

**REPORT TO THE AGRICULTURAL RESEARCH FOUNDATION
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Project Title: Evaluation of Fungicides for the Control of Gray and White Mold in Snap Beans

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Background and Justification: Cancellation of the registration of an effective bean mold fungicide, Ronilan, occurred at the end of the 2005 growing season. Finding equivalent alternatives for use in snap bean is critical. The goal of the project is to continue evaluations of alternative fungicides for their effectiveness in controlling White Mold (*Sclerotinia sclerotiorum*) and Gray Mold (*Botrytis cinerea*) on snap bean.

Effective registered fungicides for control of bean mold include Endura (boscalid), Topsin formulations (thiophanate-methyl), Rovral (iprodione), and Switch (fludioxonil + cyprodinil) (Table 1). Topsin (thiophanate-methyl) controls white mold well but has little effect on gray mold because many gray mold strains are resistant to these fungicides. Rovral (iprodione) controls gray mold but has been perceived to be inferior to Ronilan in controlling white mold but this may be due to more limited application timing. Endura (boscalid) is a relatively new chemistry in snap bean production and has shown good efficacy on white and gray mold in limited studies but has single mode of action for controlling mold diseases, thusly, is prone to development of resistance. Switch (fludioxonil + cyprodinil) was registered during 2006 on snap bean and is probably a better tool for management of gray mold than white mold but information is limited on its efficacy in snap bean. Unlike Ronilan, Topsin, Rovral, Endura, and Switch are all lacking in curative properties and if used after infection has occurred, these fungicides would appear ineffective or less effective compared to Ronilan. Thus timing of application is critical for preventing infection of blossoms that lead to infections of bean pods and stems.

Two biological products are also labeled for snap bean, Contans and Serenade. The fungus that constitutes Contans (*Coniothyrium minitans*) parasitizes sclerotia of *Sclerotinia sclerotiorum* but efficacy requires physical contact between Contans and sclerotia as the parasitic fungus will not move or grow towards sclerotia in soil. Contans is labeled for preplant or post-harvest applications and requires two to three months with soil temperatures between 40 and 77 F to be effective at parasitizing sclerotia. Published reports indicate that Contans can reduce the population of sclerotia in soil but protective fungicides are still needed on snap bean sown in Contans-treated soil. Serenade has some efficacy as a protective fungicide but may be best as a tank-mix partner.

Fungicides not registered on snap bean but that hold promise for bean mold management include Omega and other experimental products. Further study of the non-registered alternative fungicides is necessary to expedite registrations.

Table 1. Fungicides registered in 2007 for mold control in Oregon snap bean production

PHI	Plant back restrictions	Gray mold control	White mold control	Trade name	Active ingredient	Rate/A
7 days		X (ineffective)		Bravo Ultrex	chlorothalonil	2.7 lb
			X (ineffective)	Botran	(DCNA) dichloran	2.25 lb
preplant or post-harvest			X (ineffective alone)	Contans	<i>Coniothyrium minitans</i> (fungus)	1 to 4 lb
7 days	14 days	X	X	Endura	boscalid	8 to 11 oz
see label	yes, unclear	X	X	Rovral 4F	iprodione	1.5 to 2 pt
0 days			X (weak) (tank mix)	Serenade MAX	<i>Bacillus subtilis</i> (bacterium)	1 lb
7 days	30 days	X	X ?	Switch 62.5WG	fludioxonil + cyprodinil	11-14 oz
14 days	30 days	X (resistance problems)	X	Topsin formulations	thiophanate-methyl	See label

Selected products used in McReynolds' trials during 2000-2002 demonstrated effectiveness against both white and gray molds but efficacy was not always equal to that of Ronilan. In 2000, Endura and Omega (fluazinam) applications both resulted in good control of white mold and gray mold on bean pods but whole plant ratings were more severely diseased than that found with Ronilan. In 2001, white mold and gray mold levels on bean pods from plots treated with Endura, Omega (fluazinam), and Switch (cyprodinil + fludioxonil) all were statistically comparable to the Ronilan treatment but these alternative fungicides all had a greater incidence of white mold on pods than that found with Ronilan. The 2002 studies had very little disease, probably due to the drier conditions in the Willamette Valley. Studies conducted during 2004 focused on evaluating surfactants in combination with Endura and the two field studies conducted showed that Endura combined with certain surfactants controlled white mold and percentage of moldy pods were similar to that found in Ronilan treatments, while very little gray mold was found in either trial.

