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Search for Resistance in *Cucumis Melo* L. and *Citrullus Lanatus* L. to Spider Mites

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Title:

Search for resistance in Cucumis melo and Citrullus lanatus to spider mites

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I. Abstract:

Three techniques for screening for resistance in melons to spider mites were evaluated under laboratory, greenhouse and field conditions. Techniques were found to be comparable in determining effects of mite feeding on germplasm in terms of mite reproduction and survival and relation to populations under field conditions.

Approximately 500 cultivars, breeding lines, or plant introduction lines of Cucumis melo L. were exposed to populations of twospotted or carmine mites in laboratories, greenhouses and field conditions in the U.S.A. and Israel and evaluated for resistance to mites in terms of population increases. Numerous sources of germplasm were found to negatively effect mite populations. Breeding and plant introduction lines exhibiting resistance were crossed with susceptibles and evaluated to determine heritability of characteristics. The resistance characteristics were determined to be antibiotic in nature and heritable.

Seven common commercial cultivars of Citrullus lunatus were exposed to population of twospotted spider mite and evaluated to determine population response under field conditions. Several cultivars were noted as expressing resistance in terms of having reduced numbers of mites present.

II. Objectives

1. Determine and verify methods of establishing differential response of plants to spider mites.

2. Evaluate muskmelon and watermelon germplasm for sources of resistance to spider mites.

3. Quantify the levels of resistance in various lines among plants in lines.

III. Body of report

A. Evaluation of screening methods and search for resistance in muskmelon, Cucumis melo L., to the twospotted spider mite, Tetranychus urticae Koch.

Introduction

Muskmelon, Cucumis melo L. is an important horticultural crop of high economic value. The twospotted spider mite, Tetranychus urticae Koch is cosmopolitan in distribution, and can cause severe economic losses in melons by foliar feeding.

Spider mites have developed resistance to a wide variety of acaricides (Ascher & Cwilich 1960, 1962, Tahori & Raccah 1970, Mansour and Plaut 1979). Use of synthetic pyrethroids has further complicated spider mite control by increasing mite fecundity or through the selective destruction of natural enemies of the mites (Plaut and Mansour 1980). Furthermore, because spider mites typically feed on the undersides of leaves and melon canopies are thick, it is often difficult to contact spider mites with effective pesticides. Development of muskmelon cultivars resistant to spider mites should reduce the dependance on chemical control tactics.

Resistance of various types has been found in muskmelon to the melon aphid , Aphis gossypii Glover, (Kishaba et al. 1971, Bohn et al. 1972, McCreight et al. 1984). Various types of resistance in cucumber, Cucumis sativis L., to the twospotted spider mite have been identified (Da Costa and Jones 1971, Kooistra 1971, Tulisalo 1972, Soans et al. 1973, Gould 1978, De Ponti 1978). A few potential sources of resistance to spider mites in muskmelon have been identified (Mansour et al. 1987). However, little research has been conducted on spider mite resistance in muskmelon.

The objectives of this study were to identify new sources of resistance in muskmelons by screening commercial cultivars, advanced breeding lines and Plant Introductions, which had not previously been screened for twospotted spider mite resistance.

Materials and Methods

Mite colony

Mites used in the study were taken from a culture of Tetranychus urticae Koch maintained at the Texas Agricultural Experiment Station, Weslaco. The culture was maintained for more than one year on lima bean plants in an isolated room at 32 degrees C., 24 hr photophase and 45% RH.

Comparison of screening methods

Methods for screening large numbers of germplasm lines for resistance to the twospotted spider mite were evaluated. Three commonly used methods of confining spider mites on leaves were compared. Leaf tissue to be used in the study was taken from

'Perlita', a commercial muskmelon cultivar. Plants were grown in a greenhouse in commercially available potting soil mix composed of vermiculite and sterile peat moss. All plants were grown under similar conditions and tissue used in studies was collected from the first fully expanded leaf down from the vine terminal.

The three methods evaluated were: 1) leaf disc - tissue cut from whole leaves using a 25 mm diameter circular punch were floated on distilled water in 100 x 15 mm glass petri dishes; 2) clip cage - cages constructed from 25 mm diameter clear round plastic tubing cut into 25 mm lengths and one end covered by fine mesh screen were snugly attached to leaves with hair clips; 3) whole leaf - leaves were excised from vines and petioles inserted through parafilm covering a vial containing distilled water. Single adult female mites were removed from the culture and isolated on 10 replicated units using each of the above described methods. All units were then held in Percival environmental chambers at 25 degrees C. and 12 h photophase.

