Powdery Mildew: An Emerging Disease of Watermelon in the United States

A. R. Davis, B. D. Bruton, and S. D. Pair
USDA, ARS, South Central Agricultural Research Lab, Lane, Oklahoma 74555

C. E. Thomas
USDA, ARS, U. S. Vegetable Laboratory, Charleston, South Carolina 29414

Foliar diseases are common on watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai). Historically, anthracnose, gummy stem blight, and downy mildew have been the predominant foliar diseases encountered by U.S. growers (14). However, in the last few years, powdery mildew has emerged as an important disease problem of watermelon in the major U.S. production areas.

Powdery mildew symptoms on cucurbits typically appear as white powdery spots of mycelia and conidia on both sides of the leaves, but may appear on petioles and stems. Symptoms first develop on older leaves reducing plant canopy, and subsequent yield through decreased fruit size and number of fruit per plant (8). The reduced canopy may result in sunscald of the fruits making them unmarketable. The presence of the pathogen is much more readily apparent on pumpkin and squash than in watermelon, which can obscure visual detection until after plants are severely damaged by the disease. For example, watermelon leaves often begin deteriorating prior to obvious non-microscopic detection of mycelia and conidia, which makes early diagnosis and control on watermelon more difficult.

There are at least two different types of symptoms on watermelon. One is a yellow blotching (chlorotic spots) that occurs on leaves accompanied by little or no sporulation and only a small amount of mycelial development. The other symptom is powdery mycelial and conidial development on either leaf surface without the associated chlorotic spots. Often, the disease first appears as a slight yellowing of leaves in low areas of the field associated with higher relative humidity. However, an entire field should be scouted for early powdery mildew detection, since low areas are not always the first areas affected.

Because of the short disease cycle, control measures must be implemented soon after disease onset to be effective. Consequently, an accurate and rapid detection system is needed for effective powdery mildew control in watermelon. Research efforts on such a detection system are underway at the USDA, ARS South Central Agricultural Research Lab.

Two genera are considered the predominant fungi that incite powdery mildew in cucurbits, *Sphaerotheca fuliginea* (Schlechtend.:Fr.) Pollacci and *Erysiphe cichoracearum* DC. *S. fuliginea*, has as many as seven pathogenically distinct races that are presently distinguished based on differential reactions against melon genotypes (9). Identity of the causal organism is important because *E. cichoracearum* and *S. fuliginea* differ in virulence against cucurbit species and in sensitivity to fungicides (3, 6, 7). Historically, powdery mildew has been rare on watermelon in the U.S. (11). Until recently, there was little incentive to study powdery mildew resistance in watermelon. However, in the last few years, powdery mildew has caused moderate to severe damage to watermelon crops in South Carolina, Georgia, Florida, Oklahoma, Texas, and California.

Methods. On 18 April 2000, 6-week-old seedlings of 111 *C. lanatus* entries were transplanted from the greenhouse to a field plot at Lane, Oklahoma for evaluation of powdery mildew resistance. Included in this study were two commercial cultivars, 102 plant introduction (PI) accessions from the USDA, ARS germplasm collection, Griffin, Georgia, one proprietary line, and six experimental hybrids (Table 1). Ten plants of each *C. lanatus* entry were planted in the non-replicated study.

On 7 June 2000, powdery mildew severity was assessed by rating the percentage of canopy damaged by the disease on a 1 to 5 scale where: 1 = 0% to 19% of a plant canopy affected by disease, 2 = 20% to 39%, 3 = 40% to 59%, 4 = 60% to 79%, and 5 = 80% to 100% of canopy damaged. Random field samples were taken to verify that powdery mildew was the only foliar disease present. The average rating for the 10 plants of each entry was plotted as a mean disease severity rating (Fig. 1).

Table 1. Powdery mildew rating for 111 watermelon cultivars, PI accessions and experimental lines.[z]

