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Alternatives to Vinclozolin (Ronilan) for Controlling Gray and White Mold on Snap Bean Pods in New York

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Abstract

Human health and environmental concerns have led to the eventual phase-out of benomyl (Benlate) and vinclozolin (Ronilan), two efficaceous, broad spectrum fungicides widely used on a range of crops, including snap beans. With fewer registered fungicides available for mold control, snap bean growers are in need of alternatives. We compared six foliar fungicides against Ronilan for gray (*Botrytis cinerea*) and white (*Sclerotinia sclerotiorum*) mold control on snap bean pods in New York, using data collected over three consecutive years. Ronilan gave the best overall mold control and highest yields of healthy pods. Trifloxystrobin (Flint), iprodione (Rovral), and cyprodinil plus fludioxonil (Switch) gave gray mold control comparable to that obtained with Ronilan. Switch and Rovral significantly reduced the incidence of white mold on pods, but were not as effective as Ronilan. Thiophanate-methyl (Topsin M) was as effective as Ronilan in controlling white mold on pods. Switch was the most promising alternative to Ronilan for controlling both gray and white mold on pods and for increasing marketable yield. A combination of Rovral and Topsin M may also be an effective alternative to Ronilan.

Introduction

New York ranks number 4 in the United States in snap bean production for processing and fresh markets (15). In 2000, 8600 acres were planted for fresh market and 28800 acres were planted for processing. Snap beans grown for processing are mechanically harvested and sorted for quality. Processors tolerate a maximum of 6% of pods with mold symptoms. Loads which exceed this standard are rejected, as are subsequent loads harvested from the same field.

Fig. 1. Flower, still attached to a snap bean pin pod, showing fuzzy mycelial growth of *Botrytis cinerea*.

The molds of greatest concern in New York snap bean production are gray mold caused by *Botrytis cinerea* Pers.:Fr. and white mold caused by *Sclerotinia sclerotiorum* (Lib.) de Bary. Both diseases occur every season in New York, but their severity is highly weather-dependent. Both pathogens have wide host ranges that include fruit, vegetable and field crops, and weeds, which increases the difficulty of rotating to non-susceptible crops (6,7,14). Gray mold tends to develop in dense canopies when the weather is moist and warm. *Botrytis cinerea* can invade senescent floral tissues, and from there move quickly to the pin pod if the flower is still attached (Fig. 1). Large, water-soaked, necrotic lesions become visible on the bean pods. A gray-brown powdery mass of fungal spores develops in mature lesions (Fig. 2). White mold also tends to develop in dense canopies, especially when wet conditions persist. In bean cropping systems, most infections are initiated on blossoms (1,2,16). A white cottony growth develops on infected flowers (Fig. 3). Lesions on pods, leaves, branches, and stems are initially small, circular, dark green, and water-soaked but rapidly increase in size to become slimy and covered with white fungal growth. The white fungal mycelium mounds up and develops into hard, black sclerotia, which are survival structures (Fig. 4).

Fig. 2. Mass of *Botrytis cinerea* spores on an infected snap bean pod.

Fig. 3. White mycelium of *Sclerotinia sclerotiorum* on infected snap bean pods.

Fig. 4. Hard, black sclerotia of *Sclerotinia sclerotiorum* on infected snap bean pods.

Growers largely use fungicides to suppress these two diseases in snap bean fields. In 2000, 73% of the processing snap bean acreage in New York was treated with vinclozolin (3). However, with the cancellation of benomyl (Benlate) in 2001 and the phase-out of vinclozolin (Ronilan) by 2005, snap bean growers are faced with fewer options to control gray and white mold. Fungicide efficacy trials for the control of gray and white mold in snap bean have been carried out at the New York State Agricultural Experiment Station since the 1980s. In the last 10 years, Ronilan has provided effective control of gray and white mold on snap bean pods with one or two well-timed applications. In this paper we examine the efficacy of six foliar fungicide products for the control of gray and white molds on snap bean pods from 1999 to 2001. Our objective was to identify suitable replacements for Ronilan.

Fungicide Efficacy Trials

Foliar fungicide trials for the control of gray and white mold on snap bean pods were conducted at three different sites (Field 48, Field 49, Crittenden) at the New York State Agricultural Experiment Station in Geneva, New York, in 1999, 2000, and 2001. In each year, snap beans were seeded at an average of 8.7 seeds per ft at a 30-inch row spacing using a Monosem planter.

Disease pressure was encouraged by inoculating plots with spores of both *B. cinerea* (a mixture of vinclozolin -resistant and susceptible isolates) and *S. sclerotiorum*, and by using irrigation to increase the availability of free moisture.