Studies conducted during 2005 in replicated small plots showed that a tank-mix of higher rates of Rovral with Topsin controlled white mold while gray mold was present at low levels, but control of both white and gray mold would be expected. Reduced rates of Rovral+Topsin may be adequate under moderate disease pressure but further research is warranted. A tank-mix of Endura with Topsin or application of Endura after Topsin+Rovral should also control both white and gray mold. Microthiol Disperss (sulfur) is labeled for use on snap bean to control leaf spot and powdery mildew but not mold. Our studies showed that two tank-mixed applications of Microthiol Disperss+Topsin+Rovral resulted in good control of white mold. However, if temperatures exceed 90 F within 3 days after application of Microthiol Disperss, crop injury may occur. Trials during 2006 did not have sufficient disease for treatment efficacy comparisons though harvest weights did not indicate a yield reduction due to Topsin+Rovral applications compared to nontreated plots. The results from the 2005 field studies are encouraging for snap bean mold management in the absence of Ronilan. However, further studies were needed to further evaluate the use of lower fungicide rates and application timing to determine if lower rates are effective and whether a single spray is effective under moderate diseases pressure.

Objective: The purpose of this proposed research is to evaluate and compare performance of registered fungicides (Topsin, Rovral, Endura, Switch) and non-registered materials in reducing

white mold and gray mold in snap bean field studies. Spray timing, fungicide rates, and gallons of spray/A will also be examined.

Procedures: Six field trials were established in the Willamette Valley and except for one planting of wax beans, the trials were planted with the snap bean variety 91G. Three trials were conducted in commercial fields (Mark Dickman's farm and Jim Schlechter's farm) and three were located on the OSU Botany Farm, Corvallis. Bean plots on the OSU Botany Farm were infested with sclerotia of *Sclerotinia sclerotiorum* produced in the lab and sclerotia were spread in the field after a conditioning period.

The sites at Dickman's Farm in Marion County were in Dayton silt loam soil. The site at Schlechter's Farm in Marion County was in Woodburn silt loam soil. The sites on the OSU Botany Farm were in Chehalis silt loam soil. At each field site, plots were 5' by 20' and were arranged in a randomized complete block design with four replications. The OSU Botany Farm fields were planted on 6 June (study sites 1 & 2) and 26 July (study site 5) using a 30-in row spacing (190,000 seeds/A) and 400 lb/A of 12-29-10-8 fertilizer was banded at planting followed by 100 lb/A of 40-0-0-6 banded at the second to third trifoliolate leaf stage. For weed control, Eptek 7EC (3.5 pt/A) and Trifluorolin (0.5 pt/A) were broadcast and incorporated 4 days before planting; Basagran (2 pt/A) and Poast (2 pt/A) were applied 24 days after planting. Asana XL (8 oz/A) was applied one week after 10 % bloom for control of beetles. The on-farm site at Schlechter's Farm was planted on 22 May (study site 4). The on-farm sites at Dickman's Farm were planted on 8 May (study site 3) or 2 July (study site 6) using a 20-in row spacing (206,000 seeds/A) and a preplant broadcast of 14 lb/A urea and 98 lb/A muriate of potash was applied. Then a planter sidedress of 30 gal/A of 10-34-0 fertilizer and 6 gal/A of thiosul, and a broadcast of 150 lb/A ammonium sulfate was applied 4 weeks after planting. Eptek 7EC (3.5 pt/A) and Trust (0.5 pt/A) were broadcast and incorporated with a tiller 4 days before planting, and Basagran (2 pt/A) was broadcast 24 days after planting for weed control.

