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BARD

FINAL REPORT

PROJECT No. US-287-81

**Development of Cantaloupe Varieties and Advanced
Breeding Lines with Resistance to the Fungus
Disease Complex in Both the USA and Israel with
Special Emphasis on Resistance to Downy Mildew**

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1986

Date: February 1, 1986

BARD
P. O. Box 6
Bet Dagan, Israel

BARD Project No. US-287-81

Title of Research Project: Development of cantaloup varieties and advanced breeding lines with resistance to the fungus disease complex in both the USA and Israel with special emphasis on resistance to downy mildew

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Project's starting date: October 1, 1982

Type of Report: 1st Annual _____ 2nd Annual _____ Final X

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Abstract

Three multiple disease resistant inbreds from the W-line series of Cucumis melo were developed with enhanced levels of resistance to downy mildew incited by two U. S. A. pathotypes of Pseudoperonospora cubensis. These inbreds also have the horticulturally desirable fruit characteristics of commercial cantaloup cultivars for U. S. A. production. They will be increased and released to public and private breeders in 1986. In Israel parental lines with acceptable fruit quality and high levels of resistance to downy and powdery mildews were developed and crossed with commercial cultivars to generate hybrids. Some of the resultant hybrids produced high quality fruit on plants that had much higher levels of resistance to both mildews than did the parental commercial cultivars. After field evaluations in 1986, the best hybrid combinations will be released for production in Israel. Based on concurrent host specificity studies in Israel, Japan, and the U. S. A., five distinct pathotypes of the downy mildew pathogen, Pseudoperonospora cubensis, were delimited. Reaction type 4 resistance from C. melo PI 124111 was stable type 4 against all of these pathotypes as well as at least one additional pathotype indicated from incomplete concurrent studies in India. PI 124111, which is also resistant to at least 3 races of powdery mildew was used in Israel as the source of resistance to both mildews in the parental lines that were developed. In the U. S. A. an inbred line of PI 124111, designated MR-1, in which resistance against multiple pathotypes and races of both mildews had been stabilized was released to public and private breeders.

D. Objectives of original research proposal.

The four main objectives as stated in the original research proposal were:

1. To accelerate the refinement of already developed multidisease resistant cantaloup germ plasm to variety status in the U. S. A.
2. To accelerate the development of multidisease resistant cantaloup varieties and breeding lines in Israel.
3. To delimit the physiological races of downy mildew on cucurbits.
4. To identify and stabilize sources of resistance in Cucumis melo to the races of downy mildew.

Only slight deviations were made from the originally proposed objectives "1" and "2". The deviation of "1" was that advanced breeding lines with improved levels of disease resistance and horticultural acceptability rather than varieties were developed in the U. S. A. to maintain compatibility with the current research mission of the U. S. A. scientists' institution. The deviation in "2" was that in Israel breeding efforts emphasized the development of parental lines for disease resistant hybrids rather than open-pollinated varieties to ensure a degree of exclusivity of resultant germ plasm to Israel.

In the following body of this report, each objective and the research pursuant to its attainment will be discussed in individual sections in the order listed above. Tables and figures are numbered by section. Literature Cited is inclusive for all sections except where copies of publications are used as part of the report.

- E. Objective 1. To accelerate the refinement of already developed multidisease resistant cantaloup germ plasm to variety status in the U. S. A.

Introduction

As previously mentioned, this objective was slightly modified to maintain compatibility with the current research policy of the U. S. A. scientists' institution in that advanced breeding lines rather than varieties were developed.

The multidisease resistant W-line series released by Thomas and Webb culminated 12 years of intensive breeding and selection for both disease resistance and horticultural acceptability (30). These lines were initially developed through a series of complex back- and outcrosses utilizing P. I. 180280 as a resistant source against WMV-1; the "PMR-series" against powdery mildew; GA. 47, Edisto 47, and PMR 45 against *Alternaria* leaf-blight; and Edisto 47, Seminole, Rio Gold, and Texas Resistant #1 against downy mildew. These genetically diverse, broad-based lines withstood the intensive selection pressure encountered from multiple exposures to epiphytotics of downy mildew, races 1 and 2 of powdery mildew, and *Alternaria* leaf-blight. All five W-lines had high resistance to WMV-1 under field conditions and three tested homozygous resistant in the greenhouse. Three were also highly resistant to race 3 of powdery mildew (26) in the U. S. A.

The downy and powdery mildew and WMV-1 resistant cultivar Cinco was derived from line W5 as a high quality commercial type with excellent keeping qualities for long-distance shipping (28). The cultivar Mainstream represented a high quality downy and powdery mildew and cucumber beetle

resistant muskmelon especially adapted to cultivation in the southeastern U. S. A. (19).

The W-lines, Cinco, and Mainstream represented the best available sources of downy mildew resistance combined with other disease and pest resistances among USA cultivars with those horticultural characteristics desired in commercial types. Also, PI 124111, a source of high resistance to downy mildew (19, 28, 30) was in their pedigrees. Therefore, they served as the main germ plasm source in the research effort to accomplish 'Objective 1'.

Other sources of downy mildew resistance in released U. S. A. cultivars with less desirable horticultural traits were utilized as part of the research effort reported under 'Objective 4'.

Materials and Methods

All breeding, evaluation, and selection procedures were conducted at Charleston, SC. This slight deviation from the original proposal was necessitated by the Principal Investigator's transfer to the U. S. Vegetable Laboratory at Charleston in July 1982.

Two lines of endeavor were followed. In one, an effort was made to increase the intermediate (reaction type 23) level of downy mildew resistance in the W-lines through improved, more critical and highly selective evaluation procedures (7) developed to identify high levels of non-specific resistance and to then stabilize this resistance in inbreds in which a high level of horticulturally acceptability was maintained. The second effort attempted to improve the levels of downy and powdery mildew resistance in a horticulturally acceptable muskmelon type through hybridization of the cultivars Cinco and Mainstream.

Standard breeding procedures for muskmelon were used with slight modifications (31). Details of disease resistance evaluations have been

published (7, 29) and are included under 'Objective 4' of this report.

Horticultural acceptability (= fruit quality) criteria which were evaluated included: Fruit size and shape, net type, ribbing, vein tracks, stem-end scar, flesh color, cavity size, flesh firmness, and soluble solids (% sucrose).

A flow diagram (Figure 1-1) outlines the order and time frame of the work conducted under this objective.

Results and Discussion

From eight Mainstream x Cinco hybrids, 26 progeny plants were selected with the highest levels of mildew resistances and selfed. Based on fruit quality evaluations, 17 of these, designated MC-lines, were selected for field plot evaluations in summer 1983. Only 1 entry, line MC7-15 was found to have downy mildew resistance greater than either parent cultivar combined with fruit quality equal to or greater than either Mainstream or Cinco. Therefore, only line MC7-15 was selected for further evaluations for downy and powdery mildew resistances under greenhouse-growth chamber conditions in fall 1983. In these tests line MC7-15 exhibited a high level of resistance to downy mildew, but had only a moderate level of resistance to race 2 of S. fuliginea. For this reason, work with the MC-lines was discontinued.

Of 48 plants each, of lines W1, W3, W4, W5, W5sb, and W6 evaluated for downy and powdery mildew resistances through the 2-leaf stage, 21, 13, 7, 13, 14 and 10 plants, respectively, with highest resistance levels to both diseases were selected and selfed in fall 1982 and winter 1982-83. Selection for fruit quality among these 78 selfs resulted in 37 lines for replicated field plot evaluation against commercial U. S. A. cultivars in summer 1983. Twenty-four of these lines maintained moderate to high resistance (rating ≥ 6 on 1-9 scale) in a natural epiphytotic of downy mildew with acceptable fruit

quality and good overall general disease resistance in these plots. Remnant seed of these 24 lines was used to produce plants which were evaluated for downy and powdery mildew resistances in greenhouse-growth chamber conditions in the fall 1983. From these evaluations 17 lines that tested highly resistant (no macroscopic evidence of infection) to powdery mildew and highly resistant to downy mildew (≥ 7 rating on 1-9 scale) were selfed in the greenhouse in winter 1983-84. Thirteen W-line inbreds were selected on the basis of high fruit quality from these 17 selfs and evaluated in field plots in summer 1984. Downy mildew reaction types (RT) (7) on these lines (Table 1-1) identified six with predominantly reaction type 34 individuals, five derived from W6, and one from W5sb. Remnant seed of these six lines were used to produce plants of each line in the greenhouse in fall 1984. Inoculations with race 1 of S. fuliginea up to the 2-leaf stage of development elicited no visible evidence of powdery mildew infection. Inoculations at the 2-leaf stage with pathotypes 4 and 5 of P. cubensis were used to identify individual plants with RT 34. These were selfed in the greenhouse in winter 1984-85 and fruit quality evaluations made. Since no lines could be eliminated based on these quality evaluations, all six were planted in replicated field plots along with selected U. S. A. cultivars in summer 1985. Reaction type of three lines: B23-2-1, B 25-1-2, and B 27-3-4 remained stable at RT 34 when challenged by the epiphytotic resulting from artificial inoculation with two pathotypes of P. cubensis (Table 1-1). Fruit quality evaluations for these lines and commercial cultivars in the same plots are given in Table 1-2. These data illustrate that under the same growing conditions, those genotypes with RT 34 produced fruit that was equal to or exceeded that produced by commercial cultivars in horticultural acceptability.

Following confirmative evaluations of downy and powdery mildew resistances in fall-winter 1985-86, lines B23-1-1, B25-1-2, and B27-3-4 will be increased in isolation in summer 1986 for release to public and private breeders. At present, these lines represent the highest levels of resistance to at least two U. S. A. pathotypes of downy mildew combined with resistance to 3 races of powdery mildew in horticulturally acceptable multiple disease resistant muskmelons for U. S. A. production.