Mite progeny production was monitored after 7 days by counting the number of mobile mites and eggs. Data were summarized and mean number of mobile mites and eggs and associated variance components calculated for each technique for comparisons.

Greenhouse Mass Screening

All mites used in screening trials were from a culture of Tetranychus urticae (Koch) maintained at the Texas Agricultural Experiment Station, Weslaco. The culture has been maintained for more than a year on lima bean, Phaseolus limensis, in an isolated room at 32° C for a 24 hr photophase and 45% relative humidity.

Melon plants for screening trials were grown from seed in 1-gallon pots with Sunshine® #1 potting media and fertilized with 20 g of 14-14-14 (NPK) Osmocote® fertilizer. Plants were watered uniformly by drip irrigation every 2-3 days. Experimental design was a randomized complete block with three replicates. Two plants of each variety were grown in a single pot per replicate.

Screening evaluations were accomplished by placing 10 female mites on one leaf per plant. Mites were prevented from escaping from the leaf by placing a cotton per tanglefoot barrier on the leaf petiole. All plants were monitored twice a day to ensure that no leaves touched any surface that would permit mites to escape from the caged leaf. Eleven days after inoculation, the number of adult female mites per leaf, leaf area, and the number of mite eggs on four 2.2 cm diameter disks per leaf were recorded.

Separate trials, comprised of 12 to 48 lines and always containing a standard commercial line ('Perlita'), were conducted during consecutive time periods from February to November 1988, and enumerated as trials 1 to 11. Commercial line 'Magnum-45' was also included for comparison in screening trials 1 to 9. 'Magnum-45' was replaced in screening trials 10 and 11 with 'NY'.

Intensive Screening

To better evaluate the resistance observed in the greenhouse mass screenings, the most resistant line in terms of mean number of female mites per leaf was selected from each screening trial 1-5. 'BUS', a bush variety, was also included from mass screening trial 2. Screening methods were identical to the mass screening procedure, except that one plant per pot was grown, two leaves were caged per plant and up to 52 plants per line were used depending on availability of seed. Data were subjected to an analysis of variance and means separated with a Duncan's Multiple Range Test (SAS Institute 1985).

Field Evaluation

Selected lines from greenhouse mass screening trials 5 to 7 were transplanted to field plots, so results could be compared with those obtained in the greenhouse. Individual plants from each screening trial were randomly planted in a field plot and infested with mites from the laboratory colony twice during the first week after transplanting. One month after transplanting, 10 leaves were randomly selected from each plant. Adult female mites counted on the upper and lower leaf surface of each leaf and leaf area were recorded with a Li Cor -3000 area meter. A Spearman's Rank-order Correlation (SAS Institute 1985) between mean densities of female mites from each line in the field and mean numbers of female mites per leaf for each line from greenhouse screening results was used to analyze the data.

Results

Comparison of screening methods

Mites survived and produced progeny on leaf tissue using each of the three techniques. However, comparison of techniques indicated that the mean number of mobile mites and eggs was greatest using the floating disc technique but not significantly different than using the whole leaf technique (Table 1). Both the whole leaf and floating disc technique had significantly greater numbers of mobile mites than did the clip cage method.

The experimental error associated with each technique was evaluated using comparisons of variance components. Coefficient of Variaton (CV) values associated with mean numbers of mites and eggs are noted in Table 1. CV values were approximately equal for the whole leaf and floating leaf disc technique for mean number of mobile mites and eggs while both were substantially lower than that associated with the clip cage method.

The floating disc and whole leaf methods were comparable in results and therefore either could be used successfully. It was decided, based on De Ponti (1977), to use live tissue for screening germplasm, thus a non-excised whole leaf technique was used, as described in the greenhouse mass screening and methods section.

Greenhouse Mass Screening

Tables 1 to 11 list the results from groups of melon lines screened in the greenhouse from February through November 1988. These table also correspond to mass screening trials 1 to 11, respectively.

Essentially no lines were significantly different from the standard line 'Perlita' in numbers of eggs per female mite. No advanced breeding lines where significantly lower than 'Perlita' in numbers of female mites per leaf (Table 1). Commercial cultivars 'Sunshine' and 'Laguna' were significantly lower than 'Perlita' in the numbers of female mites per leaf (Table 2). 'CHI', 'BUS', and WI 298, lines showing resistance in previous research were all significantly lower than 'Perlita' in the number of female mites per leaf (Table 2). Several to many PI lines in screening trial 2 to 11 were significantly lower than 'Perlita' in the number of female mites per leaf.