Rank	Cultivar or accession	Country of origin	Disease rating
1	PI 525088	Egypt	1.50
2	PI 482277	Zimbabwe	1.88
3	[1]L 200004	United States	2.00
4	[1]L 200006	United States	2.00
5	PI 225557	Zimbabwe	2.00
6	PI 273480	Ethiopia	2.00
7	PI 378611	Zaire	2.00
8	PI 459074	Botswana	2.22
9	PI 271776	South Africa	2.29
10	PI 482248	Zimbabwe	2.33
11	[1]L 200002	United States	2.50
12	PI 270545	Sudan	2.50
13	PI 500331	Zambia	2.67
14	[1]L 200003	United States	2.75
15	PI 249008	Nigeria	2.75
16	PI 186490	Nigeria	2.80
17	PI 482291	Zimbabwe	2.80
18	PI 254624	Sudan	2.83
19	PI 260733	Sudan	2.83
20	PI 274034	South Africa	3.00
21	PI 385964	Kenya	3.00
22	PI 542120	Botswana	3.00
23	[1]L 200005	United States	3.10
24	PI 542617	Algeria	3.14
25	[2]EXP 2000 PM	United States	3.17
26	PI 296341	South Africa	3.25
27	PI 490382	Mali	3.25
28	PI 254623	Sudan	3.29
29	PI 195928	Ethiopia	3.33
30	PI 254735	Senegal	3.33
31	PI 459075	Botswana	3.38
32	PI 270546	Ghana	3.40
33	PI 542116	Botswana	3.40
34	PI 482253	Zimbabwe	3.43
35	PI 500327	Zambia	3.44
36	PI 193964	Ethiopia	3.50
37	[1]L 200001	United States	3.57
38	PI 482247	Zimbabwe	3.60
39	PI 542114	Botswana	3.60
40	PI 246559	Senegal	3.67

Table 1 (continued).[z]

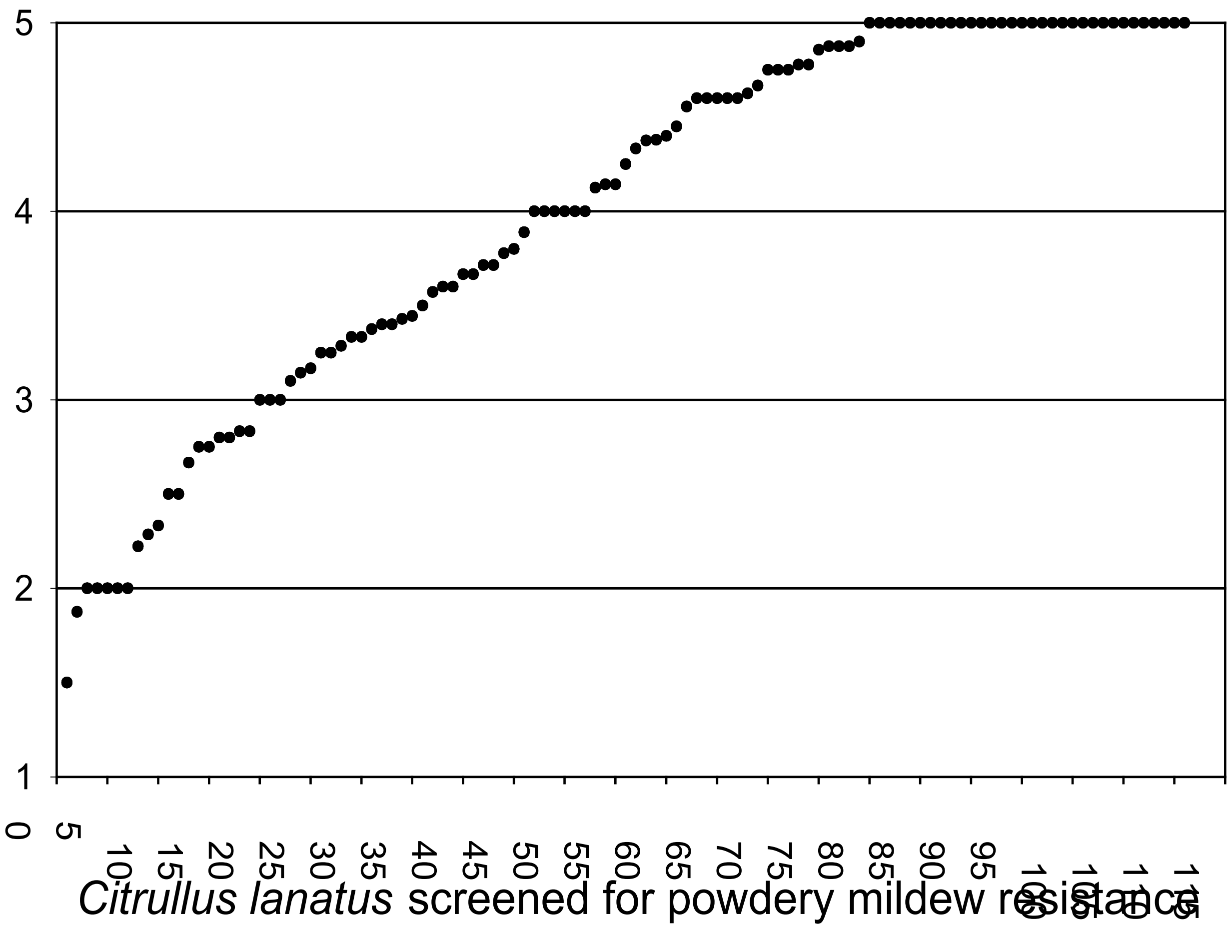
Rank	Cultivar or accession	Country of origin	Disease rating
41	PI 500336	Zambia	3.67
42	PI 482275	Zimbabwe	3.71
43	PI 490380	Mali	3.71
44	PI 270565	South Africa	3.78
45	PI 185635	Ghana	3.80
46	PI 295845	South Africa	3.89
47	PI 171392	South Africa	4.00
48	PI 183218	Egypt	4.00
49	PI 248178	Zaire	4.00
50	PI 481871	Sudan	4.00
51	PI 482284	Zimbabwe	4.00
52	PI 525096	Egypt	4.00
53	PI 254744	Senegal	4.13
54	PI 254622	Sudan	4.14
55	PI 494527	Nigeria	4.14
56	PI 490378	Mali	4.25
57	PI 271986	Somalia	4.33
58	PI 525084	Egypt	4.38
59	Tri-X 313	United States	4.38
60	PI 164247	Liberia	4.40
61	Royal Sweet	United States	4.45
62	PI 542121	Botswana	4.56
63	PI 186974	Ghana	4.60
64	PI 186975	Ghana	4.60
65	PI 271984	Somalia	4.60
66	PI 288232	Egypt	4.60
67	PI 525085	Egypt	4.60
68	PI 490381	Mali	4.63
69	PI 255139	South Africa	4.67
70	PI 189316	Nigeria	4.75
71	PI 254736	Senegal	4.75
72	PI 490375	Mali	4.75
73	PI 254738	Senegal	4.78
74	PI 254739	Senegal	4.78
75	PI 549163	Chad	4.86
76	PI 270547	Ghana	4.88
77	PI 494816	Zambia	4.88
78	PI 560000	Nigeria	4.88
79	PI 494815	Zambia	4.90
80	PI 164248	Liberia	5.00