Figure 1-1. Flow diagram of breeding and evaluation procedures conducted under 'Objective 1'.

Table 1-1. Downy mildew^z reaction type W-line inbreds and commercial cultivars in replicated (4) field plots at Charleston, SC; summer 1984 and 1985.

Source	Entry 1984 ('85)	Reaction type	
		1984	1985
W1	B16-3	13	--
W1	B17-2	13	--
W3	B18-3	13	--
W3	B19-3	23	--
W5	B22-1	23	--
W5sb	B23-2 (-1)	34	34
W6	B25-1 (-2)	34	34
W6	B26-3 (-1)	34	33
W6	B27-3 (-4)	34	34
W6	B28-2 (-4)	34	23
W6	B30-2 (-1)	34	23
W6	B31-1	24	--
W6	B32-2	23	--
--	Cinco	23	23
--	Mainstream	22	--
--	Perlita	12	12
--	Hales Best Jumbo	--	12
--	PMR 45	12	12
--	PMR 6	12	12
--	Edisto 47	13	--

^zPlots were inoculated at the 10-expanded-leaf stage with a 2.0×10^4 sporangia/ml suspension composed of equal proportions of P. cubensis pathotypes 4 & 5.

^yFirst digit represents RT of leaves 3-6 and second digit represents RT of leaves 6-10. See (7).

Table 1-2. Fruit quality evaluations and reaction types against downy mildew for W-line inbreds and commercial cultivars in field plots at Charleston, SC; summer 1985. All entries had slight ribbing with slight-moderate vein tracks, coarse-fine, flat net; moderate, entire stem-end scar; medium relative cavity size; moist-dry cavity; and firm flesh.

Entry	Size (w x l in cm)	Fruit character		Soluble solids (% sucrose)	Reaction type
		Shape	Flesh color		
B23-2-1	12.2 x 12.4	Round	Orange	7.6	34
B25-1-2	11.9 x 12.7	Slight oblong	Light orange	7.4	34
B27-3-4	11.9 x 12.5	Slight oblong	Light orange	6.9	34
Cinco	12.2 x 13.6	Slight oblong	Orange	5.1	23
PMR 45	11.4 x 13.3	Oblong	Very lt orange	4.4	12
Perlita	10.9 x 12.7	Oblong	Very lt orange	4.0	12

- E. Objective 2 -- To accelerate the development of multidisease resistant cantaloup varieties and breeding lines in Israel.

Introduction

As explained under 'D' above, emphasis was placed on the development of disease resistant parent lines for hybrid rather than open-pollinated varieties.

Information on sources of resistance in Cucumis melo against downy and powdery mildews has been available for some time (23, 24, 25). However, in examinations involving more than one pathogen race these reports could not always be verified (27). Due to the often contradictory nature of the available information, the breeding work in Israel to accomplish this objective started with re-examination of reportedly resistant genotypes from diverse sources and then proceeded toward the development of horticulturally acceptable parent lines for use in hybrids for production in Israel. Much of the work to accomplish this objective, especially the identification and stabilization of sources of resistance, was accomplished as part of the work included under Objective 4 and is detailed there.

Materials and Methods

The downy and powdery mildew resistant inbred, line 18, derived by Cohen from PI 124111 in Israel, was used as the resistant parent in crosses with established commercial cultivars for hybrid development using standard breeding procedures (31). Line 18 was also used as the resistant parent in studies on the inheritance of downy and powdery mildew resistance from PI 124111 described under Objective 4.

Details of inoculation and evaluation procedures are included in either published material pertinent to this section (6, 7, 8), applicable data

tables, or in the M.S. thesis of S. Cohen, which is included under Objective 4 of this report.

Results & Discussion

Evaluation of crosses between line 18 and cultivars Ananas Yokneam, Hemed, and Ein Dor (Table 2-1) revealed that those crosses between line 18 and Hemed ('A' types) and reciprocals ('B' types) provided the best maintenance of resistance (Tables 2-2, 2-3, 2-4, and 2-5). Therefore, the breeding schemes outlined in the diagrams (Figures 2-1 and 2-2) were conducted beginning with the 'A' types, orange-fleshed F_1 of line 18 x Hemed, and the 'B' types, green-fleshed F_1 of Hemed x line 18, respectively. Evaluation and selection for downy and powdery mildew resistances and fruit quality were conducted at each generation in these schemes.

Table 2-6 presents information on F_3 families some of which were crossed to Hemed to generate the BC_1 summarized in Table 2-7. Hybrids generated by outcrossing F_4 , F_5 , and F_6 families of 'A' types with selected cultivars exhibited a range of disease resistance and fruit acceptability (Table 2-8). Some of these resulted in acceptable fruits with much better levels of disease resistance than in the commercial parent cultivar; e.g. F_4 x Perlita 45, F_4 x Perlita, F_5 x PMR 45, F_6 x Perlita 45, and F_6 x Top Mark. Selfing of the F_3 x Hemed BC_1 for 4 generations and the F_4 x Cinco, Perlita, or Georgia 47 outcrosses for 3 generations also yielded high fruit quality types (Table 2-9).

The F_8 inbred generation of the 'A' type was very resistant to downy mildew (RT = 44) and resistant to races 1 and 2 of powdery mildew. It produced round fruit without netting which had orange flesh, small cavity, and 12% soluble solids borne on a strong vine.

F₃ families of the 'B' type exhibited wide variations in sex-expression, mildew resistances, and fruit acceptability (Table 2-10). Backcrossing selected F₃ families to Hemed generated the populations summarized in Table 2-11. Outcrosses of F₅, F₆, and F₇ families of 'B' types to selected cultivars generated hybrids with the characteristics summarized in Table 2-12. A few of these crosses resulted in acceptable fruit with higher levels of disease resistance than in the parent cultivar, e.g. 5B3-5-3 x Hemed and 5B3-5-3 x Green Ice. Selfing of the F₃ x Hemed BC₁ for 5 generations yielded high quality fruit types (Table 2-9).

The F₇ inbred generation of the 'B' type was highly resistant to downy mildew (RT = 44) and powdery mildew and was monoecious. It produced round fruit without netting, which had green flesh, a large cavity, and high soluble solids.

The inbred lines developed from the 'A' and 'B' types provide parental material with high levels of resistance to both downy and powdery mildews, which were demonstrated to be useful in the generation of resistant hybrids with acceptable fruit quality (Figure 2-3). Work in Israel with hybrids developed from these parental lines is proceeding through field tests in 1986 to select the best combinations for further development.

Figure 2-1. Diagram of breeding scheme used to incorporate downy and powdery mildew resistances from the F₁ of line 18 (inbred selection from PI 124111) x Hemed, 'A' types, into parent lines and hybrids with acceptable fruit quality.

Figure 2-2. Diagram of breeding scheme used to incorporate downy and powdery mildew resistances from the F_1 of Hemed x line 18 (inbred selection from PI 124111), 'B' types, into parent lines and hybrids with acceptable fruit quality.

Table 2-1. Original crosses of line 18 (PI 124111 inbred)
and commercial Israeli cultivars.

Code	♀		♂
A	124111	x	Hemed
B	Hemed	x	124111
C	124111	x	Ein Dor
D	Ein Dor	x	124111
E	124111	x	Ananas Yokneam
F	Ananas Yokneam	x	124111

Table 2-2. Reaction of F₁ two-leaf plants of Cucumis melo to Pseudoperonospora cubensis in growth chambers (0-5 visual scale)^a.

Cross	Code	Leaf	n	Mean	S.D.
18/34 x Hemed	1A1	1	23	1.1	0.8
		2	17	0.4	0.6
Hemed x 18/34	1B1	1	9	0.8	0.9
		2	9	0.3	0.4
Hemed x 18/34	1B2	1	39	0.7	0.8
		2	18	0.3	0.7
Eindor x 18/34	1D1	1	27	2.4	0.8
		2	19	1.3	0.7
18/35 x Ananas	1E2	1	26	1.0	0.8
		2	24	1.6	1.1
18/35 x Ananas	1E1	1	32	1.6	1.3
		2	27	1.5	1.2
Ananas x 18/35	1F1	1	40	0.8	0.9
		2	40	1.3	1.2
18/35 (resistant parent)		1	25	0.6	0.4
		2	18	0.3	0.3
Ananas (susceptible parent)		1	23	2.4	0.9
		2	20	3.8	1.2

^aNumbers represent % leaf area occupied with lesions as estimated 10 days after inoculation (at 20°C). Lesion type was not recorded; neither was sporulation quantified.

Table 2-3. Lesion type produced by Pseudoperonospora cubensis in F₁ three-leaf plants in growth chambers.^a

Cultivar or cross	Code	Leaf 1	Leaf 2	Leaf 3
Hemed (susceptible)	-	1	1	2
Eindor (susceptible)	-	1	1	1.5
Ananas-Yokneam (susceptible)	-	1	1	1
18 x Hemed	A	1	1.9	3.6
Hemed x 18	B	1	1.7	3.4
18 x Eindor	C	1	1.8	2.5
Eindor x 18	D	1	1.7	3.2
18 x Ananas	E	1	1.8	2.6
Ananas x 18	F	1	1.6	2.6
18 (resistant)	18	3	4	4

Scale: 1 = 4-6 mm, normal, irregular yellowish-brown lesions with normal sporulation.

2 = normal irregular lesions, together with 3-4 mm water-soaked lesions, with moderate sporulation.

3 = 3-4 mm, circular, restricted, yellow, water-soaked lesions with little sporulation.

4 = 1-2 mm circular, restricted, yellow, water-soaked lesions with almost no sporulation.

^aPlants (15/treatment) grown in the greenhouse (22-34°C), inoculated by spraying 1×10^4 sporangia ml^{-1} of P. cubensis, incubated in a dew chamber (20°C, dark) for 24 h and then at 25°C with a 12-h photoperiod.

