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BARD

FINAL REPORT

PROJECT NO. US - 1494 - 88

**ELUCIDATION OF THE GENETIC BASIS OF
MULTIPLE DISEASE RESISTANCE IN
CUCUMIS MELO PI 124112 FOR PRACTICAL
APPLICATION IN THE DEVELOPMENT OF HYBRIDS**

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1993

The Binational Agricultural Research
and Development Fund (BARD)
P. O. Box 6
Bet Dagan, Israel

April 23, 1993

BARD Project No. US-1494-88R

Title: Elucidation of the Genetic Basis of Multiple Disease Resistance
in *Cucumis melo* PI 124112 for Practical Application in the
Development of Hybrids

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Project's starting date: October 1, 1989

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

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Abstract

Inheritance studies showed that *Cucumis melo* PI 124112 shares one common partially dominant gene (*Pc1* or *Pc2*) with line PI 124111F and another partially dominant gene designated *Pc4* that condition downy mildew resistance. Powdery mildew resistance in PI 124112 was conferred by the dominant gene *Pm5* and a partially dominant gene *Pm4* against races 1 and 2, respectively. PI 124112 was susceptible to races 0, 1, and 2 of Fusarium wilt (FW) and to Alternaria leaf blight (ALB), but downy and powdery mildew resistant line MR-1 derived from PI 124111 was resistant to FW and ALB. Resistance to downy mildew in PI 124112 and line PI 124111F is effective at temperatures of 17-30°C, but not at 12-15°C. Line PI 124111F, but not PI 124112, contains a constitutive protein of 45 kD the synthesis of which declines at 12°C. No correlations were found between downy mildew resistance and pre-infection peroxidase levels in PI 124112, line PI 124111F, or line MR-1. Six putative RAPDs were detected that are associated with resistance against race 1 of FW in melon. In Israel, PI 124112 was crossed with Ananas Yokneam (AY) and backcrossed to AY in the F₃. F₅ families showed a high degree of resistance to both downy and powdery mildews along with the fruit quality of AY. In the U.S., PI 124112 was abandoned as a candidate source of multiple disease resistance in melons, because of its susceptibility to FW and ALB.

Objectives of Original Research Proposal

A) To provide quantitative and qualitative data on the resistances of PI 124112 to downy mildew, powdery mildew, and Fusarium wilt, and determine the effectiveness of these resistances under environmental stress.

B) To determine if the same or different genes condition resistances to mildews and Fusarium wilt in PI 124112 compared to PI 124111.

C) To incorporate the genes for resistances to mildews and Fusarium wilt from PI 124112 into high quality muskmelon germplasm and into existing horticulturally acceptable breeding lines developed from PI 124111.

As noted below, the objectives were modified as required by the results of experimentation and by other events.

Deviation from the original objectives by the researchers in the U.S. was necessitated by two events. The first of these was that initial experimentation indicated PI 124112 was inferior to breeding line MR-1 (derived from PI 124111) as a source of multiple disease resistance in melon. Even though PI 124112 was equal to MR-1 in resistance to downy and powdery mildews, it was found to be susceptible to both Fusarium wilt and Alternaria leaf blight to which MR-1 is resistant. The inferiority of PI 124112 as a source of multiple disease resistance in melon resulted in its abandonment as a candidate resistant parent for introgression into U.S. lines derived from PI 124111 and concentration of U.S. efforts on

elucidation of biochemical markers for resistance in line MR-1.

The second event was the publication in June 1992 by one of the Cooperating Investigators in Israel of two papers that addressed the mode of inheritance of downy and powdery mildew resistances in PI 124112 and determinations of the commonality between these resistance genes and those in PI 124111. Based on discussions that were held in December 1989 between the Principal Investigator (C. E. Thomas) and two of the Cooperating Investigators (J. D. McCreight and Y. Cohen), it was understood that the Principal Investigator and the Cooperating Investigator in the U.S. were to conduct the phases of the work represented by these papers. The conduct and publication of this work by one of the Cooperating Investigators in Israel obviously negated a considerable research effort that was nearing completion by the U.S. investigators.

