Project Title: Race diversity and the biology of the spinach downy mildew pathogen
CLGRB Annual Report
April 1, 2018 to March 31, 2019

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Abstract:

Spinach downy mildew disease pressure remained relatively low in the 2018 and the early part of the 2019 season. A new race, race 17, was reported in 2018 after numerous ringtests with the International Working Group on Peronospora (IWGP). The race 17 was similar to what growers and the industry were calling UA1014 that was identified previously. A total of 92 and 26 mildew isolates were collected 2018 and early 2019, from AZ, CA, FL, MA, ME, TN, VT, and WI. Twenty-five and 11 isolates were evaluated for their race identity in 2018 and early 2019. In addition to the known races 8, 12, 14, 16, 17, there were several novel strains identified. Work is currently underway to examine the novel strains in more detail. Large-scale field trials were conducted to evaluate cultivar reactions to downy mildew. Two filed trials were conducted in the Yuma Valley in Jan.-Feb. 2018 and Jan.-Feb. 2019. One trial was in the Salinas Valley in Sept-Oct. 2018. Industry-wide spinach field days to examine downy mildew variety susceptibility were held in Yuma on Feb 21, 2018 and Feb 20, 2019, and in Salinas on Oct 10, 2018. Disease pressure was high at both locations and a wide range in reactions were observed among the cultivars evaluated. These data have been published and are included below. In addition, a range of conventional and biofungicide trails were evaluated in numerous greenhouse assays in both the greenhouse and the field in Yuma, AZ. Several additional efforts being pursued include the development and standardization of a test to quantify oospores on seed, the evaluation of factors that can reduce viability of oospores on seed, and crosses of various isolates to determine how oospores are formed in plants and on seed. We have also developed a detached soil-less leaf inoculation test to evaluate resistance to downy mildew disease. Recent greenhouse tests indicate

that we can generate oospores in plants by doing inoculations with mixtures of downy mildew isolates. This development will be critical in evaluating the role of oospores in the epidemiology of the pathogen.

Objectives

1. We have worked closely with growers, seed company personnel, and PCA's to maintain a service to identify and characterize races of the downy mildew pathogen as they appear throughout the year. This effort is exceptionally labor intensive, but believe it is critical for the industry.

2. Development and evaluation of detached leaf assay for race typing and identification. This effort could greatly expedite the race identification process and reduce costs.

3. Screen spinach germplasm from plant introduction collections (PIs), advanced breeding lines, and newer (especially race 1-17 resistant) commercially released material for resistance to various contemporary races of downy mildew.

4. Establish sentinel plots in Salinas, CA and Yuma, AZ to evaluate variety performance based on naturally occurring downy mildew pressure.

5. Examine organic products for their effectiveness in reducing downy mildew on spinach under greenhouse and field conditions.

6. Development and evaluation of a bioassay to assess quantitative (QTL-type) resistance.

Objectives 1, 3 and 4

A new race, race 17, was reported in 2018 after numerous ringtests with the International Working Group on Peronospora (IWGP). The race 17 was similar to what growers and the industry were calling UA1014 that was identified previously.

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Denomination of Pfs: 17, a new race of downy mildew in spinach

Author: Jim Correll **Published on: April 16, 2018**

A new race of the downy mildew pathogen (*Peronospora farinosa* f. sp. *spinaciae* = *P. effusa*) on spinach was first identified in 2014 in Yuma, Arizona, U.S. This race was able to overcome the resistance of important spinach varieties. First, one isolate (UA1014), was characterized on a standard set of differential varieties. Subsequently, isolates with the same reaction pattern on these differential varieties have been found in numerous locations and each year since 2014. After careful evaluation of the significance of this development to the spinach industry, the International Working Group on *Peronospora* in spinach (IWGP) has denominated isolate US1602 as Pfs: 17. This isolate is available at Naktuinbouw in The Netherlands.

Race Pfs: 17 is able to infect the differentials NIL1-6, Whale, Pigeon, and Caladonia. Meerkat has intermediate resistance. The reaction of Meerkat can be variable in seedling tests. Hydrus is resistant.

The IWGP is continuously monitoring the appearance of strains of the pathogen that deviate in virulence from the known races. In this way the IWGP aims to promote a consistent and clear communication between public and private entities, such as the seed industry, growers, scientists, and other interested parties about all resistance-breaking races that are persistent enough to survive over several years, occur in a wide area, and cause a significant economic impact.