Table 2-4. Reaction of F₁ two-month-old Cucumis melo plants to downy mildew under field conditions.

Cultivar or cross	% Mildewed leaf area ^a	Lesion type ^b	Sporangia cm ⁻² x10 ^{3c}
Hemed	40	6-10 mm, N ^d	62.9 + 19.7
Eindor	40	7-12 mm, N	-
Ananas-Yokneam	48	7-12 mm, N	-
A (18 x Hemed)	10	2 mm, WS	10.8 + 7.9
B (Hemed x 18)	15	2 mm, WS	19.9 + 14.4
C (18 x Eindor)	18	3-4 mm, WS	13.4 + 11.5
D (Eindor x 18)	26	3-4 mm, WS	16.4 + 12.2
E (18 x Ananas)	23	Mixture (N+WS)	37.6 + 20.0
F (Ananas x 18)	41	Mixture (N+WS)	56.3 + 21.0
18	1	1-2 mm, WS	0 ^e

^aBased on three 20-leaf runners per cultivar or cross. Field was artificially inoculated at the 6-7-leaf stage. Records taken June-1983.

^bOn leaves 5-15 of a 20-leaf runner, lower and upper leaves exhibited larger and smaller lesions, respectively.

^cN = normal, irregular, yellowish-brown lesions

WS = circular, restricted, yellow lesions

Mixture = normal and restricted in the same leaf.

^dEight 4.2 cm diam. leaf discs per treatment taken from 8 different leaves. Four cytometer counts per disc. Leaves were collected at 06:00 hr after a heavy dewy night.

^eA few sporangia produced; below detectability of the cytometer.

Table 2-5. Reaction of F₁ plants of reciprocal crosses between line 18 (resistant) and Hemed (susceptible) to Pseudoperonospora cubensis and Sphaerotheca fuliginea (race 2) in growth chambers.

Leaf	18 ♀ x Hemed ♂		Hemed ♀ x 18 ♂	
	Lesion type ^a	Spores.cm ^{-2b} x1000	Lesion type ^a	Spores.cm ^{-2b} x1000
1	1.9 + 0.12	21.1 + 3.7	1.1 + 0.1	33.1 + 6.8
2	3.9 + 0.05	3.4 + 1.4	2.9 + 0.1	12.1 + 2.5'
3	-	2.3 + 1.8	-	5.8 + 4.1

a_n = 20. b_n = 10.

Note: Plants at the two-leaf stage were inoculated with 5x10⁴ sporangia. ml⁻¹ of P. cubensis at 18°C in a dew chamber and then for 7 days at 25°C and 120 uEinstein·m⁻²·S⁻¹ for 14 hr.day⁻¹. S. fuliginea sporulation was recorded on leaf 3 only at day 14.

Table 2-6. Sex-expression, disease resistance, and fruit acceptability for F₃ families of 'A' type.

Entry	Sex -expression	Downy mildew resistant (%)	Powdery mildew resistant (%)	Fruit (number)	
				Total	Acceptable
3A5-11	M ²	66	34	5	2
3A5-5	M	28	12	4	1
3A5-12	M	40	84	2	1
3A5-14	M	44	57	1	0
3A5-13	M	37	57	1	0
3A5-16	A	31	55	11	5
3A5-24	M	48	100	7	1
3A5-20	M	57	100	19	3
3A2-16	A	100	84	-	-
3A2-4	M	0	73	1	0
3A2-6	A	100	100	2	0

²M = monoecious; A = andromonoecious.

Table 2-7. Disease resistance and fruit acceptability in BC₁ of 'A' type F₃ to Hemed (H).

F ₃ x Hemed	Downy mildew resistance type ^w	Powdery mildew resistance ^x	Fruit acceptability ^y
3A5-28-3 x H	22	S	-
3A5-16-8 x H	11	S	-
3A5-28-19 x H	24	R	-
3A5-28-17 x H	seg ^z	seg	-
3A5-28-8 x H	22	S	-
3A5-16-4 x H	23	MR	+
3A5-16-3 x H	23	R	+
3A5-16-10 x H	23	R	+
3A5-16-6 x H	24	MR	+

^wReaction types: 11-14 = susceptible; 22-33 = moderately resistant, 34 & 44 = highly resistant.

^xS = susceptible, MR = moderately resistant, R = resistant

^y"-" = unacceptable, "+" = acceptable

^z"seg" = segregating.

Table 2-8. Disease resistance and fruit acceptability of hybrids from outcrosses of F₄, F₅, and F₆ families of 'A' types with selected cultivars.

Generation of 'A' type	Hybrid	Downy mildew reaction type ^x	Powdery mildew resistance ^y	Fruit acceptability ^z
F ₄	4A5-16-4 x Perlita 45	24	R	+
	4A5-11-1 x Hemed	11	S	-
	4A5-28-2 x Hemed	23	R	-
	4A5-16-4 x Cinco	24	R	+
	4A5-16-4 x Perlita	34	R	+
	4A5-16-4 x Georgia 47	23	R	+
F ₅	5A5-16-10 x Perlita	12	R	-
	5A5-16-10 x Cinco	23	R	+
	5A5-16-4 x Edisto 47	12	R	-
	5A5-16-4 x PMR 45	24	R	+
F ₆	6A5-16-4 x Persian	--	-	-
	6A5-28-2 x Top Mark	13	R	-
	6A5-16-4 x Edisto 47	12	R	-
	6A5-16-4 x Perlita 45	24	R	+
	6A5-16-4 x Top Mark	24	R	+
	6A5-16-4 x Charantais	13	R	+
	6A5-16-4 x PMR 45	13	R	+

^xReaction types: 11-14 = susceptible; 22-33 = moderately resistant; 34 & 44 = highly resistant.

^yS = susceptible, R = resistant.

^z"-" = unacceptable, "+" = acceptable.

Table 2-9. Plant characteristics after several generations of selfing in selected backcross and outcross families of 'A' and 'B' types.

Type	Cross	Generations of selfing	Sex- expression	Soluble solids (% sucrose)	Fruit characteristics ^x
'A'	F ₃ x Hemed	4	A	13	2, 3, 6
	F ₄ x Cinco	3	A	11	2, 3, 7
	F ₄ x Georgia 47	3	A	11.5	2, 3, 5
	F ₄ x Perlita	3	A	10	2, 3, 5
'B'	F ₃ x Hemed ^y	5	A	14	1, 4, 5
	F ₃ x Hemed x unknown ^z	5	A	15	1, 3, 5

^wA = andromonoecious.

^xNumerical code for fruit characteristics: 1 = smooth exterior, 2 = netted exterior, 3 = orange flesh, 4 = green flesh, 5 = round fruit shape, 6 = oblate, 7 = oval.

^yDesignated as line #31. Has RT 24 to downy mildew.

^zDesignated as line #29.

Table 2-10. Sex-expression, disease resistance and fruit acceptability for F₃ families of 'B' type.

Entry	Sex-expression	Downy mildew resistant (%)	Powdery mildew resistant (%)	Fruit (number)	
				Total	Acceptable
3B3-5	M-A ²	100	100	7	3
3B3-8	A	100	76	0	0
3B3-4	A	28	82	2	1
3B3-12	M	0	91	5	2
3B3-11	M	80	90	6	2
3B3-14	M	45	50	0	0
3B4-9	A	94	94	4	0
3B4-1	M	100	37	3	1
3B4-6	A-M	100	80	4	1
3B4-20	A	100	0	1	0
3B4-12	-	0	91	-	-
3B4-21	-	0	12	0	0
3B4-22	M	0	14	0	0
3B4-19	A	29	74	0	0

²M = monoecious; A = andromonoecious.

Table 2-11. Disease resistance and fruit acceptability in BC₁ of 'B' type F₃ to Hemed (H).

F ₃ x Hemed	Downy mildew reaction type ^w	Powdery mildew resistance ^x	Fruit acceptability ^y
3B3-5-3 x H	44	R	+
3B3-11-1 x H	23	seg ^z	-
3B3-7-7 x H	11	S	-
3B3-14-2 x H	11	S	-
3B3-14-3 x H	24	R	-
3B3-11-1 x H	24	R	-

^wReaction types: 11-14 = susceptible; 22-33 = moderately resistant; 34 and 44 = highly resistant.

^xS = susceptible, R = resistant.

^y"-" = unacceptable, "+" = acceptable.

^z"seg" = segregating.

Table 2-12. Disease resistance and fruit acceptability of hybrids from outcrosses of F₅, F₆, and F₇ families of 'B' types with selected cultivars.

Generation of 'B' type	Hybrid	Downy mildew reaction type ^x	Powdery mildew resistance ^y	Fruit acceptability ^z
F ₅	5B3-5-2 x Cinco	13	R	-
	5B3-5-2 x Hemed	22	S	-
	5B3-5-2 x Green Ice	12	S	+
	5B3-5-3 x Cinco	24	R	-
	5B3-5-3 x Hemed	24	R	+
	5B3-5-3 x Green Ice	34	R	+
	5B3-5-6 x Hemed	12	R	+
F ₆	6B3-5-2 x PMR 45	23	R	-
	6B3-5-2 x Georgia 47	23	R	-
	6B3-5-2 x Perlita F	13	R	+
	6B3-5-2 x Edisto 47	13	R	-
	6B3-5-3 x Perlita F	12	R	-
F ₇	7B3-5-2 x Perlita F	24	R	-
	7B3-5-2 x Green Ice	24	R	-
	7B3-5-2 x Charantais	13	R	-

^xReaction types: 11-14 = susceptible; 22-33 = moderately resistant; 34 & 44 = highly resistant.

^yS = susceptible, R = resistant.

^z"-" = unacceptable, "+" = acceptable.