Introduction

Melons (*Cucumis melo*) are an important fresh market crop with high monetary returns to growers and high nutritional value to consumers in both the U.S. and Israel. Four of the important diseases which attack this crop are downy mildew (*Pseudoperonospora cubensis*), powdery mildew (*Sphaerotheca fuliginea*), Fusarium wilt (*Fusarium oxysporum* f. sp. *melonis*), and Alternaria leaf blight (*Alternaria cucumerina*). The safest and most effective method to control these diseases is through the incorporation of high levels of genetic resistance into acceptable cultivars.

C. melo PI 124111 represents a powerful source of disease resistance against these four important diseases of melon. The genes in this PI that condition resistances against these diseases have been effectively studied and utilized by the investigators. However, as resistance genes from this source become widely deployed they might be overcome because of the plastic virulence spectra of *P. cubensis* and *S. fuliginea*.

C. melo PI 124112 has been shown to be another source of high levels of resistance against downy and powdery mildews. Preliminary observations by the investigators indicated that the genes conditioning resistance to both mildews in PI 124112 may be different from those in PI 124111, but it was not known if this PI was resistant to Fusarium wilt and Alternaria leaf blight.

Objective A) To provide quantitative and qualitative data on the resistances of PI 124112 to downy mildew, powdery mildew, and Fusarium wilt, and determine the effectiveness of these resistances under environmental stress.

Work toward Objective A in the U.S. is presented in the following.

Previous work by the investigators in both countries had demonstrated that the levels of downy and powdery mildew resistance identified in PI 124112 were as high as those in PI 124111. Because PI 124111 and breeding line MR-1 derived from this PI also serve as a source of high levels of resistance to races 0, 1, and 2 of Fusarium wilt (3) and Alternaria leaf blight (2), the U.S. investigators conducted the tests described below to evaluate the level of resistance in PI 124112 to these diseases to further assess its value as a source of multiple disease resistance in melons.

Materials and Methods

Fusarium wilt

PI 124112, breeding line MR-1, four *Fusarium oxysporum* f. sp. *melonis* (FOM) race differential melon genotypes, and the susceptible cultivar PMR-45 were tested against isolates of races 0, 1, and 2 of the pathogen.

Forty-eight plants of each genotype were tested against each race of the pathogen. Seed of each genotype, treated with a 5% calcium hypochlorite solution for 5 min. were planted in autoclaved vermiculite. Ten days later when plants were in the cotyledon to first-true-leaf stage

they were removed from the vermiculite. The roots of each plant were washed in tap water, pruned to about 2.5 cm, and dipped for 1 min in an inoculum suspension of either of the three races. Inoculum consisted of a mixture of macroconidia and microconidia (2.5×10^5 per milliliter) prepared from potato dextrose agar cultures grown for 10 days at 20-24 C under continuous illumination.

Inoculated seedlings were transplanted into cell-type plastic growing trays (1 plant per cell) filled with a sterilized potting mix. Following inoculation, plants were examined periodically for the next 28 days and the number of yellowed, necrotic, wilted, or dead seedlings was recorded. Plants that were free of symptoms were considered resistant.

This inoculation study with FOM was repeated once.

Alternaria leaf blight

PI 124112, resistant line MR-1, and the susceptible cultivar Perlita were tested for resistance against *Alternaria cucumerina* (AC) through artificial inoculations. A virulent isolate of AC was maintained in petri dish culture on V-8 juice agar under fluorescent illumination in a 12 hr light-12 hr dark regime at a laboratory temperature of 24 ± 2 C. Inocula for the studies were prepared as described previously (2).

Seeds were planted in Jiffy-7 peat pellets in the greenhouse to produce 48 plants of each genotype. Plants were handled carefully in all experimental manipulations because mechanical injury to the leaves can increase the severity of the reaction of known resistant lines to AC. Chandler and Thomas (1) have found that the presence of leafminer puncture wounds significantly increases the incidence of AC

lesions on melon leaves. To decrease the chance that leafminer or other insect wounds might confound the results of the tests, the glasshouse was fumigated weekly with either nicotine sulfate or acephate.