The IWGP is located in The Netherlands and is administered by Plantum NL. The IWGP consists of spinach seed company representatives (Pop Vriend, Monsanto, RijkZwaan, Bayer, Takii, Sakata, Bejo, Enza, Syngenta, and Advanseed) and Naktuinbouw, and is supported by research centers at the University of Arkansas. Spinach researchers over the world are invited to join the IWGP initiative and use the common host differential set to identify new isolates.

For more information on this subject you can contact Jim Correll (jcorrell@uark.edu), Diederik Smilde (d.smilde@naktuinbouw.nl), or the IWGP chairperson Jan de Visser (JandeVisser@popvriendseeds.nl).

The Table below includes the disease reactions of race 17 on the International set of differentials.

	Differential											
Race	Viroflay	NIL 5	NIL 3	NIL 4	NIL 6	NIL 1	NIL 2	Whale	Pigeon	Caladonia	Meerkat	Hydrus
Pfs: 1	+	-	-	-	-	-	-	-	-	-	-	-
Pfs: 2	+	-	+	-	+	-	-	-	-	-	-	-
Pfs: 3	+	+	-	-	-	-	-	-	-	-	-	-
Pfs: 4	+	+	+	-	-	-	-	(-)	-	-	-	-
Pfs: 5	+	+	-	+	-	-	-	-	-	-	-	-
Pfs: 6	+	+	+	+	+	-	-	(-)	-	-	-	-
Pfs: 7	+	+	+	+	-	-	-	(-)	-	-	-	-
Pfs: 8	+	+	-	+	+	+	-	-	-	-	-	-
Pfs: 9	+	+	-	+	+	-	-	-	-	-	-	-
Pfs: 10	+	+	+	+	+	+	-	(-)	-	-	-	-
Pfs: 11	+	+	-	+	-	-	+	-	-	-	-	-
Pfs: 12	+	+	-	+	+	+	+	-	-	-	-	-
Pfs: 13	+	+	+	+	(-)	-	+	+	-	-	-	-
Pfs: 14	+	+	-	+	+	+	+	-	+	-	-	-
Pfs: 15	+	+	+	-	-	-	-	(-)	-	+	-	-
Pfs: 16	+	+	-	+	-	-	+	-	+	-	+	-
Pfs: 17	+	+	+	+	+	+	+	+	+	+	(-)	-

Over 150 inoculations were conducted up through March 2019 to examine the race diversity of the downy mildew in California and Arizona. A total of 92 and 26 mildew isolates were collected 2018 and early 2019, from AZ, CA, FL, MA, ME, TZ, VT, and WI. Twenty-five and 11 isolates were evaluated for their race identity in 2018 and early 2019. In addition to the known races 8, 12, 14, 16, 17, there were several novel strains identified. Work is currently underway to examine the novel strains identified in 2018 and 2019 (up to June 2019). The novel strains are listed in Table 1. The novel strains have been tested at least twice.

Table 1. Novel spinach downy mildew strains found in 2018 and 2019 in the University of Arkansas*

Isolate	ID	NIL1	NIL2	NIL3	NIL4	NIL5	NIL6	Tarpy	Pigeon	Meerkat	Hydrus
201801	UA201801	+	+	+	-	-	+	-	+	-	-
201811C	UA201811C	-	+	+	+	+	-	-	-	-	-
201816	UA201816	+	+	-	+	-	+	-	+	-	-
201820A	201820A	+	+	+	+	+	+	+	+	-	-
201834B	201834B	+	+	+	+	+	+	+	+	-	-
201841A	201841A	+	+	+	+	+	+	-	+	-	-
UA201843D	**UA201843D**	+	+	+	+	+	+	+	+	-	(+)
201812B	UA201707A	+	+	-	+	+	+	+	+	+	-
201818B	UA201502	-	+	+	+	+	-	+	+	+	-
201820B	UA201720B	+	+	-	+	-	+	-	+	+	-
201841B	201841A	+	+	+	+	+	+	-	+	-	-
201843A	UA201621A	-	+	+	-	+	-	-	+	-	-
UA201843AV	UA201843D	+	+	+	+	+	+	+	+	-	+
UA201838BPP	201834B	+	+	+	+	+	+	+	+	-	-
UA201838BPL	201834B	+	+	+	+	+	+	+	+	-	-
UA201851B	UA201851B	+	+	-	+	+	+	-	+	(+)	-
UA201904	UA201904	+	-	+	+	+	+	+	-	-	(+)
UA201908E	UA201908E	+	+	+	+	-	+	-	+	-	-
UA201908M	201834B	+	+	+	+	+	+	+	+	-	-
UA201908L	201834B	+	+	+	+	+	+	+	+	-	-
UA201913	UA201913	+	+	+	-	+	+	+	+	-	-

* -: resistant reactions; +: susceptible reactions on cotyledons and true leaves, (+) spotty sporulation on cotyledons, but no sporulation on true leaves.