Figure 2-3. F_1 hybrid of line #29 x Perlita.

E. Objective 3 -- To delimit the physiologic races of downy mildew of cucurbits.

Introduction

In 1974 Palti (21) summarized the host range studies that had been done with downy mildew of cucurbits in various countries. The lack of concurrency and uniformity of test hosts did not allow for any absolute delimitations to be drawn from the pronounced divergencies in host range reactions both within and between countries. Rather this, plus the work of Bains, et al. (1, 2, 3, 4) in India and Iwata (11, 12, 13, 14, 15, 16) in Japan, pointed to the need for a unified, concurrent, coordinated, international research effort to determine the true status and relationships of races of downy mildew on cucurbits. The work of Thomas (27) further strengthened this need when he reported that among selected muskmelon genotypes with reported resistance to downy mildew, the level of resistance depended upon the generic host range of the challenge isolate of the pathogen.

Through the collaboration of Dr. T. Inaba of the National Institute of Agro-Environmental Sciences, Ibaraki, Japan, and Dr. S. S. Bains, Punjab Agricultural University, Gurdaspur, India, the following studies were conducted.

Materials and Methods

Controlled inoculations with local isolates of P. cubensis were conducted in India, Israel, Japan, and the U. S. A. to determine host specificities using published techniques (7, 27). In the U. S. A., Israel, and Japan, inoculations were made to 29 cultivars representing 14 species within seven genera of the family Cucurbitaceae and were repeated at least once (Table 3-1). In India, inoculations were limited to cultivars representing 6 species within 4 genera. Two, two, four, and four isolates were used in inoculations in the U. S. A., Israel, Japan, and India, respectively. Isolates in the U. S. A.

were obtained from muskmelon, Cucumis melo, at Charleston, SC, designated "C", and from squash, Cucurbita pepo, at Weslaco, Texas, designated "T". Both of the isolates studied in Israel were obtained from cucumber, C. sativus, one in 1983 and the other in 1985. Of the four isolates studied in Japan, two were obtained from C. sativus, designated "C1" and "C2", and two were obtained from C. melo var. reticulatus, designated "M1" and "M2". The four isolates studied in India were designated L6, L7, V1 and M3, but information on the source host of each is not currently available to the authors. This fact plus the limited host range challenged in the experiments involving these Indian isolates prevent direct comparisons with studies in Israel, Japan, and the U. S. A., but sufficient detail is available to permit logical inferences to be made about the isolates tested in India.

Plants were observed daily following inoculations and were returned to high humidity conditions to stimulate sporulation whenever lesion development was favorable, usually 5-8 days after inoculation. If no evidence of infection was present by 10 days after inoculation, plants were placed under high humidity during their dark periods through 14 days to stimulate sporulation. Symptom development and sporulation were observed both macroscopically and microscopically at magnifications of up to 50X. Inoculated plants were evaluated for the presence and type of lesions and presence and degree of sporulation. Sporangia length and width and sporangiophore length were measured for morphological comparisons between isolates.

Results

The results of host specificity studies in Israel, Japan, and the U. S. A. are presented in Table 3-1. Cucumis sativus Sagami-hanjiro was highly compatible with all P. cubensis isolates tested. All cultivars of C. melo

var. conomon were highly compatible with all isolates except C1 and C2.

Cultivars Kuroto and Numame were highly compatible with isolate C2, but not C1.

All other cultivars of C. melo var. conomon were incompatible with both C1 and C2. Cucumis melo var. acidulus and C. melo var. reticulatus were highly compatible with all isolates except C1 and C2.

Only the C & T isolates of P. cubensis tested in the U. S. A. demonstrated a highly compatible reaction with any of the other Cucurbitaceae genera included in these studies. Both U. S. A. isolates were highly compatible with Citrullus lanatus Shinyamoto-2 and Lagenaria sp. Williams. Also, isolate C was highly compatible with Lagenaria vulgaris and isolate T was highly compatible with all Cucurbita spp. tested.

The isolates tested in India were highly compatible with C. melo var. reticulatus PMR 45 and C. lanatus Malali. Indian isolates V1 and M3 were also highly compatible with C. maxima and Luffa sp.

In some species resistance factors were found against the isolates tested in each country. In Japan C. sativus Aonaga was resistant to isolates C1, C2, M1, and M2 compared to the fully susceptible Sagami Hanjiro. Cucumis melo var. conomon Honen-ao was resistant to the isolates in Israel and the U. S. A. compared to full susceptibility in the other cultivars tested. C. melo line 18B was resistant to all isolates tested in each country.

Determinations of length and width of sporangia and length of sporangiophores indicated no significant differences in these morphological dimensions among isolates (Table 3-2).

An inbred selection of C. melo PI 124111, designated 18B, was also included in host specificity studies in each country. In artificial inoculations with all isolates included in these studies, line 18B exhibited the highly resistant reaction type 4 against P. cubensis.

Discussion

The results of the host range tests with the isolates studied in Israel, Japan, and the U. S. A. confirm the existence of distinct physiological forms of P. cubensis based on host specificity. Table 3-3 summarizes these host specificities from the data in Table 3-1, with the exception of Lagenaria spp. The absence of data on the reaction of Lagenaria spp. to isolates C1, C2, M1, and M2 prohibits the proper assignment of Lagenaria in this scheme. The data substantiate the existence of distinct physiological forms and indicates that they may be delimited based on genera and species specificities.

Since each of these forms of P. cubensis can be differentiated on the basis of host range at distinct taxonomic levels it is tempting to assign forma speciales designations to them. To do so would probably be, in Crute's words, "a mis-leading over-simplification" (9). This is especially true when considered in light of the loss of virulence to the genus Cucurbita of isolate T obtained from Cucurbita pepo after many generations of maintenance away from the source host as occurred in the present studies. Iwata (16) encountered a similar situation with an isolate from Lagenaria siceraria (vulgaris) which exhibited a decrease in virulence against the source host, but retained virulence against C. sativus. However, the lack of sufficient details from his work preclude any direct comparisons.

Thus, the forms of P. cubensis delimited in the present work are, based on available information, most correctly designated as pathotypes. Such a designation indicates a dynamic situation in the pathogen population in which the major component conforms to certain host range characteristics, but allows for the presence of other components in varying frequencies (9). The effects of selection for fitness on populations of P. cubensis and the influence of

this selection on stabilizing equilibria for virulence factors within geographical areas will be considered later in this discussion.

Figure 3-1 is a diagrammatic representation of the host specificities among the pathotypes of P. cubensis delimited in the data presented in Tables 3-1 and 3-3 with inclusion of the inferred relationships indicated by the more limited studies with the Indian isolates. As in Table 3-3, Lagenaria is not included due to limited data, but it must fall somewhere within the range of circles 4-6 from the center. Based on the diagram, which constitutes a representation of the data from the present studies, it is proposed that a pathogen population which carries specific virulence factors constitutes a specific pathotype that is determined by the frequencies of these factors in the pathogen population. For example, pathotype 5 that is highly compatible with Cucurbita spp. carries a high frequency of virulence factors not only against Cucurbita, but also against those taxonomic entities represented by all the circles that are encompassed by the Cucurbita circle. Likewise, pathotype 1, represented by the innermost circle representing C. sativus, carries a very high and probably concentrated frequency of virulence factors against this species, but a low frequency against those host entities represented by the outer circles. Indeed, it can logically be inferred that the frequency of virulence factors in pathotype 1 towards specific hosts decreases as the distance from the center increases so that the closer a host lies to the periphery the less frequent the presence of virulence factors in pathotype 1 against it. Reference to Table 3-1 does show, however, that pathotype 1, exemplified by isolate C1, did possess a low degree of virulence toward some Luffa genotypes represented by the outermost circle of the diagram. The lack of sporulation by isolate C1 in suspect lesions produced on the

Cucurbita spp. may have been due to a lack of proper environmental conditions combined with the low frequency of virulence factors.

A brief examination of the available literature demonstrated that most, though not all, of the host specificities reported for isolates of P. cubensis fit into the scheme represented by the pathotype diagram. In the U. S. A., isolates V and H of Hughes and Van Haltern (10) fit pathotypes 3 and 4, respectively; while the host specificities of the 1978 and 1979 isolates reported by Thomas (27) fit pathotypes 4 and 5, respectively. In Japan, some of the isolates studied by Iwata (11, 12, 14), e.g. cucumber 2 = pathotype 3, cushaw 2 = pathotype 5, and oriental pickling melon 1 and 2 = pathotype 3, fit the proposed pathotype limits, except for the lack of infectivity to Citrullus lanatus of these and all other isolates that he studied. The cucumber isolate of Kurosawa (17) fits the proposed pathotype 5 limits but his four other isolates do not. The lack of fit of some of the isolates, studied by Kurosawa and Iwata, especially the strong specificities toward the original host that they often encountered, may reflect prolonged selection for fitness within those pathogen populations on those original hosts or may be attributed to lack of environmental control in their inoculation procedures, but probably are a function of both. Most reports from India (1, 2, 4) indicate pathotypes with more extensive host ranges than included in the present proposed scheme usually including Luffa spp.

The designation of pathotypes based on host specificities at the genera and species levels leaves available the assignment of physiologic race designations within these pathotypes in situations where resistant genotypes are encountered. While resistant genotypes were identified in several instances in the present study it would be premature to begin assignment of race designations at this time. To facilitate this endeavor, however, a new

set of differentials is proposed that is designed to verify the pathotype designation of a particular isolate of P. cubensis while delimiting races that may exist within that particular pathotype. This proposed new set of differentials, Table 3-4, was developed by reducing to the minimum essential representation from the present reported study with the inclusion of resistant and susceptible genotypes where they have been identified in this and other studies.