At the two-expanded-leaf stage, plants were inoculated with a suspension of 5×10^3 conidia of AC per milliliter. The adaxial surfaces of leaves 1 and 2 were sprayed to incipient runoff with a Paasche Type-H airbrush at 275 kPA. Inoculated plants were placed in the dark in a dew chamber at 20 C for 16 hr. When plants were removed from the dew chamber, they were placed in the greenhouse. Plants were subsequently placed in the dew chamber for 16 hr each night and on the greenhouse bench for 8 hr of light each day.

Test plants were evaluated at ten days postinoculation and classified into either of two classes, resistant or susceptible. Plants were classified as resistant if the lesions on leaves one and two remained small (≤ 1.0 mm) and restricted and as susceptible if the lesions on leaves one and two expanded (≥ 3.0 mm).

This inoculation study with AC was repeated once.

Results

Fusarium wilt

In both tests, plants within a genotype reacted uniformly to inoculation with isolates of the individual races of FOM. All plants of PI 124112 were susceptible and all plants of breeding line MR-1 were resistant when inoculated with either race 0, 1, or 2 of FOM. Differential genotypes Perlita FR and Doublon were resistant to races 0

and 2 and CM 17-187 was resistant to races 0 and 1. Charentais T and PMR-45 were susceptible to all three races.

Alternaria Leaf Blight

In both tests, plants within a genotype reacted uniformly to inoculation with AC. All plants of PI 124112 and the susceptible check Perlita were susceptible and all plants of MR-1 were resistant.

Conclusions

The susceptibility of PI 124112 to both FOM and AC decreases its value as a source of multiple disease resistance in melon. While the introgression of resistance genes from this PI against downy and powdery mildews might enhance the levels and durability of resistance against these two diseases in lines with resistance derived from MR-1 (PI 124111), this introgression would also serve to reintroduce susceptibility to FW and AC into these lines.

Literature Cited

1. Chandler, L. D. and Thomas, C. E. 1991. Effect of leafminer feeding activity on the incidence of Alternaria leaf blight on muskmelon. Plant Disease 75:938-940.
2. Thomas, C. E., McCreight, J. D., and Jourdain, E. L. 1990. Inheritance of resistance to Alternaria cucumerina in Cucumis melo. Plant Disease 74:868-870.
3. Zink, F. W. and Thomas, C. E. 1990. Genetics of resistance to Fusarium oxysporum f. sp. melonis races 0, 1, and 2 in muskmelon line MR-1. Phytopathology 80:1230-1232.

Work toward objective A by the Cooperating Investigator in Israel is presented in the two publications listed below, which follow:

Balass, M. Cohen, Y. and Bar-Joseph, M. 1992. A constitutive 45kD soluble protein with resistance to downy mildew in muskmelon (*Cucumis melo* L.) line PI 124111F. *Phytoparasitica* 20:3.

Cohen, Y. 1992. Genes and mechanisms of resistance against fungal pathogens in breeding lines of muskmelon. Proc. Fifth Eucarpia Cucurbitaceae Sym.,, Skierniewice, Poland. 139-141.

Objective C) To incorporate the genes for resistances to mildews and Fusarium wilt from PI 124112 into high quality muskmelon germplasm and into existing horticulturally acceptable breeding lines developed from PI 124111.

As mentioned previously, when it was determined that PI 124112 lacked resistance to Fusarium wilt and Alternaria leaf blight, the U.S. investigators abandoned this PI as a source of multiple disease resistance in melon.

Information on this objective that was provided by the Cooperating Investigator in Israel states that:

"PI 124112 was crossed with AY (Ananas Yokneam) and backcrossed to AY in F₃. F₅ families show a high degree of resistance to both downy and powdery mildew with fruit quality of AY. This program is aimed to introduce resistance to these diseases to AY which is widely used in the Mediterranean countries."