Further tests indicated that RPF10 (Meerkat type resistance) was resistant to isolate UA201943D, and this isolate can be differentiated from Pfs17 by some newer cultivars (Table 2).

The UA201843D isolate has been tested in a ringtest with a number of the E.U. labs and the Results from the tests in the E.U. differ from our tests. In the E.U. tests, cotyledons of PV1446 and Hydrus are not infected. In our tests, the cotyledons consistently show spotty sporulation. We have also tested a wide range of varieties to UA201843D (Table 3).

Table 2. Cultivars that can differentiate Pfs17 and isolate UA201843D under the University of Arkansas conditions.

Variety	**Pfs17**		**UA201843D**	
	Cotyledons	**True Leaves**	**Cotyledons**	**True Leaves**
PV1446	-	-	(+)	-
Hydrus	-	-	(+)	-
Meerkat	(+)	-	-	-
Serpens	(+)	-	-	-
Volans	(+)	-	-	-
Caelum	(+)	-	-	-

* -: resistant reactions; (+) spotty sporulation on cotyledons, but no sporulation on true leaves.

The disease reactions of a number of newer cultivars to UA201843D were listed in Table 3:

Table 3. Disease reactions of a number of newer spinach cultivars to isolate UA201843D*

Cultivar	**Isolate UA201843D**	
	Cotyledons	**True Leaves**
Flamingo	+	-
PV1446	(+)	-
Antalia	(+)	-
Hydrus	(+)	-
Shelby	+	-
Virgo	(+)	-
Nevada	(+)	-
Wombat	(+)	-
El Prado	(+)	-
Serpens	-	-
Volans	-	-
Caelum	-	-
Meerkat	-	-
Rigel	(+)	-
Galah	(+)	-
Sp966	(+)	-
Regor	-	-
Alcor	+	-
Bonobo	(+)	-
Corvus	(+)	-
Crater	-	-
Formax	(+)	-
Lorikeet	-	-
Minkar	-	-
Nembus	-	-
Regor	-	-
Tabit	-	-
Monterey	-	-
PV1444	(+)	-
PV1445	(+)	-

* -: resistant reactions; +: susceptible reactions on cotyledons and true leaves, (+) spotty sporulation on cotyledons, but no sporulation on true leaves.

SPINACH (*Spinacia oleracea*)

Downy mildew; *Peronospora farinosa* f. sp. *spinacia* (= *P. effusa*)

J.C. Correll, C. Feng[1], B. Dhillon[1], G. Bhattarai[1],

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Evaluation of spinach varieties for downy mildew resistance, Yuma, AZ 2019.

Growing resistant cultivars is the most effective and economic way to managing spinach downy mildew disease, especially for organic spinach production, which is approximately 50% of total production in the United States. Evaluation of disease resistance of spinach cultivars under natural downy mildew pressure will be helpful for growers to choose ideal varieties for their production. So the spinach variety trial was conducted in Jan. to Feb. 2019, in Yuma, AZ. A total of 69 varieties (One variety Puma from two different sources were treated as two different entries) from major spinach seed companies were tested in randomized complete block design with three replications. Each plot is 15 ft long x 6 ft wide. The trial was planted on Jan 14 and the wet date was Jan 15, Downy mildew first showed up in the field on date, and disease were evaluated three times (Feb. 19, Feb. 25, Mar. 9, 2019). Disease pressure in the field was high with about 80% of the plants of some varieties showing infection. However, 30 varieties had no disease, and another 10 varieties had less than 5% plants infection. Novel strains were found in this field, and oospores were found from a few samples collected in this trial too.