Palti (21) stated that the divergencies in distribution of P. cubensis on its crop hosts in various countries could be attributed to physiologic races, resistance of some local cultivars, and the effects of local environment on infection. We agree with his premise, but feel that the "local environment" must be partitioned into two parts; namely, meteorological environment and specific host environment. Meteorological conditions determine if infection can occur. The fitness of the pathogen population to the specific hosts encountered determine if it will occur. Thus, selection pressure for fitness that is exerted by the host population is directly related to the relative frequencies of specific hosts in that population. This holds true both for races on different genotypes within a given species and for pathotypes on different species within a higher taxonomic group, such as the Cucurbitaceae.

There are two stages in the disease cycle of downy mildew on cucurbits that are affected by selection for fitness to specific hosts. These are the hosts encountered during the seasonal cultivation of these crops in the field and the over-wintering hosts. Both of these host situations in the disease cycle are primary environmental components that tend to stabilize selection for virulence genes in the pathogen population. A gene for virulence that is too high in the pathogen population will decrease in frequency and a gene that is too low in the pathogen population will increase in frequency (18). One

can assume that in any country where downy mildew infects cucurbit crops the range of meteorological conditions is suitable for infection of any cucurbit host crop. If this is a valid assumption, then the frequency of virulence genes in the pathogen population will determine the probability that infection will occur. The downy mildew pathotype situation in three countries can be examined to illustrate the validity of this hypothesis as long as one remembers that selection has occurred over time.

In Israel the over-wintering hosts for P. cubensis are Cucumis sativus and C. melo var. reticulatus under plastic and greenhouse culture. These over-wintering hosts exert strong selection for a high frequency of virulence genes against these two species, while simultaneously selecting for low frequencies of virulence genes against other cucurbit hosts. An over-wintering pathogen population with strong virulence genes against C. sativus and C. melo var. reticulatus would fit the host range delimitation which we have designated pathotype 3. Thus primary inoculum for cucurbits in the field from over-wintering hosts in Israel would be of pathotype 3. Cucurbit crops in commercial production fields in Israel consist of C. sativus, C. melo, Citrullus lanatus, and Cucurbita spp. with the Cucumis spp. occurring in the highest frequencies. While exposure to C. lanatus and Cucurbita would exert selection for virulence on pathotype 3, any significant increase in the frequency of these virulence genes would be negated during the over-wintering cycles. Cohen's work in Israel in 1969 (5) substantiated the presence of these virulences in the pathogen population. He was able to demonstrate pathogenicity to L. cylindrica, L. vulgaris, and M. charantia under controlled conditions even though these hosts were not infected under field conditions. In the present study, the isolates tested in Israel were avirulent against L. vulgaris, L. cylindrica, and M. charantia. The weak

virulence of the isolates in Israel against C. lanatus in the present study reflects the strong selection against virulence to this host which has been exerted by many over-wintering cycles on C. sativus and C. melo.

In the USA, downy mildew of cucurbits occurs mainly in production areas near the Atlantic seaboard and Gulf of Mexico (31). The over-wintering hosts of downy mildew for each of these areas are Cucurbita pepo and Citrullus lanatus in southern Florida (20) and various cucurbits, often Cucurbita spp., in southern Mexico (C. E. Thomas, unpublished), respectively. The host population in commercial fields during the growing season consists of high frequencies of C. sativus, C. melo, C. lanatus, and in a lower frequency, Cucurbita spp. When one considers the same scenario of selection for virulence as detailed above for Israel, then it is easy to see why pathotypes 4 and 5 are so often encountered in the USA, since stabilizing selection for virulence in the over-wintering pathogen population would maintain a high frequency of those virulence genes characteristic of these pathotypes.

Similarly, the over-wintering host in India, Luffa aegyptica (1), would exert the same selection for the postulated pathotype that is compatible with Luffa, in addition to the cucurbits to which pathotype 5 is specific. The high frequency of Luffa species in commercial production fields in India along with Cucurbita, Citrullus, and Cucumis spp. would further exert stabilizing selection for this pathotype.

The above scenarios are elaborations on Pimentel's theory of genetic feedback (22) by which a stable equilibrium among parasite populations is achieved. These elaborations merely take into account some of the available facts about downy mildew of cucurbits in various countries. In Pimentel's theory a lack of diversity in the host population, especially the

over-wintering host in the case of the cucurbit downy mildew pathosystem, forces a corresponding lack of diversity in the pathogen population.

The pathotype concept discussed above for this pathosystem is not presented as the entire, definitive picture of physiological specialization in P. cubensis, but as a framework for continued study. Since it is based on the results of the most detailed examinations of host specificities within P. cubensis isolates yet conducted, it should be a valid framework.

The production of reaction type 4 lesions on the inbred line of C. melo PI 124111 when challenged by inoculation with all of the pathotypes encountered in this study indicates that resistance from this source has high promise of being pathotype non-specific against P. cubensis. This may therefore prove to be a source of durable resistance against this pathogen for the development of commercial cantaloup cultivars. That PI 124111 is also a source of resistance against at least three races of the powdery mildew pathogen, S. fuliginea, further adds to its usefulness.

Table 3-1. Reaction of selected cultivars of representative cucurbit host species to Pseudoperonospora cubensis in controlled inoculations in Israel, Japan, and the USA.

Species	Cultivar	Reaction to downy mildew ^Y							
		Country:		Japan		Israel		USA	
		Isolate:	C1	C2	M1	M2	'83	'85	C T
<u>Cucumis sativus</u>	'Sagami-hanjiro'		+++	+++	+++	+++	+++	+++	+++
<u>C. melo</u> var. <u>conomon</u>	'Aonagao'		+	+	+++	+++	+++	+++	+++
	'Katsura'		+	+	+++	+++	+++	+++	+++
	'Kuroto'		+	+++	+++	+++	+++	+++	+++
	'Numame'		+	+++	+++	+++	+++	+++	+++
	'Tokyo'		+	+	+++	+++	+++	+	+++
	'Honen-ao'	nt ²	nt	nt	nt	nt	+	+	+
<u>Cucumis melo</u> var. <u>acidulus</u>	'Ginsen'		+	+	+++	+++	+++	+++	+++
	'Houkou-new melon'		+	+	+++	+++	+++	+++	+++
	'Kinpyo'		+	+	+++	+++	+++	+++	+++
	'Ogataki-melon'		+	+	+++	+++	+++	+++	+++
<u>Cucumis melo</u> var. <u>reticulatus</u>	'Ananas Yokneam'		+++	+++	+++	+++	+++	+++	+++
	'Earl's Favorite'		+	+	+++	+++	+++	+++	+++
	'Fukamidori'		+	+	+++	+++	+++	+++	+++
	'Green Pearl'		+	+	+++	+++	+++	+++	+++
	'Sunrise'		+	+	+++	+++	+++	+++	+++
<u>Citrullus lanatus</u>	'Shinyamoto-2'		+	+	+	+	+	-	+++

<u>Cucurbita maxima</u>	(Israel cultivar)	+	-	-	-	-	o	+	+++
<u>C. pepo</u>	'Soumen'	-	-	-	-	-	o	nt	+++
<u>C. moschata</u>	'Shirokikuza'	-	-	-	-	-	o	o	+++
	'Beirut'	-	-	-	-	-	-	o	+++
<u>Benincasa hispida</u>	'Naga-tougan'	+	+	+	+	+	-	+	+
<u>Luffa acutangula</u>	(Israel cultivar)	+	+	-	-	-	o	-	+
	(USA cultivar)	+	-	-	+	+	o	-	+
<u>L. cylindrica</u>	'Furo-hechima'	-	-	-	-	-	nt	-	+
<u>Mormordica charantia</u>	'Futo-reishi'	+	+	+	+	+	-	+	+
<u>Lagenaria siceraria</u>	'Oomaru-yuugao'	+	+	+	+	+	-	nt	nt
<u>Lagenaria sp.</u>	'Williams local cv.'	nt	nt	nt	nt	nt	nt	+++	+++
<u>Lagenaria vulgaris</u>	'local Israeli cv.'	nt	nt	nt	nt	nt	+	+	o

'o' = no evidence of lesions detected.

'-' = suspect lesions present, but no evidence of sporulation.

'+' = sporulation limited to a few sporangioophores in a few lesions, but sporangioophores not present in all lesions; sporulation in this class sometimes limited to one sporangioophore in one lesion on one leaf of one plant, but usually was more.

'++' = very sparse sporulation present, but in virtually all lesions.

'+++ = moderate-profuse sporulation present in virtually all lesions present, indicating a highly compatible host-parasite relationship.

'nt' = no test, poor seed germination.

Table 3-2. Comparison of morphological dimensions of sporangia and sporangiophores of isolates of Pseudoperonospora cubensis.^y

Isolate	Sporangia		Sporangiophore length (u)
	Length (u)	Width (u)	
C1	24.2 + 3.5 ^y	16.7 + 2.0	432 + 103
C2	24.9 + 2.9	17.3 + 2.1	409 + 74
M1	22.7 + 2.9	17.4 + 1.9	366 + 62
M2	25.8 + 2.8	18.8 + 2.2	383 + 55
C	25.7 + 2.5	17.9 + 1.5	381.8 + 67.9
T	25.8 + 3.4	17.4 + 1.4	363.5 + 75.3

^ySporangia and sporangiophores of isolates C1 and C2 were produced on leaves of Cucumis sativus and those of isolates M1, M2, C, and T were produced on C. melo var. reticulatus.

^zBased on measurement of 200 sporangia and sporangiophores for isolates C1, C2, M1, and M2 and 100 for isolates C and T.

Table 3-3. Summary of host specificities of Pseudoperonospora cubensis isolates studied in Israel, Japan, and the USA.