All fields were sprinkler-irrigated weekly with 1" to 1.5" of water. Fungicide treatments (Table 1) were applied with a CO₂ backpack sprayer calibrated to deliver 22 gal of water/A (except for a treatment that delivered a spray volume of 35 gal/A) at 38-40 psi using three 8002 flat fan nozzles. Experimental fungicides that are not labeled for use on snap bean (Omega 500F and Proline) were not applied to plots on-farm. The dates and weather conditions of the 10% bloom applications and 100% bloom applications are shown in Table 2.

Table 1. Bean mold fungicide programs evaluated during 2007 in replicated small plot trials

Trade name & rate per acre	Timing
Nontreated	
Endura (8 oz) + MSO 100 (2 qt/100 gal)	10 % bloom, repeat 7 days later
Rovral 4F (2 pt) + MSO 100 (2 qt/100 gal)	10 % bloom, repeat 7 days later
Topsin 4.5FL (30 fl oz) + MSO 100 (2 qt/100 gal)	10 % bloom, repeat 7 days later
Switch 62.5WG (11 oz) + MSO 100 (2 qt/100 gal)	10 % bloom, repeat 7 days later
Rovral 4F (2 pt)+Topsin 4.5FL (30 fl oz)+MSO 100 (2 qt/100 gal)	10 % bloom, repeat 7 days later
Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)+MSO 100 (2 qt/100 gal)	10 % bloom, repeat 7 days later
Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)+MSO 100 (2 qt/100 gal)	in 35 gal H2O/A at 10 % bloom, repeat 7 days later
Rovral 4F (2 pt)+Topsin 4.5FL (40 fl oz)+MSO 100 (2 qt/100 gal)	10 % bloom
Rovral 4F (2 pt)+Topsin 4.5FL (40 fl oz)+MSO 100 (2 qt/100 gal)	100 % bloom
Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)+MSO 100 (2 qt/100 gal)	10 % bloom
Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)+MSO 100 (2 qt/100 gal)	100 % bloom
Endura (5 oz)+Topsin 4.5FL (20 fl oz)+MSO 100 (2 qt/100 gal)	10 % bloom, repeat 7 days later
Switch 62.5WG (6 oz)+Topsin 4.5FL (20 fl oz) + MSO 100 (2 qt/100 gal)	10 % bloom, repeat 7 days later
Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)+MSO 100 (2 qt/100 gal) followed by Endura (8 oz)+MSO 100 (2 qt/100 gal)	10 % bloom and then 7 days later
Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)+Microthiol Disperss (6 lb) +MSO 100 (2 qt/100 gal)	10 % bloom, repeat 7 days later
Serenade MAX (1 lb)+Break Thru (2 fl oz/100 gal)+Kumulus DF (7 lb) ^O	10 % bloom, repeat 7 days later
Omega 500F (4 fl oz) + MSO 100 (2 qt/100 gal) *	10 % bloom, repeat application 7 days later
Proline (Jau 6476) at 5.7 oz + Induce at 0.125 v/v *	10 % bloom, repeat application 7 days later
* = experimental, not labeled for use on snap bean, ^O = organic label	

Table 2. Dates and conditions of 2007 bean mold fungicide applications and hand-harvest date

Site	Crop Stage	Spray Date	Time	Temp (F)	Wind speed (mph)	Harvest Date
OSU Botany Farm (Field 1)	R1	19 June	3 PM	88	1.2	11 July
	R2	26 June	11AM	70	2	
OSU Botany Farm (Field 2)	R1	20 June	11 AM	83	1.5	12 July
	R2	27 June	7 AM	60	1.8	
Dickman's Farm (Field 3)	R1	26 June	8 AM	60	1.6	17 July
	R2	2 July	8:30 AM	68	3	
Schlechter's Farm (Field 4)	R1	19 July	7:30 AM	60	2	9 Aug
	R2	26 July	7 AM	64	1	
OSU Botany Farm (Field 5)	R1	10 Sep	11:30 AM	81	3.5	25 Sep
Dickman's Farm (Field 6)	R1	15 Aug	7:30 AM	69	1	5 Sep
	R2	21 Aug	8:30 AM	-	1	

The number of pods, presence of white or gray mold on pods ≥ 2 inches in length, and number of stems with white or gray mold were determined for 30 individual plants selected arbitrarily from the center row of each plot. Means were calculated on the % pods or stem number affected per plant. Treatments were compared with Fisher's protected LSD statistic ($P \leq 0.05$).