Cultivar	DI	Cultivar	DI	Cultivar	DI
Molokai	86.7 a	Hamilton	19.3 ghi	Galah	0.0 i
Reflect	83.3 ab	Patton	18.3 ghi	Kiowa	0.0 i
SV2146VB	80.0 ab	Midway	16.7 ghi	Kodiak	0.0 i
Pungi	78.3 ab	PV_1501	10.0 hi	Lorikeet	0.0 i
Dromedary	76.7 abc	Hammerhead	8.3 hi	Minkar	0.0 i
SV2994VC	68.3 abcd	Meerkat	8.3 hi	Nevada	0.0 i
Antigua	65.0 abcde	Baboon	3.7 i	Pinal	0.0 i
Responder	63.3 abcdef	Magnetic	3.3 i	PV_1449	0.0 i
SV6203VB	60.0 abcdef	Alcor	2.3 i	PV_1452	0.0 i
Escalade	60.0 bcdef	El_Rio	1.7 i	PV_1477	0.0 i
Starfish	58.3 bcdef	Melville	1.7 i	PV_1488	0.0 i
Renegade	56.7 bcdef	Virgo	1.7 i	PV_1512	0.0 i
SV3580VC	48.3 cdefg	Platypus	0.7 i	PV_1513	0.0 i
Spiros	48.3 cdefg	El_Caballo	0.3 i	PV_1514	0.0 i
Shelby	43.3 defgh	Java	0.3 i	PV_1515	0.0 i
Califlay	35.0 defghi	Parakeet	0.3 i	PV_1516	0.0 i
51-169	33.3 defghi	Bandicoot	0.0 i	PV_1517	0.0 i
SV2157VB	33.3 efghi	Cabozon	0.0 i	Regor	0.0 i
Tundra	33.3 fghi	Colusa	0.0 i	Serpens	0.0 i
Silverwhale	31.7 fghi	Corvus	0.0 i	Sheep	0.0 i
Tasman	28.3 fghi	El_Prado	0.0 i	SP980	0.0 i
Puma	28.3 ghi	Eland	0.0 i	Volans	0.0 i
Viroflay	20.0 ghi	Finwhale	0.0 i	Woodpecker	0.0 i

[z] Disease incidence (DI) was estimated based on visually inspecting each entire plot.

[y] Analysis of variance (ANOVA) was performed using R programming language on the arcsine transformed disease incidence, the means of DI of these varieties were compared using Bonferroni adjusted least significant difference test ($p<0.05$). Variety means with the same letter are not significantly different as determined by Fisher's LSD test (P=0.05).

SPINACH (*Spinacia oleracea*)

Downy mildew; *Peronospora farinosa* f. sp. *spinacia* (= *P. effusa*)

B. Dhillon[1], C. Feng[1], G. Bhattarai[1], B. Wodka[1] and J. C. Correll[1]. [1]University of Arkansas, Fayetteville, 72701.

Evaluation of spinach varieties for downy mildew resistance, San Juan Bautista, CA 2018.

Downy mildew is the most economically important disease of spinach. Organic spinach production in California and Arizona continues to increase and comprises approximately 50% of total production in the United States. Thus, resistance is a critical tool for downy mildew management in spinach production. This study was conducted at the Seminis Vegetable Seeds Research Station in San Juan Bautista, CA in Sept,-Oct. 2018. A total of 70 spinach cultivars were evaluated for disease reactions to downy mildew. The plots were sprinkler-irrigated to germinate seed on 10 Sept. on beds with 84 in. between bed-centers, with each bed containing 16 lines of plants, at a seeding rate of 3.5 million seed/A. The total plot area was 75 x 225 ft. Treatments were replicated three times in a randomized complete block design. Each replicate plot consisted of a 15 ft length of bed. Maximum and minimum ranges (°F) of air temperature were as follows: 68.0-90.8, 37.4-59.0 during 10 Sept. to 23 Oct. There was only a trace of rain (0.16 inches) during the trial. Plants were watered with overhead sprinklers 2-3 times per week for the duration of the trial. Three independent observers made a final evaluation on 23 Oct. by visually estimating the disease in each of the three replicate plots per cultivar. Mean disease incidence values were calculated using the three replications and the three separate observations. Downy mildew was first observed in plots on 12 Oct. The data in the table illustrate the wide range in disease incidence (0.0 to 100%) for the collection of varieties evaluated. This was a baby-leaf spinach planting, where tolerance for leaves infected with downy mildew would be extremely low (typically less than 3%) in a commercial planting.

