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Evaluation of U.S. Plant Introductions of Watermelon for Resistance to Powdery Mildew

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Abstract. **Two hundred sixty-six *Citrullus lanatus* (Thumb.) Matsum. & Nakai accessions (Plant Introductions and named cultivars) were tested against a race 2 *Sphaerotheca fuliginea* (Schlechtend.: Fr.) Pollacci isolate to evaluate for resistance to powdery mildew disease. Growth room-grown seedlings were artificially inoculated with conidia from watermelon host leaves at 2-day intervals from the appearance of the first true leaf until test results data were taken, when the second true leaf was fully expanded. Plants were evaluated on a 1 to 9 scale of increasing disease severity. Disease indices (DIs) were calculated as weighted averages for each entry. All genotypes with resistant plants (powdery mildew rating 1 to 3) were reevaluated in a replicated test of 3 replications of 10 plants each. Disease indices were again calculated. Twenty-two plant introductions (PIs) and one named variety displayed intermediate resistance to powdery mildew in the replicated test with DIs ranging from 5.0 to 6.0.**

Historically, watermelon has been considered the most resistant of the cucurbits to powdery mildew (Krístková and Lebeda, 2000). The incidence of the disease usually increases as rainfall decreases (Sitterly, 1978). Dry conditions in recent years in the southeastern and southwestern United States have favored the increase of powdery mildew infection to the point that significant production losses were caused in watermelon cultivars heretofore unaffected by powdery mildew (Davis et al., 2001; Keinath and Dubose, 2004) . Powdery mildew is also now limiting production in Israel, with widespread infection occurring toward the end of the growing season (Cohen et al., 2000).

Symptoms of powdery mildew infection on watermelon are generally of two types. Chlorotic spots may appear on leaves with little or no sporulation and little mycelial growth. The fungus may also produce mycelial growth and conidial production on either leaf surface without accompanying chlorotic spots. The disease can develop on petioles and stems, although this occurrence is less frequent (Davis et al., 2001). Cucurbit vines shade the ground and their dense foliage favors the growth of powdery mildew, which develops better in low light intensity than in full sunlight (Sitterly, 1978; McGrath and Thomas, 1996). Because fungal growth develops on both leaf surfaces and on petioles and stems, disease control by chemical means requires that protective fungicides reach the undersides of the leaves as well as the lower canopy. Economic and environmental concerns, as well as reduced sensitivity to fungicides, dictate that identification of powdery mildew resistance in watermelon and the development of resistant cultivars is the best choice for control of this disease (McGrath and Thomas, 1996). Davis et al. (2001) found several watermelon Plant Introductions (PIs) with moderate resistance to powdery mildew, but none exhibited a high level. This work is a further evaluation of available watermelon PIs and cultivars for resistance to powdery mildew.

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Materials and Methods

Plant material. Ten plants each of the 237 core watermelon accessions supplied by the USDA Plant Genetics Resources Conservation Unit at Griffin, Ga., and 29 named cultivars were tested in initial studies (Table 1). Because of space limitations of the growth room where the plants were maintained, the accessions were tested in five groups. The highly susceptible cultivar 'Crimson Sweet' was the control. Seeds were sown directly to flats containing a commercial potting mix and placed on glasshouse benches until cotyledons emerged. Seedlings were then moved to a growth room and maintained at 22 °C and 70% RH with 12 h of light per 24 h for the duration of the test.

Disease organism. An isolate of race 2 of *S. fuliginea* indigenous to the Charleston, S.C., area was maintained on watermelon host plants isolated in a growth chamber at the U.S. Vegetable Laboratory. Artificial inoculations of watermelon test seedlings were performed by manually dusting the seedlings at 2-d intervals from heavily sporulating host leaves. Test plants were initially inoculated when the first true leaf began to expand. Inoculations continued at two-day intervals until disease ratings were made, when the majority of the plants had reached the two-expanded-leaf stage.

Plants were rated for powdery mildew infection at 16 to 28 d postemergence, depending on development rate of the accessions. A 1 to 9 scale of increasing disease severity was used where 1 = no evidence of infection, 2 = trace infection of cotyledons only, 3 = low infection of cotyledons only, or low infection of leaves only, 4 = moderate infection of cotyledons only, trace infection of leaves, or no infection of cotyledons, slight infection of leaves, 5 = severe infection of cotyledons, slight infection of leaves, 6 = severe infection of cotyledons, moderate leaf infection as evidenced by leaf deformity and or sporulation on leaves, 7 = severe infection with abundant sporulation on cotyledons and leaves, or on leaves only, 8 = severe infection of leaves with some necrosis of leaves, and 9 = plant dead due to powdery mildew. Disease indices (DIs) were calculated as a weighted average for each of these entries. Plants having powdery mildew ratings of 1 to 3 were classed as resistant, 4 to 6 were classed as intermediate resistance, and 7 to 9 were classed as susceptible.