Results: Very low levels of white or gray mold were found at five of the six study sites, so harvesting of all treatments was done only at field 6 (on-farm site at Dickman's Farm). No phytotoxicity was observed in any of the treatments. In field 6, percentage of pods \geq 2-in. in length and stem number affected by white mold was lower in all of the fungicide treatments compared to the nontreated plants, where affected pods and stems were 7.5 and 1.8%, respectively. Rovral 4F (2 pt)+Topsin 4.5FL (30 fl oz) resulted the lowest white mold incidence on pods or stems. When Rovral 4F (2 pt) or Switch 62.5WG (11 oz) were used, diseased pod levels were similar to the aforementioned Rovral/Topsin tank mix. When a tank mix of Rovral/Topsin was followed by Endura, or included Microthiol, white mold incidence on pods and stems was similar to Rovral 4F (2 pt)+Topsin 4.5FL (30 fl oz). Rovral+Topsin at lower rates (1.5 pt and 20 fl oz, respectively) as 2 applications, or a single application at 10 % bloom, resulted in white mold incidence on pods similar to Rovral 4F (2 pt)+Topsin 4.5FL (30 fl oz), but a single application of these reduced rates at 100 % bloom had a significant increase in white mold on pods and stems. Reduced rates of Topsin+Rovral in a 2-spray program delivered in 35 gal water/A, or when Endura or Topsin were applied alone, resulted in significantly higher white mold pod and stem incidence compared to Rovral 4F (2 pt)+Topsin 4.5FL (30 fl oz). A tank mix of Serenade and Kumulus (organically-acceptable) or Switch and Topsin had significantly higher levels of white mold on pods compared to Rovral 4F (2 pt)+Topsin 4.5FL (30 fl oz).

When the number of pod plus pin bean hits with white mold are compared, or pod hits alone, some treatments resulted in less desirable levels of white mold. When Endura, Rovral, Topsin, or Switch were applied alone, slightly higher white mold incidences on pods and pin beans occurred compared to a tank mix of Rovral 4F (2 pt/A) + Topsin 4.5FL (30 fl oz/A) in a 2-spray program. The 2-spray program of Rovral 4F (2 pt/A) + Topsin 4.5FL (30 fl oz/A) was significantly better at **managing white mold pod + pin bean hits** than applications of Endura alone, Rovral alone, Topsin alone, reduced rates of Topsin+Rovral at 100 % bloom or in a 2-spray program, Switch+Topsin at section 2 (ee) recommended rates, or the organically-acceptable program of Serenade Max + Kumulus.

A tank-mix of Endura+Topsin or application of Endura after Topsin + Rovral also resulted in good white mold management. The addition of sulfur to Rovral+Topsin didn't markedly improve management in this trial. The tank mix of Serenade and Kumulus (organically-acceptable) also resulted in a significant decrease in control of white mold on pods, though not stems, compared to the 2-spray program of Topsin+Rovral at higher rates, and may fail under higher disease pressure. The lower rate of Switch tank mixed with Topsin had the second highest levels of white mold infected bean pods while Rovral alone had the second highest level of stem hits with white mold.

Low levels of gray mold were detected on pods (< 0.27 pod/plant) or stems (< 0.09 stem/plant), and the nontreated control had no pod infections. Nontreated plots had the highest presence of gray mold on stems and all fungicide applications resulted in reduction of the slight gray mold level.

Conclusions: Sclerotia of white mold germinate and produce a small fruiting structure which releases millions of spores into the air. Under moist conditions, spores may infect senescent tissue such as blossoms. After colonizing blossoms or senescing leaves, the white mold fungus can invade any healthy plant part it contacts. So, to protect developing bean pods, pods must be protected from contact with infected blossoms. Oregon growers must manage closely for bean mold because the currently registered materials lack the kick-back activity associated with Ronilan, thus timing of applications is important.

