FINAL REPORT

Project Number: 13C-3361-4795

TITLE: Epidemiology and control of apple powdery mildew

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Objectives

- Develop a forecasting model to improve management of apple powdery mildew, caused by *Podosphaera leucotricha*.
- Develop biorational disease and fungicide-resistance management programs
- Lower disease pressure through changes in cultural practices. *2001 progress in this area was not made due to lack of water and mildew.*

Significant findings:

- Research was conducted in Yakima, Benton, Franklin, and Chelan counties. A large test orchard comprised of Pink Lady, GingerGold, Gala, Fuji, and Braeburn apples was established to facilitate water management: disease pressure studies.
- Three different treatment initiation thresholds (of the degree-day model) were tested. Disease control resulting from the different regimes was similar.
- Mildew control at 14, 18, and 21 days intervals following the initial DMI application provided similar levels of disease control.
- DMI and strobilurin fungicides were equally effective as the initial fungicide in a model-based program
- Model-based spray approaches in all cases provided disease control equal to that obtained using a phenology based approach. In most cases, this was attained while utilizing fewer fungicide applications.
- An SAR compound shows promise as a "soft alternative" to DMI/strobilurin fungicides and as a rotation material.
- The order of strobilurin/DMI fungicides in resistance management alternations was insignificant.
- Temperature had a significant effect on colonization of apple leaf disks by *P. leucotrica.*

Field Testing of the Washington Apple Mildew Model

Degree Day Treatment Thresholds. Phenology-based spray programs are traditionally used for managing powdery mildew of apple. This has in some cases resulted in treatments being applied as early as green tip or half-inch green despite the absence of inoculum. We have developed a predictive model that accurately identifies the onset of primary inoculum availability. We have found that *P. leucotricha* conidia are available in the orchard air beginning at 80-100 cumulative degree days (> 50 F) past green tip. Results of earlier studies indicated that initiating control measures at the onset of inoculum production resulted in savings of 1-3 sprays, depending on variety. Investigations in 2001 were designed to investigate possible additional spray savings by delaying the initial fungicide treatment. Experiments were conducted in low (cv. Honeycrisp) and high (cv Jonagold) pressure orchards in Wenatchee and Prosser. Initial DMI applications were made at 80, 100, or 120 cumulative degree days ≥ 50 F past green tip. On Jonagolds, disease severity was 6.3, 6.9, and 7.6 % when the initial DMI application was made at 80, 100, and 120 degree days, respectively (Table 1). On Honeycrisp, severity at the respective thresholds was 1.0, 1.4, and 1.1%. Severity on untreated Honeycrisp and Jonagolds was 5.0 and 24.0% respectively. *Initiation threshold was statistically insignificant.* Severity on Honeycrisp and Jonagold apples treated beginning at green tip was 1.0% and 6.0% respectively. *Timing the initial application according to degree days saved 1-2 sprays without compromising mildew control.*

Post-Threshold Spray Intervals Following the initial model-based fungicide application, the Gubler-Thomas grape powdery mildew index was used to adjust subsequent spray intervals. The latter model uses an algorithm based upon daily hours of temperatures of 60-85 F. The algorithm is then used to adjust the treatment interval for DMI fungicides to 14, 18, or 21 days. Disease severity was similar in plots treated with Procure at 14, 18, and 21 day intervals (based following the initial temperature-based "threshold" application. Incidence was 4.1% in the untreated control and 0.34, 0.38, and 0.43 in the 14, 18, and 21 day treatments (Table 2). Spray interval following the initial treatment was statistically insignificant. *Results indicate that post-threshold temperatures and relative humidity (and their affects of conidia formation and dispersal) should be investigated to further improve the new model.*

Studies were initiated in 2001 to determine the effect of temperature on powdery mildew incidence and severity. Apple leaf disks were inoculated with a single-spore isolate of *P. leucotricha* and subjected to various temperatures over a 7 day period. Mildew incidence was 0, 14, 80, 87, 52, 2, and 0 % at 5 (41 F), 10 (50 F), 15 (59 F), 20 (68 F), 25 (77 F), 30 (86 F), and 35 C (95 F), respectively (Table 3). Although the results of only 1 experiment, these data indicate that further investigations in this area are warranted. Because they should have a significant influence on spray intervals, the effect of moderate and high temperatures on *Washington* isolates of *P. leucotricha* should be incorporated into the model

Role of Systemic Activated Resistance Compounds in Chemical Management Programs.
Alternations of systemic activated resistance compounds (SAR; Vacci-Plant) and DMI (Procure) fungicide alternations were evaluated for potential new approach to disease control. Because they reportedly boost the host plant's resistance to infection by fungal pathogens, Vacci-Plant comprised the early component of the mildew management program. Alternations (Vacci-Plant at 80 cumulative degree days and petal fall, Procure at first and second cover) provided foliar mildew control equal to that obtained using DMI (Procure) or DMI (Procure)/Strobilurin (Flint) programs. Foliar disease incidence was 2.6, 6.9, 3.4, and 32.7% in the Vacci-Plant/Procure, Procure, Procure/Flint, and untreated programs, respectively (Table 4). *Management of mildew on fruit was unsatisfactory, indicating that an alternative compound or mode of action should be used at petal fall.*