Cultivar	Disease incidence[z]		Cultivar	Disease incidence		Cultivar	Disease incidence	
Tundra	99.7	A	Puma1	53.3	a-i	Corvus	0.3	i
Escalade	96.7	Ab	Magnetic	48.3	a-i	Sheep	0.3	i
SV1846VC	96.7	Ab	Spoonbill	45.0	a-i	Virgo	0.3	i
SV6203VB	96.7	Ab	El Caballo-SP976	38.3	a-i	Canapus	0.0	i
SV2146VB (treated)	93.3	a-c	Hammerhead	38.3	a-i	Colusa/PV1445	0.0	i
Antigua	91.7	a-d	Puma2	38.3	a-i	El Rio-SP975	0.0	i
Dromedary	91.7	a-d	Meerkat	33.7	a-i	Kiowa/PV1446	0.0	i
Molokai	91.7	a-d	Midway (treated)	31.7	b-i	Minkar	0.0	i
Reflect	90.0	a-e	Patton (3181)	28.3	c-i	Nevada/PV1444	0.0	i
Shelby	90.0	a-e	Java	25.7	d-i	Pinal/PV1490	0.0	i
Viroflay	86.0	a-f	Parakeet	23.3	e-i	PV1449	0.0	i
Responder	85.0	a-f	Melville	21.7	f-i	PV1452	0.0	i
Renegade	84.0	a-f	Woodpecker	4.7	g-i	PV1477	0.0	i
Pungi-SP963 (treated)	83.3	a-f	Alcor	4.0	g-i	PV1488	0.0	i
SV3580VC	78.3	a-f	Galah	3.7	g-i	PV1512	0.0	i
Califlay	73.3	a-f	PV1501	3.7	g-i	PV1513	0.0	i
Starfish1	71.7	a-f	Finwhale	2.7	hi	PV1514	0.0	i
Tasman	69.7	a-g	Serpens	2.3	hi	PV1515	0.0	i
Silverwhale	67.7	a-h	Eland	1.7	hi	PV1516	0.0	i
SV2157VB	66.7	a-i	Bandicoot	1.0	hi	PV1517	0.0	i
51-169	65.0	a-i	El Prado-SP967	0.7	I	Regor	0.0	i

Spiros	63.3	a-i	SP980	0.7	I	Volans	0.0	i
SV1714VC	63.3	a-i	Baboon	0.3	I			
Starfish2	60.0	a-i	Bonobo	0.3	I			

[z] Disease incidence (DI) was estimated based on visually inspecting a 1 x 1 m square area in the center of each plot.
[y] Analysis of variance (ANOVA) was performed using R programming language on the arcsine transformed disease incidence, the means of DI of these varieties were compared using the least significant difference test ($p<0.05$). Variety means with the same letter are not significantly different as determined by Fisher's LSD test (P=0.05). The LSD for disease incidence (untransformed data) was 25.0%.

Objective 2

Table 4. Disease responses of spinach differential cultivars to the spinach downy mildew pathogen [*Pernospora effusa* race 13 (Pfs 13)] maintained on whole plants (WP) or on detached leaves (DL) in a whole plant or detached leaf bioassay. Disease response of the differential cultivars inoculated using Pfs maintained exclusively on the detached leaf are also presented.

Cultivars	DM disease response[t]			Pfs maintained on WP[u]				Pfs maintained on DL[v]	
				DI[w]		DS[x]		DI[w]	DS[x]
	Expected[y]	WP	DL	DL	WP	DL	WP	DL	DL
Virolfay	+	+	+	1.00 a	1.00 a	85.2 ab	83.3 bc	1.00 a	84.0 a
NIL2	+	+	+	1.00 a	1.00 a	87.5 a	87.0 a	1.00 a	84.0 a
NIL3	+	+	+	1.00 a	1.00 a	85.4 ab	85.0 abc	1.00 a	83.3 a
NIL4	+	+	+	1.00 a	1.00 a	87.5 a	85.4 ab	1.00 a	82.6 a
NIL5	+	+	+	1.00 a	1.00 a	85.0 ab	85.1 abc	1.00 a	84.7 a
NIL6	+	+	+	1.00 a	1.00 a	83.8 b	82.6 c	1.00 a	83.3 a
Whale	+	+	+	1.00 a	1.00 a	86.1 ab	84.7 abc	1.00 a	86.8 a
Califlay	+	+	+	1.00 a	1.00 a	83.3 b	83.1 bc	1.00 a	82.6 a
NIL1	-	-	-	0.00 b	0.00 b	0.0 c	0.0 d	0.00 b	0.0 b
Caladonia	-	-	-	0.00 b	0.00 b	0.0 c	0.0 d	0.00 b	0.0 b
Pigeon	-	-	-	0.00 b	0.00 b	0.0 c	0.0 d	0.00 b	0.0 b
Hydrus	-	-	-	0.00 b	0.00 b	0.0 c	0.0 d	0.00 b	0.0 b
Meerkat	-	-	-	0.00 b	0.00 b	0.0 c	0.0 d	0.00 b	0.0 b
$HSD_{0.05}$[z]				0.00	0.00	3.3	2.6	0.00	5.2