Unstated Objectives - U.S.

Investigation of disease resistance markers for
Pseudoperonospora cubensis and Fusarium oxysporum

f.sp.melonis in Cucumis melo¹

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The objective of this research was to identify biochemical and genetic markers for resistance to Fusarium oxysporum f. sp. melonis (Fusarium wilt) and Pseudoperonospora cubensis (downy mildew) in Cucumis melo (melon). The biochemical focus was on preinfection peroxidase activity and endogenous salicylic acid levels. The search for genetic markers utilized PCR based bulked segregant analysis. This was performed on susceptible and resistant F₂ populations of a susceptible x resistant cross (AY x MR-1). It is anticipated that these markers can provide for the development of a reliable nondestructive assay to identify resistance to Fusarium and downy mildew in melon. This assay will greatly enhance the breeding process for new resistant melon lines.

¹Information contained in this report represents a portion of the thesis research being conducted by the senior author and may not be cited or referenced in any fashion.

Materials and Methods

All plants were grown in Redi Earth Peatlite and fertilized daily with a 1/4 strength solution of Peters 15-16-17 peatlite special. Plants were grown in a greenhouse at 30 $\pm$ 6°C with natural and artificial lighting.

The lines and crosses used in the investigation were:

MR-1 - resistant to Fusarium wilt (FW) and downy mildew (DM)

AY - susceptible to FW and DM

Perlita - susceptible to FW and DM

PI 124112 - susceptible to FW, resistant to DM)

F₂ MR-1 X AY - 3 resistant:1 susceptible to FW

Resistance to FW and DM was tested in each group of plants, but only FW resistance was considered in screening for markers in the F₂ populations. FW resistance was chosen because only a single dominant gene is involved and because scoring of resistant versus susceptible plants is a clear + or - rating. Fusarium infection in susceptible C. melo plants results in death of the plant. Thirty of each of the above lines and crosses were grown under the conditions described above. At the five leaf stage, three 3 mm leaf discs were removed from the second true leaf for peroxidase tests. The remainder of the leaf was removed and stored at -80°C, then freeze-dried for salicylic acid and PCR analysis. One-third of the MR-1, AY, Perlita and PI 124112 plants were inoculated with F. oxysporum f. sp. melonis race 1, one third with P. cubensis and one third with both pathogens. F₂ plants were all inoculated with both pathogens. Control plants from each group were inoculated using only sterile distilled water.

Downy mildew inoculations were performed using the methods of Thomas et al. (5). P. cubensis sporangia at a concentration of 2×10^4 /ml were sprayed on the adaxial surface of the third true leaf with a Paasche air brush to incipient runoff. Control plants were inoculated with sterile distilled water. Test plants were then placed in a dark dew chamber at 20°C for 12 hours before being removed and placed in the greenhouse for 7 days. The plants were then returned to the dew chamber for 12 hours and were evaluated for disease reaction eight days after inoculation.

The rating scale used was adapted from Kenigsbuch and Cohen (2) and was as follows:

- 1 = 1mm chlorotic lesions with necrotic centers and watersoaked margins, no sporulation
- 2 = mixture of type 1 and type 3 symptoms.
- 3 = 3-4mm chlorotic lesions with watersoaked margins and sparse sporulation
- 4 = mixture of type 3 and type 5 symptoms
- 5 = 10-15mm chlorotic lesions with profuse sporulation which commonly extends beyond the lesion margins

Fusarium inoculations were performed simultaneously with the downy mildew experiments. A F. oxysporum f. sp. melonis race 1 isolate was maintained on PDA plates at 21°C for 14 days. To isolate spores, plates were flooded with distilled water and scraped with a glass rod. The slurry was passed through four layers of cheesecloth and the filtrate was adjusted in volume with distilled water, until a conidial suspension of 10^4 per ml was achieved. Spore counts were performed using a hemacytometer.