Table 1 (continued).[z]

Rank	Cultivar or accession	Country of origin	Disease rating
81	PI 183217	Egypt	5.00
82	PI 184800	Nigeria	5.00
83	PI 185636	Ghana	5.00
84	PI 186489	Nigeria	5.00
85	PI 189317	Zaire	5.00
86	PI 193490	Ethiopia	5.00
87	PI 193963	Ethiopia	5.00
88	PI 195562	Ethiopia	5.00
89	PI 222137	Algeria	5.00
90	PI 254737	Senegal	5.00
91	PI 254741	Senegal	5.00
92	PI 271774	South Africa	5.00
93	PI 271982	Somalia	5.00
94	PI 271983	Somalia	5.00
95	PI 271987	Somalia	5.00
96	PI 273479	Ethiopia	5.00
97	PI 299563	South Africa	5.00
98	PI 306367	Angola	5.00
99	PI 319212	Egypt	5.00
100	PI 378615	Zaire	5.00
101	PI 392291	Kenya	5.00
102	PI 482260	Zimbabwe	5.00
103	PI 482269	Zimbabwe	5.00
104	PI 490377	Mali	5.00
105	PI 490384	Mali	5.00
106	PI 494821	Zambia	5.00
107	PI 500305	Zambia	5.00
108	PI 500320	Zambia	5.00
109	PI 525095	Egypt	5.00
110	PI 542115	Botswana	5.00
111	PI 559992	Nigeria	5.00

[z] The rating system consisted of 1 = 0% to 19% of a plant canopy affected by powdery mildew, 2 = 20% to 39%, 3 = 40% to 59%, 4 = 60% to 79%, and 5 = 80% to 100% of canopy affected; 1 indicates ARS, Lane, Oklahoma crosses; 2 indicates proprietary line from Syngenta Seeds.

Figure 1. Disease severity rating of 111 *C. lanatus* entries screened for powdery mildew resistance. Each dot represents the average disease rating for each of the 111 *C. lanatus* screened. The disease severity units are given on the left, which is an average of plant canopy ratings for each selection evaluated. The rating system consisted of 1 = 0% to 19% of a plant canopy affected by powdery mildew, 2 = 20% to 39%, 3 = 40% to 59%, 4 = 60% to 79%, and 5 = 80% to 100% of canopy affected.