Results and Discussion

Thirty-seven accessions in the preliminary tests had one or more plants exhibiting some degree of resistance, with powdery mildew ratings ≤3. These 37 PIs (designated with * in Table 1) and 'Crimson Sweet' were retested in replicated trials of three replications of 10 plants each to confirm the presence of resistance. Test plants for the replicated study were grown and artificially inoculated in the same manner as in the initial tests. Disease indices were again calculated. Disease indices in Table 1 are those calculated from the replicated test for the 37 PIs in that test. All other DIs were calculated from the results of the nonreplicated tests.

No genotypes were found with high resistance to powdery mildew. Disease indices for PIs ranged from 5.0 to 8.7. Twenty-two PIs and the named cultivar Fairfax (DIs between 5.0 and 6.0), were considered to have intermediate resistance. No plants in the replicated test exhibited resistance (powdery mildew rating ≤3). Five of the 22 PIs (306367, 225557, 494530, 189225, and 532730) had DIs indicating intermediate resistance in the replicated test as well as plants exhibiting powdery mildew resistance in the preliminary test. Some seedlings from these five PIs may carry genes for resistance to powdery mildew.

Sphaerotheca fuliginea is the predominant causal agent of powdery mildew on watermelon in the U.S. (Robinson et al., 1975; McGrath and Thomas, 1996) and in Israel, with *Erysiphe cichoracearum* DC ex Mecat attacking some cultivars in Israel (Cohen et al., 2000). Conversely, *E. cichoracearum* is the predominant causal agent in the Czech Republic (Krístková and Lebeda, 2000).

In New York, Robinson et al. (1975), in an inheritance study for susceptibility of watermelon to powdery mildew race 2, or another race different from race 1, crossed the susceptible accession PI 269677 with resistant 'Sugar Baby'. They concluded susceptibility to be conditioned by a single recessive gene, *pm*. In Israel, conidia collected from field-grown watermelon plants infected with powdery mildew produced disease symptoms

Table 1. Reaction of U.S. plant pntroduction (PIs) including *Citrullus lanatus* var. *lanatus* (L), *C. lanatus* var. *citroides* (C), *C. colocynthis* (O), *Praecitrullus fistulosus* (F) and watermelon cultivars to inoculation with *Sphaerotheca fuliginea*, the incitant of powdery mildew.