Fungicides were applied to single-row plots 43 to 45 ft long arranged as randomized complete blocks replicated four times, with a 3-ft-wide strip of untreated beans between blocks. Two applications were made during bloom, except at the Crittenden site in 2001, when only one application of each fungicide was made at full bloom. In all site-years (including Crittenden 2001), Actigard was applied pre-bloom as well as during bloom.

The results for individual years and locations are available (4,5,8,9,10,11). A range of compounds were tested each year, but the six products analyzed in this paper were chosen because they were tested over the three years (Table 1). They represent a range of chemistries and modes of action. Table 2 compares the costs of the products at the rates used in the trials.

Table 1. Chemical and mode of action details of foliar fungicides evaluated for the control of gray and white mold on snap bean pods in New York from 1999 to 2001.

Trade name	**Active ingredient**	**Chemical family**	**Mode of action**
Actigard	acibenzolar-S-methyl	host plant resistance inducer	no direct activity against plant pathogens; inducer of plant's systemic activated resistance (SAR) response
Flint	trifloxystrobin	strobilurin	interferes with fungal respiration; broad spectrum; preventative and specific curative activity; exhibits rain-fastness; has some translaminar activity
Ronilan	vinclozolin	dicarboximide	contact fungicide; non-systemic; spore germination inhibitor
Rovral	iprodione	dicarboximide	contact fungicide; protective and curative activity; inhibits spore germination and the growth of fungal mycelium
Switch	cyprodinil + fludioxonil	anilino-pyrimidine + phenylpyrrole	(cyprodinil) systemic, taken up into plant after foliar application; inhibits fungal penetration and mycelial growth both inside and outside the leaf; (fludioxinil) non-systemic; long residual activity; mainly inhibits the germination of fungal conidia
Topsin M	thiophanate-methyl	benzimidazole	systemic; protective and curative activity; absorbed by the leaves and roots

Table 2. Per acre costs of fungicides assessed for the control of gray and white mold on snap bean pods in New York, 1999 to 2001.

Fungicide	**Unit size**	**Price ($US) per unit** [a]	**Application rate (units/acre)**	**Cost ($US) per acre** [b]
Actigard	oz	45.90	0.75	68.85
Flint	oz	12.96	2.00	51.84
Ronilan	lb	23.48	1.00	46.96
Rovral	gal	148.79	0.25	74.40
Rovral + Topsin M	gal + lb	166.41	0.125 + 0.70	61.87
Switch	oz	3.88	11.00	85.25
Topsin M	lb	17.62	1.40	49.34

[a] Averaged list prices from major farm chemical suppliers.

[b] Cost represents two applications of formulated product.

Data Analysis

Response variables examined were the incidence of harvested pods with gray or white mold, and marketable yield. Marketable yield was defined as the total yield less the total yield of diseased pods. Plant density (number of snap bean plants per ft of row) was examined as a possible covariate in the response of marketable yield to fungicide treatment.

The Mixed procedure of SAS (SAS Institute, Cary, NC) was used to investigate the effects of fungicides on marketable yield, while simultaneously accounting for the variations due to experimental site and year (12). The incidence of pod infection is a proportional response variable (ranges between 0 and 1) and hence has a non-normal distribution along with nonhomogenous error variances. Therefore, incidence data were analyzed as a Generalized Linear Mixed Model, using the SAS Glimmix macro. This allows for a more natural modeling of the binomial property of the number of pods with gray or white mold (13).

A larger data set (595 observations from 1998 to 2001) was used to examine the relationship of marketable yield to the incidences of gray and white mold on pods. Plant density was used as a covariate. The Reg procedure in SAS was used for modeling. The intercept was restricted to zero, as there is no marketable yield if plant density (and hence gray and white mold incidences) is zero.

Traditionally, data from fungicide trials are analyzed separately each year. However, one is faced with the problem of having a chemical which seems to provide effective control in one year or field, but which falls short at another site or in another year. In years with low disease pressure, all chemicals may appear equal in their ability to control a disease. This makes assessing the longer term mean effect of a fungicide product on disease control somewhat difficult. In this paper, we applied statistical techniques to the data combined over years and fields with the objective of identifying fungicide products which have given consistent mold control on snap bean pods over location and time.

Mold Incidence and Marketable Yield

Marketable yield was related to plant density and the incidence of gray and white mold on pods according to the following equation (Equation 1):

$$y = 0.055\ pft + 15.87\ gm + 0.89\ wm - 116\ gm*wm \quad \text{(adj R2 = 0.85)},$$

where y is marketable yield in tons per acre, pft is the number of snap bean plants per ft row, gm is the incidence (0 to 1) of pods with gray mold, wm is the incidence (0 to 1) of pods with white mold, and gm*wm represents the interaction term between gray and white mold incidence. Equation 1 illustrates a greater effect of white mold on marketable yield compared to the effect of gray mold. Assuming all other parameters are held constant, a 1% increase in pods with gray mold would be correlated with a 1.0-ton/acre reduction in usable pod yield. Similarly, a 1% increase in pods with white mold would be correlated with a 1.15 tons/acre reduction in usable pod yield. This is with the understanding that any load with the incidence of mold greater than the acceptable threshold is entirely rejected.