[t] Downy mildew disease response of each cultivar following the whole plant (WP) and detached leaf (DL) inoculation assay from three independent tests. A plant showing chlorosis and sporulation on cotyledons, true leaves, or both was classified as susceptible (+). A plant without chlorosis or sporulation was rated as resistant (-). A spinach cultivar was classified as susceptible if more than 85% of the plants were diseased (+), or classified as resistant if less than 15% of plants were diseased (-).
[u] Pfs inoculum was prepared weekly on the whole plants of the susceptible cultivar Viroflay in a separate tray.

Method of inoculation to evaluate whole plant and detached-leaf inoculation approaches.

Objective 5

Spinach (*Spinacia oleracea* 'Lanzarote')
Porchas[1], andDowny mildew; *Peronospora farinosa* f. sp. *spinaciae*
Yuma(= *P. effusa*)

M. E. Matheron[1], J. C. Correll[2], M. C. Feng[2]. [1]University of Arizona, Agricultural Center, Yuma, AZ
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Evaluation of fungicides for management of downy mildew of spinach, 2018.

This study was conducted at the Yuma Valley Agricultural Center. The soil was a silty clay loam (7-56-37 sand-silt-clay, pH 7.2, O.M. 0.7%). On
16 Jan, Spinach 'Lanzarote' was seeded onto beds with 84 in. between bed centers each containing 18 lines of seed per bed and then sprinkler- irrigated to promote seed germination. All irrigation water was supplied by sprinkler irrigation. Treatments were replicated four times in a randomized complete block design. Replicate plots consisted of a 15 ft length of bed separated by 3 ft of nontreated bed. Treatments were applied
with a CO_2 backpack sprayer that delivered 50 gal/acre at 40 psi to flat-fan nozzles. Application date for at emergence treatment was 25 Jan and subsequent foliar treatments were applied 31 Jan, and 6, 19, and 27 Feb, depending on the treatment. Downy mildew was visually detected in plots
approximately 3 weeks after the first foliar treatment application. Mean maximum and minimum air temperatures (°F) were as follows: 75, 44 during 16 to 31 Jan; 74, 42 during Feb; 76, 44 during 1 to 8 Mar. Mean maximum and minimum percent relative humidity were as follows: 67, 14
during 16 to 31 Jan; 77, 17 during Feb; 61, 12 during 1 to 8 Mar. Monthly rainfall in inches was as follows: 16 to 31 Jan, 0.00; Feb, 0.01; 1 to 8 Mar,
0.00. Disease severity was assessed 8 Mar by determining the percentage of infected leaves present within three 1-ft^2 areas within each of the four replicate plots per treatment. The number of spinach leaves in a 1-ft^2 area of bed was approximately 300. The three subsamples per plot were averaged prior to analysis.

Many of the treatments provided a statistically significant reduction of disease compared to nontreated plants; however, four treatments provided exceptional disease control with no evidence of downy mildew present. In comparison, 82.5% of leaves in nontreated plots were infected with downy mildew. Phytotoxicity symptoms were not noted for any treatments.