PI or cultivar	Powdery mildew disease index	PI or cultivar	Powdery mildew disease index	PI or cultivar	Powdery mildew disease index
PI 388770 (O)	5.0	PI 525095 (L)	6.8	PI 244018* (C)	7.4
PI 482343 (L)	5.1	PI 534533 (L)	6.8	PI 271467 (F)	7.4
PI 306367*(L)	5.2	PI 560901 (L)	6.8	PI 276445* (L)	7.4
PI 225557*(L)	5.3	PI 164685 (L)	6.9	PI 368519 (L)	7.4
PI 494530*(L)	5.3	PI 169237 (L)	6.9	PI 500313 (L)	7.4
PI 379229 (L)	5.5	PI 171581 (L)	6.9	PI 500320 (L)	7.4
PI 482284 (L)	5.5	PI 177327 (L)	6.9	PI 512359 (L)	7.4
PI 175654 (L)	5.6	PI 211915 (L)	6.9	PI 535948 (L)	7.4
PI189225*(C)	5.6	PI 212983 (L)	6.9	PI 536451 (L)	7.4
PI 500301 (L)	5.6	PI 278044* (L)	6.9	PI 537468 (L)	7.4
PI 505584 (L)	5.6	PI 279461 (L)	6.9	PI 561138 (L)	7.4
PI 532730*(L)	5.6	PI 306782 (L)	6.9	PI 179234 (L)	7.5
PI 549159 (L)	5.6	PI 379256 (L)	6.9	PI 249008* (L)	7.5
PI 560006 (L)	5.7	PI 381704 (L)	6.9	PI 487476* (L)	7.5
PI 459074 (L)	5.8	PI 491265 (L)	6.9	PI 505595* (L)	7.5
PI 457916 (L)	5.9	PI 612459 (L)	6.9	PI 507862 (L)	7.5
PI 186489 (L)	6.0	PI 612464 (L)	6.9	PI 560002* (L)	7.5
PI 270551 (L)	6.0	Grif 1734 (L)	7.0	PI 560024* (L)	7.5
PI 295850 (C)	6.0	Grif 5597 (L)	7.0	PI 169256* (L)	7.6
PI 418762 (L)	6.0	PI 113326 (L)	7.0	PI 172786 (L)	7.6
PI 470249 (L)	6.0	PI 163574 (L)	7.0	PI 174100 (L)	7.6
PI 482373 (L)	6.0	PI 167059 (L)	7.0	PI 184800 (L)	7.6
Fairfax (L)	6.0	PI 169289 (L)	7.0	PI 271988 (L)	7.6
PI 179883 (L)	6.1	PI 175102 (L)	7.0	PI 370430 (L)	7.6
PI 271771 (C)	6.1	PI 176923 (L)	7.0	PI 508441 (L)	7.6
PI 482283 (C)	6.1	PI 183217 (L)	7.0	PI 559994* (L)	7.6
PI 177331*(L)	6.2	PI 357708 (L)	7.0	Kengarden (L)	7.6
PI 381753 (F)	6.2	PI 357716 (L)	7.0	New Hampshire (L)	7.6
PI 596667 (C)	6.2	PI 381725* (L)	7.0	Sweet Jubilee (L)	7.6
PI 254623 (L)	6.3	PI 482266 (L)	7.0	PI 163203 (L)	7.7
PI 270563 (C)	6.3	PI 482345 (L)	7.0	PI 226460* (L)	7.7
PI 296341 (C)	6.3	PI 490384 (L)	7.0	PI 254735* (L)	7.7
PI 299378 (C)	6.3	PI 512361 (L)	7.0	PI 278028 (L)	7.7
PI 344066 (L)	6.3	PI 512373 (L)	7.0	PI 345545 (L)	7.7
PI 482291 (L)	6.3	PI 512391 (L)	7.0	PI 368502 (L)	7.7
PI482311*(C)	6.3	PI 518608 (L)	7.0	Allsweet (L)	7.7
PI 490377 (L)	6.3	PI 525089* (L)	7.0	Malali (L)	7.7
PI 494527 (L)	6.3	PI 536459 (L)	7.0	PI 182176 (L)	7.8
PI 494815 (L)	6.3	PI 542122 (L)	7.0	PI 270522 (L)	7.8
PI 532624 (C)	6.3	PI 542123 (C)	7.0	PI 271981 (L)	7.8
PI 212094 (L)	6.4	PI 543211 (L)	7.0	PI 314236 (L)	7.8
PI 246559 (L)	6.4	Grif 1728 (L)	7.1	PI 512399 (L)	7.8
PI 357702 (L)	6.4	PI 169266 (L)	7.1	PI 559995*(L)	7.8
PI 435991 (L)	6.4	PI 178874 (L)	7.1	Dixielee (L)	7.8
PI 505604 (C)	6.4	PI 181935 (L)	7.1	Minilee (L)	7.8
PI525082*(C)	6.4	PI 193963 (L)	7.1	Regency (L)	7.8
PI 542617 (L)	6.4	PI 227205 (L)	7.1	Sunshade (L)	7.8
Summit (L)	6.4	PI 234603 (L)	7.1	PI 172804 (L)	7.9
PI 164539 (L)	6.5	PI 269465 (L)	7.1	PI 176494 (L)	7.9
PI 174812 (F)	6.5	PI 271132 (L)	7.1	PI 277991 (L)	7.9
PI 254741 (L)	6.5	PI 271778* (L)	7.1	PI 526235 (L)	7.9
PI 307750 (L)	6.5	PI 357736 (L)	7.1	PI 534591*(L)	7.9
PI 357727 (L)	6.5	PI 370424 (L)	7.1	PI 538888 (L)	7.9

on watermelon inoculated in growth chambers. Race 1 *S. fuliginea* isolates collected from glasshouse cucumber and melon infected only the hypocotyls of watermelon. Race 2 isolates from glasshouse-grown cucumber and melon did not cause disease in watermelon test plants (Cohenet al., 2000). A recent study of 111 field grown watermelon PIs and cultivars in Oklahoma (Davis et al., 2001) found no immunity to an undetermined race of *S. fuliginea*. Plants were rated on a 1 to 5 scale of increasing disease severity. Of these, only seven accessions had a disease severity rating <2.0 (20% to 39% of the plant canopy affected by disease). A disease rating of ≤3.0 was considered necessary for a genotype to be classed as moderately resistant. Twenty-two genotypes, 18 PIs and 4 *C. lanatus* crosses were rated as moderately resistant.

Registered fungicides are available for control of powdery mildew on watermelon. However, environmental concerns, difficulty achieving adequate coverage, likelihood of the pathogen developing resistance to chemicals used for control, and shifts in virulence of the organism mean that total reliance upon chemical means of control is insufficient (McGrath 2001). The best method to control powdery mildew would be provided through use of resistant varieties, with only occasional use of chemical control if necessary. Careful screening and selection from the five accessions that exhibited intermediate resistance in both the replicated and nonreplicated tests in this

Table 1. Continued.