Gray mold incidence. Ronilan gave the best overall control of gray mold on snap bean pods (Table 3). Gray mold control obtained with Flint (trifloxystrobin), Rovral (iprodione), and Switch (cyprodinil plus fludioxonil) was (statistically) as good as that obtained with Ronilan. Flint, Rovral, or Switch may be suitable alternatives to Ronilan for the control of gray mold. Topsin M is not expected to control gray mold effectively when part of the *B. cinerea* population is resistant to benzamidazoles, and this was evident in the results. Combining Topsin M with Rovral at a reduced rate of application (1.0 pt/acre) was not effective in controlling gray mold when compared to Rovral alone at a higher rate (2.0 pt/acre).

Table 3. Effect of foliar fungicides on the incidence of white and gray mold on snap bean pods in New York over the years 1999 to 2001.

Fungicide	Gray mold(%) [a]	White mold(%) a
none (control)	8.5 **	7.2 **
Actigard	5.6 **	4.8 **
Flint	3.1	2.6 **
Ronilan	1.8	0.7
Rovral	2.2	1.8 *
Rovral + Topsin M	4.3 *	0.6
Switch	2.5	2.2 **
Topsin M	7.6 **	0.3

[a] Percentage of pods with either gray mold or white mold. Asterisks indicate values which are significantly different from the percentage shown for Ronilan (* indicates $P < 0.05$, ** indicates $P < 0.01$).

White mold incidence. The best overall white mold control was obtained with Ronilan and with Topsin M, either alone or in combination with Rovral (Table 3). There appeared however to be no benefit of using a mixture of Topsin M at 0.7 lb/acre and Rovral at 1.0 pt/acre over Topsin alone at 1.4 lb/acre.

Marketable yield. There was no effect of fungicide on plant density (P = 0.44). Marketable yield did not vary with plant density (P = 0.61), and therefore the latter was not used as a covariate in the analysis of fungicide effects on marketable yield.

Marketable yields obtained with the different fungicides were compared to those obtained with untreated controls. Marketable yields were in general increased by fungicide use (Table 4), but were only significantly higher than control plot yields with Ronilan, Switch, and Topsin M. Interestingly, the good control of gray and white mold provided by Rovral did not translate into a significant increase in marketable yield over that of the unsprayed controls, and there was no return on the investment in fungicide application. Actigard, a host plant defense inducer, did not lead to significant marketable yield increases over unsprayed controls. Moreover, the relatively high cost of this material negated any benefit derived from its use (Table 4).

Table 4. Assessment of the financial return due to foliar fungicide use for the control of gray and white mold on snap bean pods in New York over the years 1999 to 2001.

Fung icide	Marketable yield[a] (tons per acre)	Marketable yield increase[b] (tons per acre)	Yield increase value[c] ($US per acre)	Fungicide cost[d] ($US per acre)	Return on fungicide investment ($US per acre)
none (control)	4.15	...	...	...	...
Actigard	4.17	0.02	3.59	68.85	-65.26
Flint	4.60	0.45	80.82	51.84	28.98
Ronilan	4.98 **	0.83	149.07	46.96	102.11
Rovral	4.44	0.29	52.08	74.40	-22.31
Rovral + Topsin M	4.73	0.58	104.17	61.87	42.30
Switch	4.98 **	0.83	149.07	85.25	63.82
Topsin M	4.91 *	0.76	136.50	49.34	87.16

[a] Marketable yield was calculated as total yield minus total diseased yield and is represented here as tons per acre. Asterisks indicate values which are significantly different from the percentage shown for the untreated control (* indicates $P < 0.05$, ** indicates $P < 0.01$).

[b] Increase in marketable yield when compared to untreated control plots.

[c] Assumes a 10-yr average NY farm price of $US 179.60 per ton (15).

[d] Does not include the cost of application. See Table 2.

Summary

Switch showed the most promise overall as an alternative to Ronilan for controlling both gray and white mold on pods and for increasing the marketable yield. Further research is required to ascertain the minimum rate of Switch necessary for consistent, marketable yield increases and effective mold control. Topsin M can be an effective alternative to Ronalin in situations where gray mold disease pressure is low and white mold pressure is high. A combination of Rovral and Topsin M still looks attractive from a hypothetical standpoint, but the current results show that reducing their rates of application when applied as a mixture is not a suitable option. Further research on the appropriate rates of these two fungicides when applied together for mold control needs to be conducted. Newer compounds, such as BAS516 and TM-40204, are also promising based on recent field evaluations (10,11).

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