Treatment and rate of product/A	Days after first application[z]	Percent infected leaves[y]
Nontreated control	-------	82.5 a
Serenade ASO 4.0 qt	0, 6, 12, 25, 33	67.5 b
LifeGard WG 2.25 oz	6, 12, 25, 33	60.0 bc
Serenade ASO 4.0 qt	6, 25	57.5 bc
Sonata 4.0 qt	12, 33	
LifeGard WG 2.25 oz	6, 25	40.0 d
Revus 2.08SC 8.0 fl oz	12, 33	
Ranman 2.75 fl oz	6, 12, 25, 33	37.5 d
Revus 2.08SC 8.0 fl oz	6, 25	37.5 d
Ridomil Gold 480SL 1.25 pt + Quadris 2.08SC 10.6 fl oz	0	25.0 e
Forum 6.0 fl oz	6	
Prophyt 6.64SL 4.0 pt	12	
Prophyt 6.64SL 4.0 pt + Presidio 4SC 4.0 fl oz	25	
Zampro 4.38SL 14.0 fl oz	33	
Zampro 4.38SL 14.0 fl oz	6, 12, 25, 33	20.0 ef
Actigard 50WG 1.0 oz	6, 12, 25, 33	20.0 ef
Revus 250SC 8.0 fl oz	6, 12, 25, 33	20.0 ef
Ridomil Gold 480SL 1.25 pt + Quadris 2.08SC 10.6 fl oz	0	12.5 f
A-21591 5.5 fl oz	6	
Actigard 50WG 0.75 oz	12, 25	
Revus 250SC 8.0 fl oz	33	
Actigard 50WG 1.0 oz	6,25	10.0 fg
Revus 250SC 8.0 fl oz	12, 33	
Orondis Gold 200 4.8 fl oz + Ridomil Gold 480SL 8.0 fl oz	6, 12, 25, 33	0 g
Actigard 50WG 1.0 oz	6	0 g
Orondis Gold 200 4.8 fl oz + Ridomil Gold 480SL 8.0 fl oz	12	
Revus 250SC 8.0 fl oz	25	
Zampro 4.38SL 14.0 fl oz	33	

Ridomil Gold 480SL 1.25 pt + Quadris 2.08SC 10.6 fl oz Actigard 50WG 0.75 oz A-21591 5.5 fl oz Revus 250SC 8.0 fl oz	0 6, 12 25 33	0 g
Ridomil Gold 480SL 1.25 pt + Quadris 2.08SC 10.6 fl oz Actigard 50WG 0.75 oz A-21591 5.5 fl oz Revus 250SC 8.0 fl oz	0 6, 25 12 33	0 g
P-value (treatment)		<0.0001
LSD ($P = 0.05$)[x]		11.8

[z] At emergence treatments applied 25 Jan and other foliar treatments were applied 31 Jan, and 6, 19, and 27 Feb.
[y] Disease severity determined 8 Mar by determining the percentage of infected leaves present within three 1-ft^2 areas within each replicate plot.
[x] Least Significant Difference at $P = 0.05$. Values differing by more than the least significant difference are significantly different from each other according to Fisher's Protected LSD test.

Objective 6. Efforts are underway to evaluate quantitative resistance to the downy mildew pathogen. Such an approach involves a much higher level of precision to evaluate this type of resistance and various variables including inoculum level, temperature, plant nutrition, etc., are being evaluated.

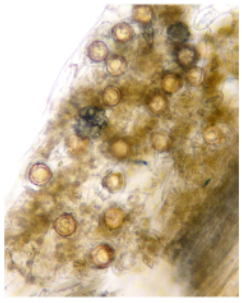
Additional Efforts

We are evaluating the role of oospores in the epidemiology of the downy mildew pathogen on spinach. We have been able to observe oospores in inoculation tests with mixtures of specific isolates of the pathogen. Thus, this will allow us to evaluate a wide range of parameters on how oospores develop, how the viability can be reduced, and how important they are in the development of epidemics.

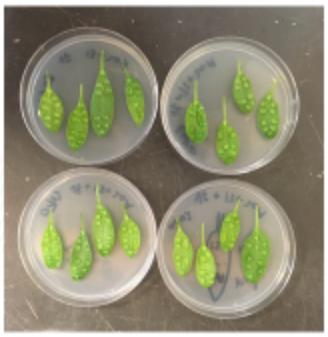
Oospores of the downy mildew pathogen generated in spinach leaf tissue.

Oospores - 8 days post inoculation

- Abundant oospores observed on spinach leaves

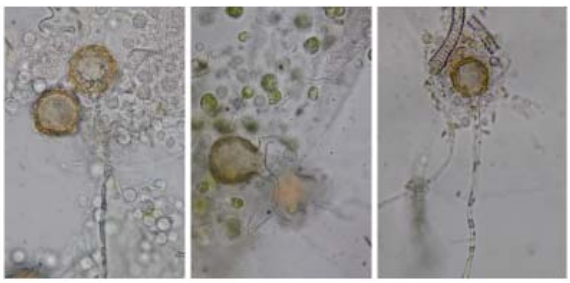


Inoculated intact plants and detached leaves



Oospores production on different growth stages of spinach

Germinating oospores



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