Candidate plants were carefully removed from their pots and the lower 1 cm of the root ball cut off with a sterile razorblade. The root ball was then dipped into the conidial suspension for ten seconds after which time the root ball was replaced in its pot. Symptoms typically developed within 21 days in susceptible plants. Plants were rated as either dead or alive. Crown sections from all dead plants were surface sterilized and plated on PDA to verify fusarium infection. Control plants were treated as described above, except that sterile distilled water was used instead of the spore suspension. The F₂ plants were all inoculated with both DM and FW.

The peroxidase assay was performed on leaf discs from leaf 2 taken at the time of inoculation, using the method of Reuveni et al. (4) which had been adapted for use with a 96-well microtitre plate containing 100 μ l of reaction mix. Leaf discs were placed in wells containing a Guaiacol based reaction mix and color was allowed to develop for five minutes. Fifty μ l of TCA was then added to stop the reaction. The discs were then removed and the colored product in the plates measured on an ELISA reader set at 450 nm.

Salicylic acid was extracted from the freeze-dried plant material using a miniprep variation of Raskin et al. (3). Twenty-five mg of dried tissue was used, compared with 1 g of fresh material as indicated in Raskin's paper. A Sorval speedvac was used for all the supernatant concentration steps. The final product was brought to 250 μ l with the mobile phase and separated by reverse phase C-18 chromatography. Salicylic acid was detected with a fluorochrome detector at an excitation wavelength of 325 nm and an emission wavelength of 400 nm.

DNA was extracted from individuals bulked together following a rating of resistance and susceptibility to *Fusarium*. Tissue from F₂ plants which showed resistance, were pooled together in one "bulk", while tissues of the susceptible plants were pooled into another. DNA was extracted from each bulk separately. This procedure should provide near isogenic DNA with the exception of the gene conferring FW resistance. DNA was extracted using a variation of the Dellaporta et al. (1) procedure. Freeze-dried material was used instead of fresh tissue. Microgram quantities of high molecular weight genomic DNA were obtained with this extraction method.

PCR amplifications were carried out using reaction buffers and conditions recommended by the manufacturer (Perkin-Elmer). Amplified product was electrophoresed through 3% agarose gel in TAE buffer at 45 Volts for 3 hr. Gels were stained in ethidium bromide and photographed under UV.

Results and Conclusions

Peroxidase assay data showed no discernable correlation between preinfection levels of peroxidase activity and DM resistance (Tables 1, 2, and 3). Similar results were found for peroxidase activity and FW resistance (Table 4). This was observed in both the individual parent melon lines as well as the F₂ generation of the MR-1 X AY cross. The data from these experiments conflicts with the results reported by Reuveni et al. (4). Our studies did not detect the levels of peroxidase they reported.

Plants from duplicate experiments grown two weeks later showed an

overall increase in peroxidase activity levels. While temperatures remained relatively constant, weather conditions caused a reduction in available natural light for extended periods of time in the greenhouse. Perhaps reduction of sunlight resulted in activation of peroxidase in all plants to approximately the same level. On the other hand, exposure of plants to other environmental stresses may be required to reveal a correlation between peroxidase activity and resistance. Variations in vigor among the lines used in these experiments may also have contributed to these differences. F₂ populations were used in these studies to compensate for dissimilar growth properties observed between the parent lines. The F₂ generation from this cross exhibits uniformly robust vigor.

The salicylic acid study has not been completed. Initial data shows a difference in the preinfection salicylic acid levels of FW resistant plants compared with susceptible genotypes. The results of additional tests that are currently underway will have to be interpreted before final conclusions are reached.

In the search for genetic markers using bulked segregant analysis, of 120, 10-mer primers tested so far, 6 putative RAPDs (Randomly Amplified Polymorphic DNA) have been detected that are associated with FW resistance (Figure 1). Work is continuing to verify these 6 RAPDs as well as screening additional primers. F₃ plants from MR-1 X AY are currently being grown for additional experiments in which just the homozygous resistant and susceptible plants will be bulked and then screened with PCR. This will confirm the validity of any RAPDs identified.