Host	Isolate (Country)				
	C1 (Japan)	C2 (Japan)	M1, M2 (Japan) 83, 85 (Israel)	C (USA)	T (USA)
<u>Cucumis sativus</u>	+ ^z	+	+	+	+
<u>C. melo</u> var. <u>conomon</u>	-	+	+	+	+
<u>C. melo</u> var. <u>reticulatus</u> and <u>C. melo</u> var. <u>acidulus</u>	-	-	+	+	+
<u>Citrullus lanatus</u>	-	-	-	+	+
<u>Cucurbita</u> spp.	-	-	-	-	+
PROPOSED PATHOTYPE DESIGNATION	1	2	3	4	5

^z'+' = highly compatible host-pathogen interaction.

'-' = incompatible host-pathogen interaction.

Table 3-4. Proposed new set of differential cultivars of selected Cucurbitaceae to delimit pathotypes of Pseudoperonospora cubensis.

Genus	Species	Cultivar
<u>Cucumis</u>	<u>sativus</u>	Sagami-hanjiro Aonagu
<u>Cucumis</u>	<u>melo</u>	PI 124112
<u>Cucumis</u>	<u>melo</u> var. <u>conomon</u>	Numame Honen-ao
<u>Cucumis</u>	<u>melo</u> var. <u>reticulatus</u>	Ananas Yokneam Sunrise F ₁
<u>Cucumis</u>	<u>melo</u> var. <u>acidulus</u>	Kinpyo
<u>Citrullus</u>	<u>lanatus</u>	Shin-yamato 2 Summerfield Malali
<u>Cucurbita</u>	<u>moschata</u>	Shiraga Kuzi
<u>Luffa</u>	<u>acutangula</u>	U. S. A. (Seed source)
<u>Benincasa</u>	<u>hispida</u>	Naga-tougan
<u>Lagenaria</u>	<u>siceraria</u>	Oomaru-yuugao
<u>Lagenaria</u>	sp.	Williams
<u>Momordica</u>	<u>charantia</u>	Futo-reishi

Figure 3-1. Diagram representing host specificities within *Pseudoperonospora cubensis*. Circles represent outer limit of host range of individual pathotypes.

E. Objective 4 -- To identify and stabilize sources of resistance to the races of downy mildew.

Most of the work under this objective has been published, accepted for publication, or is included in the M.S. thesis of Mr. Schmucl Cohen. Therefore, copies of these works are included here in an approximate chronological sequence.

PRELIMINARY OBSERVATIONS ON RESISTANCE OF *CUCUMIS MELO* TO
SPHAEROTHECA FULIGINEA AND *PSEUDOPERONOSPORA CUBENSIS*

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The reaction of various melon cultivars, P.I. (U.S.) entries, and F_1 hybrids to powdery mildew (PM) and downy mildew (DM), was examined under field conditions and in greenhouses and growth chambers, during the years 1978-1983.

The Israeli cvs. 'Ananas-Yokneam', 'Hemed' and 'En Dor' were highly susceptible to DM at all growth stages, in both the field and greenhouse; the first two were also highly susceptible to PM. As regards American cultivars, 'Iroquois' was susceptible to both pathogens, 'Mainstream' was susceptible to DM but segregated in resistance to PM; 'Perlita-45', 'PMR 5', 'PMR 6', 'Edisto 47' and 'Cinco' were resistant to PM, and all except 'Cinco' were susceptible to DM.

The P.I. entries 123517, 177334, 136224, 164323, 164723, 164796, 200819 and 164797 were susceptible to PM, while 182954, 182953 and 234607 were highly resistant. The P.I. entries 164765, 212895 and 321005 segregated in resistance to PM. The P.I. entries 124112, 165449, 164323 and 124111 exhibited considerable resistance to DM in the field and slight susceptibility in growth chambers.

F_1 hybrids between some of the latter resistant P.I. entries and the susceptible Israeli cvs. 'Ananas-Yokneam', 'En Dor' and 'Hemed' were resistant to both PM and DM in the greenhouse and growth chamber inoculations.

In January 1983 abundant cleistothecia of *Sphaerotheca fuliginea* were found on susceptible plants growing in the greenhouse.

Our results indicate that resistance to both PM and DM could be transferred to Israeli cultivars from P.I. entries.

(P)

17. Evaluating Downy Mildew Resistance in Cucumis melo L.

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This research was supported by Grant No. US-287-81 from BARD--The United States-Israel Binational Agricultural Research & Development Fund.

Downy mildew incited by Pseudoperonospora cubensis (Berk. & Curt.) Rostow. is an important disease on cantaloup (C. melo) in many production areas of both the U. S. A. and Israel. A major phase of our research has involved the evaluation of C. melo germplasm for resistance against this disease. As better sources of resistance have been identified, modifications have been made in our screening procedures to accommodate them. From 1977-82, the yellow vs. brown lesion reaction served as the basic criterion for evaluating young plants inoculated at the 2-leaf stage. This reaction was first described by Barnes and Epps (1) in cucumber, and was elaborated by Thomas in cantaloup (2). The following 1-9 scale has been used by Thomas and others to evaluate gradations of the yellow vs. brown lesion reaction observed:

- 1 = entire leaf necrotic
- 2 = coalesced yellow lesions, general sporulation
- 3 = yellow lesions, moderate to abundant sporulation
- 4 = brown lesions with yellow halo, moderate sporulation
- 5 = large brown lesions, light to moderate sporulation
- 6 = medium-sized brown lesions, light sporulation
- 7 = small brown lesions, trace to very light sporulation
- 8 = pin-prick brown lesions, no sporulation
- 9 = entire leaf healthy, no evidence of infection

The main problem with this rating system was that leaf 1 and leaf 2 did not always react the same. Except in those cases where they did react the same, leaf 1 always exhibited a more susceptible reaction than did leaf 2. Therefore, the one digit rating assigned represented the most severe reaction present to avoid overestimating resistance.

In field plots a 1-9 scale was also used, but this scale rated gradations in amount of observed infection and subsequent disease damage as expressed by numbers of lesions and leaf loss. Since it did not rate lesion (reaction) type, correlations between artificial inoculations in the 2-leaf stage and reactions of older plants in field plots were difficult. Partly because of this difficulty, Thomas (3) used percent leaf loss to more critically describe the reaction of selected plant introductions and cultivars in field plots. This technique was very effective, but labor intensive.

More recently, due to the recognition of a different reaction (lesion) type as an expression of resistance and incorporation of this resistance into our breeding programs, a new protocol has been devised. This reaction type (RT) is characterized by 1 mm, circular, water-soaked, yellow lesions with no apparent sporulation. This protocol, which we refer to as a double rating

technique, accommodates the newly recognized RT and better facilitates correlations between reactions of plants inoculated at the 2-leaf stage and older plants in the field.

Recognition of this resistant RT is difficult unless the following inoculation and post-inoculation procedures and conditions are followed. Plants are grown in the greenhouse (day:night temperature $20^{\circ}\text{C} + 2: 27^{\circ}\text{C} + 3$) to the 2-true leaf stage, one plant per pot. The adaxial leaf surfaces are inoculated at about 1800 hr with a 1.0×10^4 sporangial suspension with a hand sprayer. Inoculated plants are placed overnight in a high humidity tent and then transferred to the greenhouse bench until seven days after inoculation, when they are returned to the high humidity tent for 20 hr to induce fungal sporulation. Disease evaluations are made separately for leaf 1 and leaf 2 on each plant using the following index of RT's:

- 1 = 10-15 mm, chlorotic, irregular, heavily-sporulating lesions
- 2 = type '1' lesions, above, mixed with type '3' lesions, below
- 3 = 3-4 mm, irregular to circular, water-soaked, chlorotic, sparsely sporulating lesions
- 4 = 1 mm, circular, water-soaked, yellow lesions with no apparent sporulation

After this evaluation, plants are transplanted to the field (mid-April through mid-September) and inoculated with *P. cubensis* as described above when they reach the 10-leaf stage. Eight to 10 days after this field inoculation, separate evaluations are made for leaves 3-6 and leaves 7-10 using the reaction type index described above.

The above evaluation procedures result in a two digit number to describe the reaction of inoculated plants at either the 2-leaf or 10-leaf stage. The first digit (1-4) expresses the reaction of leaf 1 (or of leaves 3-6) and the second digit expresses that of leaf 2 (or of leaves 7-10) in the greenhouse (or in the field). Observed RT's range from 11, highly susceptible, to 44, highly resistant.

Using this protocol we have observed that on 2-leaf plants in the greenhouse, RT4 on leaf 1 was always associated with RT4 on leaf 2; whereas, RT4 on leaf 2 may have been associated with RT's 2 or 3 on leaf 1. Similarly in the field with 10-leaf plants, RT4 in lower leaves was always associated with RT4 in upper leaves; whereas RT4 in upper leaves may have been associated with RT's 2 or 3 in lower leaves.

F₂ populations of crosses made between a highly resistant breeding line (RT 44 in both greenhouse and field) and the cultivars 'Hemed', 'Ein-Dor' and 'Ananas-Yokneam' (RT's 11 and 12) segregated in greenhouse tests to RT's 11, 12, 13, 23, 24, 33, 34, and 44; with 3.2-12% of the populations showing RT 44. Most plants reacting with a RT 44 in the greenhouse (2-leaf) tests retained a RT 44 in the field until maturity, while none of the plants reacting with RT's 11-33 did so. Occasionally, plants reacting with RT 34 in the greenhouse exhibited a higher degree of resistance (RT 44) in the field.

The double rating technique described above facilitates the selection of highly resistant (RT's 34 and 44) plants both in the greenhouse and in the field. If RT4 is present in the germplasm and its selection is the objective of the evaluation, we recommend use of this technique to identify plants exhibiting RT 34 and 44. If RT4 is not present, we suggest use of the 1-9 rating scale to assess the yellow vs. brown lesion reaction.

