

Project Title: Race diversity and the biology of the spinach downy mildew pathogen
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Project Investigators:

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Abstract:

In 2022-2023, spinach downy mildew disease pressure remained relatively low and was similar to the three previous years. A total of 19 races have been described and the disease reactions of the 19 races on the standard set of spinach differentials was re-examined (Table 1). Due to low disease pressure, fewer downy mildew isolates were examined. Only previously identified races were found and the isolates originated from conventional production fields. Several novel isolates are currently being examined and are being discussed by the IWGP for nomination as new races. However, the IWGP met in October of 2023 and discussed how to proceed with naming several novel isolates. But currently, nothing has been demarcated as a new race. Results of downy mildew disease development in the San Juan Bautista Spinach Field Trial for September-October 2022 and the Yuma, AZ Spinach Field Trial for January-March, 2023 are included below.

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. Evaluate advanced breeding lines, and newer commercially released material for resistance to new races and novel strains of downy mildew.
3. Establish sentinel plots in Yuma, AZ, to evaluate variety performance based on naturally occurring downy mildew pressure.

Table 1. Disease reactions of differentials to the 19 races of *P. effusa*.

Race	Viroflay	NIL1	NIL2	NIL3	NIL4	NIL5	NIL6	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	+	+	+	+	+	+	+	+	+	(+)	-
Pfs 18	+	-	+	+	+	+	-	+	+	+	-
Pfs 19	+	+	+	-	+	+	+	+	-	+	+

* +: >85% plants were susceptible, -: >85% plants were resistant; (+): sporulation was found on cotyledons, but not on true leaves.

Evaluation of spinach cultivars for downy mildew resistance in San Juan Bautista, CA 2022.

Downy mildew (*Peronospora effusa*) is a major constraint to spinach production. The pathogen produces wind-dispersed spores, and requires cool, wet conditions for infection. Increased canopy density and overhead irrigation create optimal conditions for the pathogen and subsequent spread of the disease. Management strategies in conventional fields consist of fungicide applications and resistant cultivars. Host resistance in spinach is the only effective management strategy for organic production, which represents about half of U.S. production. At present, there are 19 described races of *P. effusa*, as well as isolates with novel virulence patterns on spinach differentials. The purpose of this study was to assess resistance to *P. effusa* among commercial spinach cultivars, with a total of 70 cultivars that were rated at the Enza Zaden Research Institute in San Juan Bautista, CA, between 20 Oct-17 Nov 2022. Seed was sown on 14-16 Sept. with a “wet-date” of 19 Sept. Individual plots were 15 ft by 6 ft and seed was planted at a density of 4 million seed/A, and beds were 600 ft in length with three separated replications. Each replication consisted of rows with 10 cultivars per row. The trial was set up as a completely randomized block design. The trial was flanked by a single bed of the cultivar Woodpecker and a single bed of a mixture of cultivars. Maximum air temperature ranged from 65-95°F and minimum from 36-58°F, cumulative rainfall was 0.00 in., and the maximum wind peak was 4 mph. Plants were watered with overhead sprinklers 2-3 times per week for the duration of the experiment. Downy mildew incidence was rated by visually estimating the percentage of plants showing downy mildew symptoms for each of the three replicate plots per cultivar. Mean disease incidence was calculated by averaging the three replications. Disease incidence ranged from 0.0 – 78.3. Analysis of variance (ANOVA) was performed ($P \leq 0.05$) followed by Post Hoc analysis

using Fisher's least significant difference (LSD) test. Mean DI scores with the same letter are not significantly different as determined by Fisher's LSD test ($P \leq 0.05$). Each susceptible cultivar was examined microscopically for oospores at the end of the trial and no oospores were observed.

Downy mildew disease pressure for this trial originated from naturally occurring inoculum and was first observed on 10 Oct. Disease incidence (DI) was evaluated on 28 Oct when plants were 43 days old. Disease pressure was high as indicated by the DI detected on several cultivars and the overall range of DI was from 0.0 to 78.3%.