Literature Cited

1. Dellaporta, S. L., Wood, J., and Hicks, J. B. 1983. Plant DNA minipreparation version #2. *Plant Molec. Biol. Repr.* 1:19-21.
2. Kenigsbuch, D., and Cohen, Y. 1989. Inheritance of resistance to downy mildew in a gynoeceious muskmelon. *Plant Disease* 73:994-997.
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4. Reuveni, R., Shimoni, M., and Karchi, Z. 1990. A rapid assay for monitoring peroxidase activity in melon as a marker for resistance to Pseudoperonospora cubensis. *J. of Phytopathology* 129:333-338.
5. Thomas, C. E., Cohen, Y., McCreight, J. D., Jourdain, E. L., and Cohen, S. 1988. Inheritance of resistance to downy mildew in Cucumis melo. *Plant Disease* 72:33-35.

Table 1. Peroxidase levels¹ compared with downy mildew rating.

Plant	Rating	Average	Std. Dev.	# Pln
MR-1 12/15	1	26.61	6.17	12
	2	24.53	6.93	3
Perlita 12/15	3	27.13	2.21	2
	4	26.54	6.61	10
	5	29.85	16.18	9
124112 12/15	1	15.00	4.37	9
	2	17.18	7.25	8
	3	16.04	1.34	4
AY 12/15	3	14.52	1.37	3
	4	13.22	3.42	11
	5	16.23	7.39	6
MR-1 12/25	1	44.77	6.33	9
	2	43.59	4.27	3
Perlita 12/25	2	40.86	1.45	3
	3	37.65	4.25	6
	4	43.27	2.35	6
	5	42.31	7.45	7

¹ one unit is equivalent to the formation of 1.0 ug of purpurogallin from pyrogallol in 100 secs at pH 6 and 20°C.

Table 2. Peroxidase levels¹ compared with downy mildew rating.

Plant	Rating	Average	Std. Dev.	# Pln
124112 12/25	1	39.57	11.63	4
	2	45.00	15.95	2
	3	42.70	13.92	3
AY 12/25	2	33.78	6.75	4
	3	33.92	8.74	11
	4	30.08	7.53	5
	5	37.40	2.54	2

¹ one unit is equivalent to the formation of 1.0 ug of purpurogallin from pyrogallol in 100 secs at pH 6 and 20°C.

Table 3. Peroxidase levels¹ compared with downy mildew rating.

Plant	Rating	Average	Std. Dev.	# Pln
AY X MR-1 1/10	2	13.20	2.05	3
	3	13.28	1.31	10
	4	12.91	2.16	12
	5	11.92	0.94	4
AY X MR-1 1/10	1	12.33	2.31	8
	2	10.70	1.11	5
	3	12.01	2.11	6
	4	10.66	1.87	5
	5	12.60	SSS	1
AY X MR-1 1/25	1	12.36	2.25	6
	2	12.95	1.56	6
	3	12.97	2.98	6
	4	12.01	1.85	8
	5	12.01	2.46	4
AY X MR-1 1/25	1	8.96	2.30	4
	2	8.79	1.51	8
	3	9.43	2.02	6
	4	10.45	2.67	3
	5	9.61	1.52	3

¹ one unit is equivalent to the formation of 1.0 ug of purpurogallin from pyrogallol in 100 secs at pH 6 and 20°C.

Table 4. Peroxidase levels¹ in comparison to Fusarium wilt resistance.

Plant	Susceptible		Resistant	
	Average	Std. Dev.	Average	Std. Dev.
<u>First test</u>				
AY X MR-1	13.56	1.84	12.69	1.72
# Plants 9				
AY X MR-1	11.94	2.00	11.55	1.99
# Plants 10				
<u>Second test</u>				
AY X MR-1	11.96	2.04	12.65	2.16
# Plants 8				
AY X MR-1	9.29	1.93	9.29	1.93
# Plants 7				

¹ one unit is equivalent to the formation of 1.0 ug of purpurogallin from pyrogallol in 100 secs at pH 6 and 20°C.