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STABILIZING RESISTANCE IN CUCUMIS MELO AGAINST DOWNY AND POWDERY MILDEWS IN ISRAEL AND THE USA. Y. Cohen¹, H. Eyal¹, and C. E. Thomas². ¹Dept. Life Sciences, Bar-Ilan University, Ramat-Gan, Israel; ²USDA, ARS, Vegetable Laboratory, Charleston, SC 29407.

High levels of resistance against downy (Pseudoperonospora cubensis) and powdery (Sphaerotheca fuliginea) mildews were found in Cucumis melo (cantaloup) PI 124111. Downy mildew resistance expressed as small (1-2 mm dia), circular, yellow, water-soaked lesions with extremely limited sporulation was effective against two races of the pathogen in the U. S. A. and the race in Israel. Powdery mildew resistance expressed as absence of lesions on true leaves, stems, and petioles was effective against races 1, 2, and 3 in the U. S. A. and races 1 and 2 in Israel. Six generations of selection and selfing within PI 124111 were required to stabilize resistance against both diseases. No linkage of the two resistances was observed since plants with resistance to either or to both diseases could be selected. The stabilized inbred of this PI is currently used in cooperative breeding programs. Research supported by BARD.

14. Inheritance of Resistance to Downy Mildew in
Cucumis melo PI 124111

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This research was supported by Grant No. US 287-81 from BARD--The United States-Israel Binational Agricultural Research & Development Fund.

Downy mildew of cucurbits incited by Pseudoperonospora cubensis (Berk. & Curt.) Rost. is a devastating foliar disease world-wide (3). Major economic hosts include Cucumis sativus L. (cucumber) and Cucumis melo L. (muskmelon), although Cucurbita sp. (squash and pumpkin), Citrullus lanatus (watermelon) and others are also affected (3, 4). In 1944, Ivanoff (2) reported that four cantaloup varieties of West Indies origin were resistant to downy mildew under south Texas conditions. In an incomplete study, he concluded that resistance was partially dominant when crossed to susceptible cultivars. Thomas (4) found that among C. melo PI's and cultivars, PI 124111 (PI) expressed the highest resistance to downy mildew under field conditions in south Texas. This paper reports the reaction to downy mildew of this PI, its F₁, F₂, and BC₁ reciprocal crosses to the susceptible commercial cultivars 'Hemed' (H) and 'Ananas-Yokneam' (AY) under growth chamber-greenhouse and field conditions.

Methods. A high degree of resistance to both downy and powdery mildews was stabilized in the PI by five generations of selection and inbreeding. This inbred of the PI was used as the resistant parent. The commercial cultivars H and AY were used as susceptible parents.

A local race of P. cubensis, collected from cucumber cv. 'Bet-Alfa' in 1979, was used for all inoculations. Inoculations of 2-leaf stage plants were conducted in chambers by spraying the adaxial leaf surfaces with a suspension of 2000 sporangia/ml. After inoculation plants were kept in a dew chamber at 17C in the dark for 30 hr and were then placed in the greenhouse (22-27C) for 7-8 days. Inoculations of 10-leaf stage plants in the field were done in a similar manner at about 2000-2100 hr, when relative humidity was 85% and temperature 22C.

Resistance in 2-leaf stage plants was assessed according to reaction type (1) and degree of sporulation at 7-8 days after inoculation. In the field, percentage leaf area mildewed was determined at about the 20-leaf stage. Fungal sporulation was determined from potted infected plants after a 20-hr incubation period in a moist atmosphere at 18C $\pm$ 1 in the dark. Leaves were removed to a fixative solution and the number of sporangia counted with a cytometer.

Results. Reaction type and fungal sporulation in AY, the PI, and their F₁ reciprocal crosses are presented in Table 1. While AY supported luxuriant sporulation of the pathogen, these were limited on the PI. In F₁ plants, fungal sporulation was markedly inhibited, especially in progeny with the PI as the female parent. Intermediate resistance was also observed in F₁ plants of the crosses between H and the PI (Table 2). Resistant reaction type in the PI was better expressed in leaf 2, but the maternal effect of the PI on reducing

sporulation was expressed only in leaf 1. In the field, F_1 plants exhibited about a 50% reduction in percent leaf area infected compared to H, while the PI showed some "pinpoint" (≤ 1 mm) yellow lesions which did not support sporulation. F_2 and some BC_1 populations were examined for reaction type only (Table 3). With either AY or H as susceptible parents, ratios of 6:9:1 susceptible, moderately resistant, and resistant were observed in some F_2 populations. BC_1 resulted in a 3:1 ratio of moderately resistant to resistant plants in the populations inoculated.

Table 1. Sporulation of Pseudoperonospora cubensis on Cucumis melo PI 124111 (PI), 'Ananas-Yokneam' (AY), and their F_1 and reciprocal crosses.^a

Feature	AY	AY x PI	PI x AY	PI
Sporangia per cotyledon, $\times 10^3$	141.6 $\pm$ 38.6	67.2 $\pm$ 47.0	6.0 $\pm$ 7.1	0.5 $\pm$ 0.8
Sporangia per cm^2 leaf 2, $\times 10^3$	56.4 $\pm$ 22.6	13.7 $\pm$ 7.1	3.8 $\pm$ 3.3	0

^aCotyledon tests conducted at 10 days after planting and leaf-2 tests on 3-week-old plants, both at 20C. Ten plants/treatment. In crosses, first parent (on the left) served as the female parent.

Table 2. Sporulation of Pseudoperonospora cubensis and reaction type to downy mildew in Cucumis melo PI 124111 (PI), 'Hemed' (H), and their reciprocal crosses.

Feature	H	H x PI	PI x H	PI
Sporangia per cm^2 , $\times 10^3$				
Leaf 1	78.6 $\pm$ 33.4	54.3 $\pm$ 22.3	20.3 $\pm$ 8.9	5.4 $\pm$ 5.9
Leaf 2	70.6 $\pm$ 32.0	5.7 $\pm$ 5.7	7.8 $\pm$ 5.6	0.3 $\pm$ 0.6
Reaction type ^a				
Leaf 1	1.0 $\pm$ 0	1.0 $\pm$ 0	1.0 $\pm$ 0	1.9 $\pm$ 0.4
Leaf 2	1.0 $\pm$ 0	1.4 $\pm$ 0.7	2.9 $\pm$ 0.5	4.0 $\pm$ 0
% leaf area infected in the field	66.0 $\pm$ 18.3	31.4 $\pm$ 11.1	33.0 $\pm$ 12.7	0 ^b

^a1 = highly susceptible; 4 = highly resistant (see citation 1 for details); 24-51 plants/treatment.

^bPinpoint yellow lesions on lower leaves.

Table 3. Segregation of the reaction of F₂ and BC₁ progenies from reciprocal crosses of PI 124111 (PI) with 'Ananas-Yokneam' (AY) and 'Hemed' (H) to downy mildew (Pseudoperonospora cubensis) at the two-leaf stage.^a

Generation	Pedigree	Observed			Expected ratio			Chi-square	df	P
		S	MR	R	S	MR	R			
F ₂	(PIxAY) x (PIxAY)	31	56	8	6	9	1	1.4398	2	.3-.5
	(AYxPI) x (AYxPI)	28	90	7	6	9	1	13.1973	2	.001-.01
	(HxPI) x (HxPI)	67	91	10	6	9	1	0.4074	2	.8-.9
	(PIxH) x (PIxH)	46	93	18	6	9	1	9.8960	2	.001-.01
	Combined	172	330	43	6	9	1	9.2654	2	.001-.01
	Homogeneity							15.6751	6	.01-.02
BC ₁	PI x (PIxAY)	50	16		3	1		0.0202	1	.8-.9
	PI x (AYxPI)	44	22		3	1		2.4444	1	.1-.2
	(AYxPI) x PI	52	17		3	1		0.0048	1	.9-.95
	Combined	146	55		3	1		0.5987	1	.3-.5
	Homogeneity							1.8707	2	.3-.5

^aReaction types 11, 12, 13 grouped as susceptible - S; types 22, 23, 24, 33 grouped as moderately resistant - MR; types 34, 44 grouped as resistant - R; according to citation 1.

Discussion. PI 124111 has been used in the past in cantaloup breeding programs, especially as a source of resistance to powdery mildew (Bohn, personal communication and Thomas, unpublished). The high level of resistance in this PI against downy mildew, expressed as reaction type 4, has not been utilized. The evidence presented here indicates that two incompletely dominant genes condition the highly resistant reaction of this PI to the Israeli race of P. cubensis since: a) F₁ plants showed intermediate levels of resistance; b) some F₂ populations segregated in a ratio of 6:9:1 (susceptible:moderately resistant:resistant); and c) BC₁ populations segregated in a ratio of 3:1 (moderately resistant:resistant). Differences in resistance levels of the reciprocal crosses in F₁ plants as expressed by pathogen sporulation, point to the possible involvement of cytoplasmic factors. These differences were not observed in the other parameters used to measure resistance in these populations. Additional studies are needed to verify the existence of such factors. At this time, we cannot fully explain the deviations from the expected ratio in some F₂ populations.

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INHERITANCE OF REACTION TYPE 4 AGAINST DOWNY MILDEW IN CUCUMIS
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Reaction type (RT) 4 indicates a high level of resistance against downy mildew incited by Pseudoperonospora cubensis in Cucumis melo germplasm. This RT was stabilized in an inbred line of C. melo PI 124111 which was used as the resistant parent in crosses with the susceptible cultivars 'Hemed' and 'Ananas-Yokneam'. Artificial inoculations were used to evaluate the parental, F₁, F₂, and BC₁ generations for reaction type against the pathogen. F₁ plants had intermediate levels of resistance. F₂ populations segregated in a ratio of 6:9:1 (RT's 1:2 and 3:4). BC₁ to the resistant parent segregated in a ratio of 3:1 (RT's 2 and 3:4). These data indicate that two incompletely dominant genes condition inheritance of RT 4 from the resistant parent. Some data and observations also indicate possible involvement of cytoplasmic factors. Research supported by BARD.