Our studies during 2007 did not have sufficient mold levels at all locations for comparing fungicides, levels of active ingredients, or application timing. However, treatments at study site 6 resulted in significant differences among treatments, and the 2-spray program of Rovral 4F (2 pt/A) + Topsin 4.5FL (30 fl oz/A) was numerically best at managing white mold on bean pods. Our studies during 2005 also showed that a 2-spray program of Rovral 4F (2 pt/A) + Topsin 4.5FL (30 fl oz/A) gave good control of white mold. Tank mixtures at reduced rates of Rovral (1.5 pt) and Topsin (20 fl oz) **in a two-spray program may be adequate under moderate disease pressure**. A single spray program of Rovral 4F (2 pt/A) + Topsin 4.5FL (30 fl oz/A) or reduced rates of this tank mix may be adequate **if perfectly timed, under lower disease pressure, and if environmental conditions during pod development don't become too moist**. In cultivars with long flowering periods, a 2-spray program will protect a greater percentage of blossoms, and as blossom infections lead to pod and stem infections, potentially more serious losses can be avoided if disease develops. A tank-mix of Endura with Topsin or application of Endura after Topsin + Rovral should control mold on snap bean. The full labeled rate of each material in the combination will give good control of white mold and gray mold. A reduced rate tank mix of Endura (5 oz) and Topsin (20 fl oz) should be adequate under **moderate disease pressure**. The results from our 2005 and 2007 field studies are encouraging for snap bean mold management in the absence of Ronilan. But timing of protective fungicide applications, amount of active ingredients, and subsequent environmental conditions during flowering and pod development are very critical considerations for white and gray mold management. **A lower risk of failure to manage mold disease in snap bean fields is anticipated if a 2-spray program of Rovral 4F (2 pt/A) + Topsin 4.5FL (30 fl oz/A) is effectively applied to the snap bean canopy pods**. **A 1-spray program, as demonstrated, has more inherent risk for protection failure** and timing for a 1-spray application is still not well-defined for success; e.g., even a 1-spray at 10 % bloom may fail if conditions for disease prevail, and certainly late applications of protective fungicides warrant concern for pod losses due to mold.

Table 3. Healthy pod numbers and incidence of white mold in 2007 snap bean trial

Healthy pod#		% pods with white mold		% pods & pin beans with white mold		Stem # with white mold		Material(s) - Trade Name (& Rate)	Timing
13	h	7.5	a	8.5	a	1.78	a	Nontreated	
19	bc	1.7	c	2.1	d	0.50	de	Endura (8 oz)	10 % bloom, repeat 7 days later
20	b	1.5	cd	4.1	bc	1.04	b	Rovral 4F (2 pt)	10 % bloom, repeat 7 days later
23	a	2.1	c	2.5	cd	0.45	def	Topsin 4.5FL (30 fl oz)	10 % bloom, repeat 7 days later
17	cd	1.0	cd	1.7	de	0.33	defg	Switch 62.5WG (11 oz)	10 % bloom, repeat 7 days later
18	c	0.1	d	0.1	e	0.04	h	Rovral 4F (2 pt)+Topsin 4.5FL (30 fl oz)	10 % bloom, repeat 7 days later
18	c	1.6	cd	1.9	d	0.20	gh	Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)	10 % bloom, repeat 7 days later
16	def	1.8	c	1.8	de	0.30	defg	Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz) in 35 gal H ₂ O/A	10 % bloom, repeat 7 days later
20	b	1.2	cd	1.2	de	0.38	defg	Rovral 4F (2 pt)+Topsin 4.5FL (40 fl oz)	10 % bloom
14	gh	0.8	cd	1.0	de	0.21	fgh	Rovral 4F (2 pt)+Topsin 4.5FL (40 fl oz)	100 % bloom
16	def	1.3	cd	1.5	de	0.53	d	Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)	10 % bloom
16	de	3.7	b	4.3	b	0.80	bc	Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)	100 % bloom
20	b	0.8	cd	1.0	de	0.26	efgh	Endura (5 oz)+Topsin 4.5FL (20 fl oz)	10 % bloom, repeat 7 days later
15	fgh	4.2	b	5.0	b	0.79	bc	Switch 62.5WG (6 oz)+Topsin 4.5FL (20 fl oz)	10 % bloom, repeat 7 days later
14	gh	0.7	cd	1.7	de	0.43	defg	Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz) followed by Endura (8 oz)	10 % bloom and then 7 days later
15	efg	0.8	cd	1.0	de	0.28	efgh	Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)+Microthiol Disperss (6 lb)	10 % bloom, repeat 7 days later
13	h	2.2	c	2.4	cd	0.25	fgh	Serenade MAX (1 lb)+Kumulus DF (7 lb)	10 % bloom, repeat 7 days later