Fungicide Resistance Management Strategies and Investigation of Alternative Mode of Action. Experiments were conducted to evaluate the effect of DMI: strobilurin fungicide sequence on mildew incidence and severity, and to determine if either class of compound was more effective for use as the first treatment in the spray program. A DMI subclass alternation was also compared to an approach comprised of multiple applications of a single DMI fungicide. Programs consisting of purely DMI or DMI: Strobilurin compounds were superior or equal to a straight strobilurin program. On foliage, incidence was 1.7, 6.3, 4.4, 8.1, and 40.1% in Rally, Procure, Procure/Flint, Sovran, and untreated treatments Fruit incidence was 2.0, 4.4, 5.0, 8.5, and 22.0 % in the respective treatments. Results indicate that either strobilurin or DMI fungicides can be used as the initial model spray when the 80 CDD threshold is used (Table 5; this may *not* apply at later thresholds).

A program consisting of a DMI subclass alternation (Procure, imidazole; Rally, Triazole, and Rubigan, pyrimidine) performed as well as either Rally or Procure alone (also Table 5). Results indicate that if multiple DMI applications are required for sufficient mildew management, a program consisting of the three DMI subclasses is a viable option.

New fungicide modes of action. Nutrol (nitrogen phosphate potash), and quinoxyfen were ineffective for management of mildew on foliage or fruit. BAS51602 was moderately effective at 10.5 oz/A and ineffective at 14.7 oz/A (data not shown).

Treatment Threshold	**Fungicide**	**Incidence % (Jonagold)**	**Incidence % (Honeycrisp)**
80	Procure	6.3 a	1.0 a
100	Procure	7.9 a	1.4 a
120	Procure	7.6 a	1.1 a
Half-inch green[1]	Procure	6.0 a	1.0 a
Untreated	-	24.0 b	4.0 b

Table 1. Mildew disease severity on Jonagold and Honeycrisp apples when fungicide programs were initiated using different (based on cumulative degree days > 50 F past green tip) treatment thresholds. All threshold treatments were followed by strobilurin: DMI alternations through the second cover spray.
[1] industry-standard approach

Treatment[1]	**Interval**	**Foliar Incidence**
Procure	14	0.34 a
Procure	18	0. 38 a
Procure	21	0.43 a
Untreated	-	40.1 b

Table 2. Effect of post-threshold spray interval on foliar mildew incidence on Pink Lady apples in Richland, WA. Initial Procure application was made at 80 cumulative degree days past green tip. Subsequent applications were made at 14, 18, or 21 day intervals.

Temperature	Disease incidence (%)[1,2]
5	0
10	14
15	80
20	87
25	52
30	2
35	0

Table 3. Influence of temperature on severity of powdery mildew on apple leaf disks. Apple tissue was inoculated using conidia derived from a single-spore isolate of *P. leucotricha*. Inoculated tissue was subjected to various temperatures for 1 week, after which the percentage of leaf disk area colonized was determined using digital image analysis[1]. Data represents the mean of severity values from 20 leaf disks[2].

Treatment	Phenology	Foliar Severity	Fruit Severity
Vacci-Plant +	PK, PF	2.6 a	18.8 b
Procure	1C, 2C		
Procure	PK, PF, 1C, 2C	6.9 a	5.1 a
Flint +	TC, PF, 2C	5.8 a	2.5 a
Procure	PK, 1C		
Untreated		32.6 b	17.5 b

Table 4. Effect of Vacci-Plant/DMI fungicide applications on infection of apple foliage and fruit by the apple mildew fungus. Because SAR compounds reportedly boost host plant resistance to infection, Vacci-Plant applications were scheduled during the early phases of the disease epidemic as predicted by the degree day threshold. Experiments were conducted on 'Rome' apples.

Initial Treatment (80 CDD > 50 F)	Compound	Foliar incidence	Fruit incidence
Strobilurin [1]	Flint	3.4 abc	4.7 abc
Strobilurin[1]	Sovran	7.4 cde	5.5 abc
DMI (imidazole)[1]	Procure	4.4 abcd	5.0 abc
DMI (triazole)[2,3]	Rally	1.7 a	2.00 ab
DMI (imidazole) [2,3]	Procure	6.3 bcde	4.4 abc
Strobilurin[2]	Sovran	8.1 de	8.5 abc
DMI subclass alternation[4]	Procure Rally Rubigan	4.2 abcd	5.5 abc
Untreated	-	40.1 f	22.0 de

Table 5. Performance of DMI or strobilurin fungicides when used as the initial spray according to the 80 CDD threshold.

[1]Treatments were followed by a DMI application, then further strobilurin/DMI alternation.
[2]Treatment consisted solely of this compound
[3]Not recommended for resistance management
[4]Recommended as *one* (less desirable) means of DMI resistance management