RESISTANT REACTION OF MUSKMELON LINE MR-1 AGAINST DOWNY MILDEW.
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Charleston, SC 29407.

Muskmelon (Cucumis melo L.) line MR-1 is an inbred derived from P.I. 124111. It has a unique resistant reaction against downy mildew incited by Pseudoperonospora cubensis (Berk. & Curt.) Rost. Lesions on leaves of MR-1 are small (1-2 mm), circular, chlorotic, and water-soaked; whereas, lesions on leaves of susceptible cultivars are large (10-15 mm), irregular, and yellow. Previously, the recognition of downy mildew resistance in C. melo germplasm has been based on the presence of brown rather than yellow lesions. Extremely limited sporulation is present on MR-1 only when environmental conditions are optimal. Sporulation per unit of leaf area on MR-1 is <1% of that on susceptible commercial cultivars. Lesions on MR-1 do not expand and result in leaf collapse as they do on susceptible cultivars.

Research supported by BARD.

UNITED STATES DEPARTMENT OF AGRICULTURE
 AGRICULTURAL RESEARCH SERVICE
 WASHINGTON, DC 20250

NOTICE OF RELEASE OF DOWNY AND POWDERY MILDEW RESISTANT
 MUSKMELON (Cucumis melo L.) BREEDING LINE MR-1¹

The United States Department of Agriculture, Agricultural Research Service, announces the release of MR-1, downy and powdery mildew resistant muskmelon breeding line. MR-1 is unique in that it is highly resistant to two prevalent races of downy mildew incited by Pseudoperonospora cubensis (Berk. & Curt.) Rostow. and races 1, 2, and 3 of powdery mildew incited by Sphaerotheca fuliginea (Schlecht. ex Fr.) Poll. MR-1 was developed at the U. S. Vegetable Laboratory, Charleston, South Carolina.

MR-1 was derived from 90319, an inbred line of C. melo P. I. 124111 that had been selected for powdery mildew resistance at the U. S. Horticultural Field Station in La Jolla, California from 1938-1948. Researchers at that station had also noted evidence of downy mildew resistance in P. I. 124111 when it was introduced in 1937; they selected for this resistance for three generations in the field, but this work was discontinued in 1939. In 1977 and 1978, a high level of resistance in 90319 against two physiologic races of P. cubensis was recognized and a program was begun to stabilize this resistance while maintaining the high level of powdery mildew resistance. In controlled inoculations for each generation of selection, plants were first evaluated for powdery mildew resistance at the cotyledon through first leaf stages and resistant plants were subsequently evaluated at the two leaf stage for downy mildew resistance. Plants which survived both of these inoculations were then alternately sibbed and selfed for six generations. Races of both pathogens were alternated in each selection cycle to avoid selection for race specific resistance. MR-1 is a bulked lot of seed from resistant F₆ plants grown in an isolation plot in 1984.

An evaluation protocol which favors the recognition of the resistant reaction of MR-1 to downy mildew was developed and has been published (Cucurbit Genetics, Cooperative Newsletter 7:38-40, 1984). This reaction has been designated RT (reaction type) 4 and represents the highest level of resistance discovered in C. melo against downy mildew.

This high level of resistance to two races of P. cubensis, coupled with high resistance to three races of S. fuliginea, make MR-1 a unique source of resistance against these important foliar pathogens of muskmelon.

Breeder seed is available on a pro-rata basis to both public and private breeders who request it prior to April 30, 1985. Requests should be addressed to Dr. Claude E. Thomas, Research Plant Pathologist, USDA, ARS, U. S. Vegetable Laboratory, 2875 Savannah Highway, Charleston, SC 29407.

T. B. Kenney

Administrator
 Agricultural Research Service

FEB 5 1985

Date

¹This research was supported by Grant No. US-287-81 from BARD--The United States-Israel Binational Agricultural Research & Development Fund.

Downy and Powdery Mildew Resistant Muskmelon Breeding Line MR-1

Claude E. Thomas¹

U. S. Department of Agriculture, Agricultural Research Service,

U. S. Vegetable Laboratory, Charleston, SC 29407

Additional index words. Cucumis melo, disease resistance, Pseudoperonospora cubensis, Sphaerotheca fuliginea, vegetable breeding

Muskmelon (Cucumis melo L.) breeding line mildew resistant (MR) 1 was developed by the U. S. Department of Agriculture to provide breeders and seedsmen with a source of high levels of resistance to both downy, incited by Pseudoperonospora cubensis (Berk. and Curt.) Rostow., and powdery, incited by Sphaerotheca fuliginea (Schlecht. ex Fr.) Poll., mildews. It is resistant to two undesignated races of downy mildew and to races 1, 2, and 3 of powdery mildew.

Received for publication 17 June 1985. This research was supported by Grant No. US-287-81 from BARD--The United States-Israel Binational Agricultural Research and Development Fund. The author gratefully acknowledges G. W. Bohn, USDA, ARS (ret.) of Del Mar, CA, who located and provided research notes which elucidated unpublished early work with this germplasm. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be marked advertisement solely to indicate this fact.

¹Research Plant Pathologist.

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1 History and Origin

2 MR-1 was derived from 90319, an inbred line of C. melo P. I. 124111 that
3 had been selected for powdery mildew resistance at the U. S. Horticultural Field
4 Station in La Jolla, California from 1938-1948. I. C. Jagger of that station
5 had noted evidence of downy mildew resistance in PI 124111 when it was
6 introduced from India in 1937. He selected for this resistance for 3
7 generations in the field, but this work was discontinued in 1939 due to his
8 death. In 1977 and 1978, a high level of resistance against two physiologic
9 races of P. cubensis was again recognized in 90319, the inbred line of P. I.
10 124111 (5). A program was begun to stabilize this resistance while maintaining
11 the high level of powdery mildew resistance in this line.

12 Populations were first evaluated for powdery mildew resistance from the
13 cotyledon through the first leaf stages. During this period plants were
14 inoculated by blowing powdery mildew conidia from infected donor leaves of
15 'Early Prolific Straightneck' (Cucurbita pepo L.) into the air over the
16 greenhouse bench and allowing these conidia to settle on the plants in still air.
17 Beginning at the unfolding of the cotyledons, plants were inoculated 3 times in
18 this manner at 3-4 day intervals. When plants reached the 2-leaf stage, usually
19 7-8 days after the third powdery mildew inoculation, those which showed no
20 macroscopic evidence of powdery mildew infection were subsequently evaluated for
21 downy mildew resistance using the previously described inoculation procedure for
22 2-leaf stage plants (1). Plants were inoculated and treated as prescribed by
23 this protocol, except that only the reaction of leaf 1 was evaluated. The
24 objective of this work was to select plants which exhibited the highly resistant
25 reaction type (RT) 4 (1, 6). Since RT 4 against downy mildew on leaf 1 of
26 2-leaf stage plants of C. melo is always associated with RT 4 on leaf 2 and
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subsequent leaves, it was, therefore, only necessary to evaluate leaf 1 to accomplish the objective.

Powdery mildew isolates representing races 1, 2, and 3 (2, 4) were alternated at each generation of testing so as to avoid selection of race specific resistance. Likewise, U. S. A. isolates representing two physiologic races of downy mildew as distinguished by host range within the cucurbitaceae (3) were also alternated for the same reason at each generation of testing.

Plants which survived both the powdery and downy mildew selection procedures were sib-pollinated in the greenhouse to produce the F_1 , which was also evaluated and selected, first for powdery mildew resistance and then for downy mildew resistance as described above. The survivors were self-pollinated to produce the F_2 . This cycle was repeated twice so that the F_3 and F_5 generations were produced by sib-crossing survivors of the selection procedures, and the F_4 and F_6 generations were produced by selfing survivors. MR-1 represents a bulked lot of seed produced by resistant F_6 plants which were grown in an isolation plot in the field at Charleston, SC in 1984.

Description

Vines of MR-1 are long and spreading so that the dense foliar cover produced is similar to that of muskmelon 'Edisto 47'. The fruit (Fig. 1) are essentially the same as first described in 1937. They are oblate with an average width of 11.7 cm. and an average length of 9.2 cm. Average fruit weight is 0.75 kg. The fruit exterior is smooth and slightly ribbed with a hard, dark green rind that turns yellow at maturity. The vein tracts are prominent and remain dark green at maturity. Most fruit slip from the stem when mature and crack open to reveal a fairly firm, spherical mass composed of seed and

Fig. 1

1 placental material. Flesh is off-white to creamy white in color with a mealy
2 texture and insipid taste. Soluble solids as percent sucrose average 6.1.

3

4 Disease Resistance

5 Resistance to powdery mildew in line MR-1 is characterized by the absence
6 of macroscopic lesions on leaves, stems, or petioles. A few lesions may
7 occasionally be found on cotyledons, but these do not indicate susceptibility of
8 other plant parts. Resistance to downy mildew in this line is characterized by
9 the production of RT 4 type lesions in response to infection by P. cubensis.
10 These roughly circular, 1-2 mm, water-soaked, yellow lesions, with no or
11 extremely limited sporulation, do not expand and coalesce so that leaf collapse
12 does not occur even when large numbers of infection sites are present (6).

13

14 Availability

15 Limited quantities of seed are available to plant breeders and seed
16 producers upon request, addressed to the author at: USDA, Agricultural Research
17 Service, U. S. Vegetable Laboratory, 2875 Savannah Hwy., Charleston, SC 29407.

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Fig. 1. Fruit of muskmelon line 'MR-1'. (Ruler = 30.48 cm).