* 10% bloom applications were made on 15 Aug and 100% bloom application were made on 23 Aug.

** Means are based on the incidence of diseased pods or number of diseased stems per plant. Numbers within a column followed by the same letter are not significantly different at $P \leq 0.05$ as determined by Fisher's protected LSD test.

Table 4. Incidence of gray mold in 2007 OSU-BPP snap bean trial

% pods with gray mold		% pods & pin beans with gray mold		Stem # with gray mold		Material(s) - Trade Name (& Rate)	Timing
0.00	b	0.08	0.00	b	0.08	Nontreated	
0.18	ab	0.18	0.18	ab	0.18	Endura (8 oz)	10 % bloom, repeat 7 days later
0.04	b	0.14	0.04	b	0.14	Rovral 4F (2 pt)	10 % bloom, repeat 7 days later
0.07	ab	0.07	0.07	ab	0.07	Topsin 4.5FL (30 fl oz)	10 % bloom, repeat 7 days later
0.18	ab	0.18	0.18	ab	0.18	Switch 62.5WG (11 oz)	10 % bloom, repeat 7 days later
0.05	b	0.05	0.05	b	0.05	Rovral 4F (2 pt)+Topsin 4.5FL (30 fl oz)	10 % bloom, repeat 7 days later
0.05	b	0.12	0.05	b	0.12	Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)	10 % bloom, repeat 7 days later
0.00	b	0.00	0.00	b	0.00	Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz) in 35 gal H ₂ O/A	10 % bloom, repeat 7 days later
0.03	b	0.03	0.03	b	0.03	Rovral 4F (2 pt)+Topsin 4.5FL (40 fl oz)	10 % bloom
0.10	ab	0.10	0.10	ab	0.10	Rovral 4F (2 pt)+Topsin 4.5FL (40 fl oz)	100 % bloom
0.00	b	0.00	0.00	b	0.00	Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)	10 % bloom
0.04	b	0.04	0.04	b	0.04	Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)	100 % bloom
0.26	a	0.29	0.26	a	0.29	Endura (5 oz)+Topsin 4.5FL (20 fl oz)	10 % bloom, repeat 7 days later
0.00	b	0.03	0.00	b	0.03	Switch 62.5WG (6 oz)+Topsin 4.5FL (20 fl oz)	10 % bloom, repeat 7 days later
0.12	ab	0.12	0.12	ab	0.12	Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz) followed by Endura (8 oz)	10 % bloom and then 7 days later
0.07	ab	0.07	0.07	ab	0.07	Rovral 4F (1.5 pt)+Topsin 4.5FL (20 fl oz)+Microthiol Disperss (6 lb)	10 % bloom, repeat 7 days later
0.00	b	0.08	0.00	b	0.08	Serenade MAX (1 lb)+Kumulus DF (7 lb)	10 % bloom, repeat 7 days later

* 10% bloom applications were made on 15 Aug and 100% bloom application were made on 23 Aug.

** Means are based on the incidence of diseased pods or number of diseased stems per plant. Numbers within a column followed by the same letter are not significantly different at $P \leq 0.05$ as determined by Fisher's protected LSD test.