Figure 1 showing RAPD polymorphism for resistance of muskmelon to *Fusarium oxysporum* f. sp. *melonis*. Amplification products shown were obtained using 10bp primers 50-58. Polymorphism can be seen using primer #52.

S=amplified products from pool bulked from susceptible F₂ plants.

R= amplified products from pool bulk from resistant F₂ plants.

M=123 bp ladder.

Unstated Objectives - Israel

Information furnished by the Cooperating Investigator in Israel pertaining to unstated objectives is as follows:

1. "*C. melo* PI 124111F has a constitutive cytoplasmic protein of 45kD which cosegregates with resistance. This protein disappears at a low temperature of 12°C (number 1 in List of Publications). We believe that this 45 kD protein is a product of *Pc-2*. Partial sequence of the protein was obtained and attempts are currently made to clone it for the production of transgenic plants."
2. "Callous deposition was found to be an important feature of resistance against powdery mildew in PI 124112. EGTA (a calcium chelator) applied to lower leaf surfaces of PI 124112 turned 55% of the treated plants to produce no callose and to react compatibly with *Sphaerotheca fuliginea*." (number 8 - List of Publications)
3. "Peroxidase activity was tested in PI 124111F, PI 124112 and susceptible cultivars such as AY and Charantais. Results showed that constitutive peroxidase is not a biochemical marker of resistance. However, peroxidase increased much more rapidly in resistant vs. susceptible plants after inoculation."
4. "A protocol was established to produce flowering plants of PI 124112 from mesophyll protoplasts. Plants retained their resistance to disease and phenotypic features. Protoplast fusion protocols are currently developed."

Literature Cited

See citations with each section/publication.

Description of Cooperation

Cooperation between U.S. and Israeli investigators in the conduct of this research project has included joint discussions involving conduct, planning, and review of the research. All of the investigators regret the misunderstanding that resulted in considerable duplication of research effort between the investigators in the U.S. and Israel.

Evaluation of Research Achievements with Respect

to the Original Research Proposal and

Benefits to Agriculture

The achievements of this research have either accomplished or substantially advanced towards the accomplishment of the originally proposed research objectives. In several instances these original objectives have been extended substantially.

The benefits to agriculture from the reported research include:

- a) elucidation of the mode of inheritance of resistance to downy and powdery mildews in melon PI 124112
- b) insight into the effects of low temperature on downy mildew resistance
- c) elucidation of the strengths (resistances) and weaknesses (susceptibilities) inherent in PI 124112 as a source of multiple disease resistance in melon enhancement programs
- d) initial studies into the use of biotechnological approaches and genetic markers in development of disease resistant melons

List of Publications

1. Ballas, M. 1991. Temperature-dependent resistance to downy mildew in *Cucumis melo* PI 124111F. Ph.D. Thesis, Bar-Ilan University, Israel. 122 pp.
2. Ballas, M., Cohen, Y. and Bar-Joseph, M. 1992. Identification of a constitutive 45 kD protein associated with resistance to downy mildew in muskmelon (*Cucumis melo* L.) line PI 124111F. *Physiol. Molec. Plant Pathol.* (Accepted)
3. Cohen, Y. 1992. Genes and mechanisms of resistance against fungal pathogens in breeding lines of muskmelon. Fifth Eucarpia Cucurbitaceae Sym. Skierniewice, Poland. pp 139-141.
4. Cohen, Y., Eyal, H., and Hanania, Y. 1990. Ultrastructure, autofluorescence, callose deposition and lignification in susceptible and resistant muskmelon leaves infected with powdery mildew fungus, *Sphaerotheca fuliginia*. *Physiol. Molec. Plant Pathol.* 36:191-204.
5. Kasas-Atinger, R. 1990. The inheritance of resistance to Fusarium wilt in *Cucumis melo* PI 124111F. M.S. Thesis, Bar-Ilan University, Israel. 59 pp.
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