PI or cultivar	Powdery mildew disease index	PI or cultivar	Powdery mildew disease index	PI or cultivar	Powdery mildew disease index
PI 379237 (L)	6.5	PI 381734 (L)	7.1	PI 593365 (L)	7.9
PI 430615 (L)	6.5	PI 438675 (L)	7.1	Congo (L)	7.9
PI 504519 (L)	6.5	PI 500307 (L)	7.1	PI 255662 (L)	8.0
PI 171392 (L)	6.6	PI 512367 (L)	7.1	PI 269677 (L)	8.0
PI 254740 (L)	6.6	PI 169232 (L)	7.2	PI 270141 (L)	8.0
PI 378612 (L)	6.6	PI 182933* (L)	7.2	PI 273429 (L)	8.0
PI 381749 (F)	6.6	PI 212209 (L)	7.2	PI 277976 (L)	8.0
PI 431579 (L)	6.6	PI 270545 (L)	7.2	PI 357690 (L)	8.0
PI 476325 (L)	6.6	PI 381715 (L)	7.2	Bitter Hawksberry (L)	8.0
PI 482359 (L)	6.6	PI 500329* (L)	7.2	Black Diamond (L)	8.0
PI 490386 (L)	6.6	PI 164634 (L)	7.3	Calsweet (L)	8.0
PI 500317 (L)	6.6	PI 165448 (L)	7.3	Citron (from Hart) (L)	8.0
PI 512340 (L)	6.6	PI 172798 (L)	7.3	Desert King (L)	8.0
PI 532723 (L)	6.6	PI 176487 (L)	7.3	Improved Peacock(L)	8.0
PI 536464 (L)	6.6	PI 180426 (L)	7.3	Mickylee (L)	8.0
PI 593347 (L)	6.6	PI 189318 (L)	7.3	Moon and Stars (L)	8.0
PI 612472 (L)	6.6	PI 193490 (L)	7.3	Royal Charleston (L)	8.0
PI 183398*(L)	6.7	PI 222710* (L)	7.3	Sangria (L)	8.0
PI 190050 (L)	6.7	PI 266027 (L)	7.3	PI 357656 (L)	8.1
PI 279459 (L)	6.7	PI 326516* (L)	7.3	PI 505592*(L)	8.1
PI 344395 (L)	6.7	PI 368526 (L)	7.3	PI 357681 (L)	8.2
PI 370015 (L)	6.7	PI 458739 (L)	7.3	Sunsweet (L)	8.2
PI 392291 (L)	6.7	PI 482323 (L)	7.3	Texas W-5 (L)	8.2
PI 482305 (L)	6.7	PI 482367 (L)	7.3	PI 293766 (L)	8.3
PI 534596 (L)	6.7	PI 512368 (L)	7.3	PI 326515*(L)	8.3
PI 595203 (L)	6.7	PI 512405 (L)	7.3	PI 344300 (L)	8.3
PI 169274 (L)	6.8	PI 537269* (L)	7.3	PI 357672 (L)	8.3
PI 174106 (L)	6.8	PI 542115 (L)	7.3	Calhoun Grey (L)	8.3
PI 217522 (F)	6.8	PI 560020 (L)	7.3	Crimson Sweet*(L)	8.4
PI 254428*(L)	6.8	PI 593341 (L)	7.3	PI 346787 (L)	8.5
PI 271775 (C)	6.8	PI 596671 (C)	7.3	PI 482272*(L)	8.5
PI 296384 (L)	6.8	PI 596676 (C)	7.3	Dixie Queen (L)	8.5
PI482334*(C)	6.8	Hawksberry (L)	7.3	PI 357750 (L)	8.6
PI 500343 (L)	6.8	PI 169282 (L)	7.4	PI 506439*(L)	8.7
PI 502318 (L)	6.8	PI 176916 (L)	7.4	Klondike Stripped (L)	8.7
PI 512381 (L)	6.8	PI 219691 (L)	7.4		

[z]Powdery mildew reaction for all PIs and cultivars was rated on a 1 to 9 scale, and the disease index (DI) calculated from that scale where: 1.0 to 3.0 = resistant, 3.1 to 6.0 = intermediate resistant, and 6.1 to 9.0 = susceptible.

*Each of the 37 PIs that were retested in replicated trials to confirm level of resistance.

study may provide a source of intermediate or moderate resistance to some strains of powdery mildew. However, PI accessions beyond the core collection (including PIs of *C. lanatus* var. *citroides* and *C. colocynthis* that showed greater genetic and geographical diversity than PIs of *C. lanatus var. lanatus;* Levi et al. 2001) should be evaluated in an effort to identify a source of a higher level of resistance that would be more useful for disease management.

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