Results. The powdery mildew pathogen present in the plots was identified as *S. fuliginea* (J.P. Damicone, Oklahoma State University), although the race was not determined. Disease severity ratings for the 111 *C. lanatus* entries ranged from 1.5 to 5.0 (Fig. 1). None of the entries exhibited immunity to powdery mildew, and only seven of the PIs screened had a disease severity rating of less than 2.0. Selections with a disease rating of 3.0 or less were considered moderately resistant to the *S. fuliginea* race present since plants with a 2.5 or lower disease severity rating showed no noticeable reduction in fruit quality or quantity. The commercial cultivars 'Tri-X 313' and 'Royal Sweet' had disease severity ratings of 4.4 and 4.5, respectively. Disease severity ratings among the PI accessions ranged from 1.5 to 5.0, of which 90 had ratings above 3.0, 63 had ratings of 4.0 and above, and 32 had ratings of 5.0.

Since powdery mildew epiphytotics have not been a problem on watermelon in the U.S. until recently, and the source of the apparent new strain is unknown. Perhaps a more virulent strain of powdery mildew was introduced, a new strain evolved, or a previously existing strain has become more prevalent. A similar situation was reported in Israel, where powdery mildew has recently become a limiting factor in watermelon production (4). Interestingly, Brazil has had a problem growing American watermelon cultivars due to susceptibility to the local race(s) of *S. fuliginea* (10).

Understanding the inheritance of powdery mildew resistance in cucurbits is complicated by the difficulty in differentiating between the two genera, and the races of powdery mildew that attack cucurbits. Further complicating this issue is the rapidity with which the predominant races can shift (13). Alvarez et al. (1) stated that the present classification of physiological races was inadequate for *S. fuliginea* isolates from Spain. They noted that different isolates belonging to race 2, based on current differentials (9), exhibited different patterns of virulence on certain melon genotypes. In Israel, the situation is even more perplexing. In 1988, Cohen and Eyal (5) reported that *C. lanatus* cultivars were resistant to race 1 of *S. fuliginea* and susceptible to race 2. More recently, Cohen et al. (4) stated that *S. fuliginea* race 1 isolates collected from cucumber and melon were infective only on the hypocotyls of watermelon. On the other hand, race 2 isolates from cucumber or melon failed to initiate disease on watermelon. In the U.S., Robinson et al. (11) stated that only one of the 590 *C. lanatus* accessions they tested was susceptible to an undetermined race of powdery mildew. In contrast, 248 of the 250 *C. lanatus* and *C. colocynthis* accessions tested in Israel were susceptible (4). Robinson et al. (12) used a susceptible accession from Belize (PI 269677) to study the inheritance of powdery mildew susceptibility in watermelon. Using PI 269677 X 'Sugar Baby' F1, F2, and backcross generations, they noted that susceptibility was due to a single recessive gene. Over the last several years, Thomas (unpublished data) has examined some powdery mildew isolates from watermelon in the U.S. Based on the widely-accepted conidial characteristics described by Ballentyne in 1963 (2), all of these watermelon isolates were identified as *S. fuliginea*. Based on inoculation tests to the cantaloupe differentials established by Pitrat et al. (9) to identify races of *S. fuliginea*, all of the isolates were race 2. However, these race 2 isolates from watermelon were more aggressive on race 2 susceptible differential cultivars, such as PMR 45, than older race 2 isolates that have been maintained at the U.S. Vegetable Laboratory in Charleston, SC.

The present study demonstrated a continuum in disease severity ratings from 1.5 to 5.0 among the watermelon entries screened. These preliminary data suggest that genetic resistance to the unknown race of *S. fuliginea* may be controlled by multiple genes. Since we are likely screening for resistance to a different race or strain of *S. fuliginea* compared to the 1975 studies (12), it is likely that a different array of genes may be involved in conferring the resistance observed.

Without resistant cultivars and with limited fungicide availability, U.S. watermelon growers could experience severe crop losses in years with optimal conditions for powdery mildew development. Currently, fungicide application and planting resistant cultivars remain the best controls for powdery mildew outbreaks on cucurbits. However, there is no published information available on relative resistance or susceptibility in U.S. watermelon cultivars against the new strain of *S. fuliginea*. Because of the capacity of this fungus to develop resistance to fungicides (7), alternating fungicides with different modes of action should be integrated into the disease management program.

In the present study *C. lanatus* entries were evaluated for resistance to a naturally-occurring, but as of yet undetermined strain of *S. fuliginea*. Based on this study some watermelon accessions are resistant to this undetermined, but highly virulent, strain of the pathogen. Crosses between PIs with low disease severity ratings, and commercial open-pollinated cultivars of *C. lanatus* have been produced to study the inheritance of this resistance.

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