Cultivar	Mean disease incidence	Cultivar	Mean disease incidence	Cultivar	Mean disease incidence
Red Kitten 1	78.3 a	Treasure	1.7 ij	El Caballo	0.0 j
Red Kitten 2	76.7 a	PV1719	1.3 j	El Rio	0.0 j
606	56.7 b	07542	1.0 j	Finwhale	0.0 j
SV2157VB	50.0 bc	DS30159	0.7 j	Frontier	0.0 j
Avenger	43.3 bcd	PV-1702	0.7 j	Kiowa 1	0.0 j
Responder	33.3 cde	Tabit	0.7 j	Kiowa 2	0.0 j
DS40001	31.7 cdef	07553	0.3 j	Kodiak	0.0 j
Longhorn	26.7 defg	Opal	0.3 j	Laredo	0.0 j
SV2146VB	26.7 defg	SVVC5998	0.3 j	Minikar	0.0 j
Revere	25.0 defgh	1038	0.0 j	Nimbus	0.0 j
PV-1716 1	20.0 efghi	3592	0.0 j	Nevada	0.0 j
SV5883	15.7 efghij	Baboob	0.0 j	Onyx	0.0 j
Carmel	13.3 fghij	Bandera	0.0 j	Pheasant	0.0 j
Tasman	13.3 fghij	Bandicoot	0.0 j	Prosper	0.0 j
Viroflay 1	11.7 ghij	Bonefish	0.0 j	PV-1526 1	0.0 j
Viroflay 2	8.3 ghij	Cabezon 1	0.0 j	PV-1526 2	0.0 j
El Prado	7.0 hij	Cabezon 2	0.0 j	PV-1610	0.0 j
Kona	6.7 hij	Cocopath	0.0 j	PV-1656	0.0 j
Patton	6.7 hij	Colusa	0.0 j	Quartz	0.0 j
Magnetic	5.7 ij	Corvus	0.0 j	Regor	0.0 j
Mykonos	3.3 ij	Dallas	0.0 j	RZ51733	0.0 j
Crosstrek	2.0 ij	Denton	0.0 j	Woodpecker	0.0 j
PV-1716 2	2.0 ij	Dracus	0.0 j		
SVVC6091	1.7 ij	DS30199	0.0 j		

^z Downy mildew incidence was rated by visually estimating the percentage of plants showing downy mildew symptoms for each of the three replicate plots per cultivar. Mean disease incidence was calculated by averaging the three replications.

^y Analysis of variance (ANOVA) was performed ($P \leq 0.05$) followed by Post Hoc analysis using Fisher's least significant difference (LSD) test. Mean DI scores with the same letter are not significantly different as determined by Fisher's LSD test ($P \leq 0.05$).

Evaluation of spinach cultivars for downy mildew resistance in Yuma, AZ 2023.

Downy mildew disease pressure for this trial originated from naturally occurring inoculum and was first observed on 12 Feb. Disease incidence (DI) was evaluated on 24 Feb when plants were 44 days old. Disease pressure was high as indicated by the DI detected on several cultivars and the overall range of DI was from 0.0 to 98.3%.

Cultivar	Mean disease incidence (DI)		Cultivar	Mean DI		Cultivar	Mean DI
Red Kitten	98.3	a	Mykonos	0.7	k	Magnetic	0.0
C2-606	83.3	ab	Cocopah	0.0	k	Maya	0.0
SV2157VB	83.3	ab	Cocopah 2	0.0	k	Minkar	0.0
Acadia (trt)	80.0	bc	Colusa	0.0	k	Nembus	0.0
SV1714VC	71.7	bcd	Colusa 2	0.0	k	Neveda	0.0
Revere	66.7	cde	Corvus	0.0	k	Opal	0.0
SV2146VB	60.0	def	Crater	0.0	k	Patton (trt)	0.0
Avenger (trt)	56.7	def	Dracus	0.0	k	PV-1516	0.0
Marabu (trt)	53.3	efg	Eland	0.0	k	PV-1526	0.0
Riverside	50.0	fgh	El Caballo	0.0	k	PV-1610	0.0
Raccoon (trt)	48.3	fgh	El Prada	0.0	k	PV-1664	0.0
Viroflay	40.0	ghi	Finwhale	0.0	k	Quartz	0.0
Oceanside	40.0	ghi	Frontier	0.0	k	Quartz 2	0.0
Bassoon	35.0	hi	Gala	0.0	k	Regor	0.0
Tasman	25.0	ij	Houston	0.0	k	Skarne/PV-1656	0.0
Disco	11.7	jk	Jeep	0.0	k	Tabit	0.0
Prosper	11.7	jk	Jolo	0.0	k	Thanos	0.0
Bandera	8.3	k	Jolo 2	0.0	k	Tragopan (trt)	0.0
Whale	6.7	k	Kiowa	0.0	k	Traverse	0.0
Sioux	5.0	k	Kodiak	0.0	k	Treasure	0.0
Woodpecker	3.3	k	Kona	0.0	k	Wombat	0.0
Nevada (trt)	3.3	k	Laredo	0.0	k	Yuma (trt)	0.0
Onyx	1.7	k	Laredo 2	0.0	k		
Crosstrek	0.7	k	Longhorn	0.0	k		

^z Downy mildew incidence was rated by visually estimating the percentage of plants showing downy mildew symptoms for each of the three replicate plots per cultivar. Mean disease incidence was calculated by averaging the three replications.

^y Analysis of variance (ANOVA) was performed ($P \leq 0.05$) followed by Post Hoc analysis using Fisher's least significant difference (LSD) test. Mean DI scores with the same letter are not significantly different as determined by Fisher's LSD test ($P \leq 0.05$).