comparison method).



Figure 3. A late blight infected research plot. Seed pieces infected with late blight may rot in the soil resulting in delayed or non-emergence of plants. Alternatively, infected shoots may transmit the disease to surrounding healthy plants.

Fungicide treatment and rate/100g seed ¹	Inoculation ²	Storage type ³	Incidence of seed piece decay (%) ⁴	Seed piece decay (%) ⁵
None	-	A	0.0 g	0.0 e
		B	0.0 g	0.0 e
		C	0.0 g	0.0 e
	+	A	87.5 ab	74.5 ab
		B	100.0 a	81.6 ab
		C	50.0 cd	25.3 de
Serenade Max (250g)	-	A	0.0 g	0.0 e
		B	0.0 g	0.0 e
		C	0.0 g	0.0 e
	+	A	55.0 cd	43.1 cd
		B	92.5 a	85.4 ab
		C	30.0 def	8.3 e
T-22 Planter Box (125g)	-	A	5.0 fg	1.4 e
		B	10.0 efg	1.8 e
		C	2.5 g	0.3 e
	+	A	32.5 de	18.5 de
		B	100.0 a	95.5 ab
		C	12.5 efg	2.9 e
Maxim MZ (500g)	-	A	0.0 g	0.0 e
		B	0.0 g	0.0 e
		C	0.0 g	0.0 e
	+	A	32.5 de	18.6 de
		B	65.0 bc	61.5 bc
		C	10.0 efg	1.1 e

Table 2. Effect of storage method, seed treatment application and inoculation with *Phytophthora infestans* on seed piece health of potatoes stored for 14 days in controlled environments after the scheduled time of planting.



Figure 4. (a) Sprout rot, caused by *Phytophthora infestans* in a late blight infected seed piece. (b) Cross section through the back of a seed piece heavily infected with late blight showing discoloration of the potato skin and a dry granular rot underneath the skin.

Fungicide treatment and rate/100g seed ¹	Inoculation ²	Storage type ³	RAUEPC (%) ⁴	Final plant stand (%) ⁵
None	-	A	15.2 a ^a	89.2 a
		B	13.9 ab	80.0 abcd
		C	6.8 def	49.2 efg
	+	A	7.7 cdef	45.8 fgh
		B	7.7 cdef	45.0 fgh
		C	7.8 cdef	40.0 gh
Serenade Max (250g)	-	A	14.5 ab	85.0 abc
		B	13.9 ab	81.7 abcd
		C	8.2 cdef	57.5 bcdefgh
	+	A	9.4 bcdef	56.7 bcdefgh
		B	6.0 ef	34.2 h
		C	7.7 cdef	55.8 cdefgh
T-22 Planter Box (125g)	-	A	14.8 a	86.7 ab
		B	13.4 ab	78.3 abcde
		C	4.4 f	31.7 h
	+	A	12.1 abc	72.5 abcdef
		B	9.4 bcdef	53.3 defgh
		C	6.1 def	44.2 fgh
Maxim MZ (500g)	-	A	16.0 a	93.3 a
		B	15.1 a	86.7 ab
		C	10.9 abcde	71.7 abcdef
	+	A	12.1 abc	70.0 abcdef
		B	6.7 def	40.8 gh
		C	11.3 abcd	70.0 abcdefg

Table 5. Effect of timing of seed treatment application and inoculation with *Phytophthora infestans* on emergence and final plant stand of potato.