Differences observed in numbers of female mites per leaf could be due to resistance via physical or chemical confrontation (Harris 1979). Mites were rarely found trapped in tanglefoot barriers and were never observed outside caged leaves, so escapes are unlikely to have occurred.

Intensive Screening

Results from the initial phase of the intensive screening work were in agreement with results from greenhouse mass screenings. Lines that had few mites in the greenhouse mass screenings ('CHI', PI 179895, 'BUS' and PI 164343) all had significantly lower numbers of female mites per leaf than 'Perlita' (Table 12). BB 1036 was not significantly different from 'Perlita' in mass screening 1 or the intensive screening. One exception, PI 123689, which was significantly different from 'Perlita' (Table 5) in female mites per leaf in the mass screening , was not significantly different from 'Perlita' in the intensive screening.

No lines had significantly fewer eggs per female mite in the intensive screening study than 'Perlita'. 'BUS', which had the fewest number of eggs per female mite in mass screening trial 2, had significantly more eggs per female mite in the intensive screening study (Table 12).

Field Evaluation

The Spearman's Rank-order Correlation between greenhouse mass screening trial 5 (female mites per leaf) and field counts on these same plants(female mites per cm^2) was $r = 0.80$ with $Pr > r = 0.20$ (Table 13). The correlation between mass screening trial 6 (female mites per leaf) and field counts (female mites per cm^2) was $r = 1$, indicating a perfect correlation based on rank (Table 14). The correlation between the female mites per leaf counts in mass screening trial 7 and field counts was $r = 0.90$ and $Pr > r = 0.037$

(Table 15). The correlations between eggs per female mite counts for greenhouse mass screening trials and field counts on these same lines(female mites per cm^2) were not statistically significant.

Discussion and Summary

Results from the initial phase of the intensive screening studies were consistent with results from the greenhouse mass screenings. Two lines 'BUS' and 'CHI' that performed well in previous testing (Mansour et al. 1987), also performed well in these greenhouse mass and intensive screening tests. Two PI lines (164343 and 179895) also expressed resistance in both the greenhouse mass and intensive screenings. PI lines that performed well in both field and greenhouse trials were 124101, 124431, 125896, and 125956. However, more in-depth studies need to be conducted on the nature, degree, and heritability of the resistance observed.

A successful mass screening technique allows for quick, efficient, and unbiased evaluation of large numbers of different plant lines, but the results of greenhouse or laboratory screenings must also accurately predict expression of characteristics under field conditions. Based on the correlations between greenhouse and field data from these studies, the number of female mites on leaves in a greenhouse screening is a good to excellent indicator of the mite density that will occur on these same lines under field conditions.

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Table 1. Results from greenhouse mass screening trial 1.

PI/Line	N	Eggs/ Female Mite	PI/Line	N	Female Mites/ Leaf
BB 1052	6	3.8 a	BB 1036	6	5.1 b
PWE 1025	5	5.1 a	'Perlita'	6	19.1 ab
BB 1036	6	6.9 a	BB 1061	6	23.7 ab
'Perlita'	6	8.4 a	BB 1052	6	28.4 ab
BB 1059	6	8.6 a	BB 1004	6	29.6 ab
'Magnum-45'	5	9.6 a	PWE 1025	6	32.0 ab
BB 1037	6	12.8 a	PWE 1028	5	32.3 ab
PWE 1028	5	13.3 a	BB 1037	6	35.4 ab
BB 1061	6	13.7 a	BB 1022	6	35.7 ab
PWE 1023	5	15.1 a	PWE 1023	6	39.1 ab
BB 1004	6	16.3 a	'Magnum-45'	5	47.2 a
BB 1022	6	17.0 a	BB 1059	6	47.4 a

Means in a column followed by the same letter are not significantly different ($P > 0.05$, Duncan's NMRT).

Table 2. Results from greenhouse mass screening trial 2.

PI/Line	N	Eggs/ Female Mite	PI/Line	N	Female Mites/ Leaf
'BUS'	6	1.9 e	'CHI'	6	20.3 h
183052	6	2.7 e	'Sunshine'	6	23.8 h
183047	6	3.7 de	182938	6	25.7 gh
'Top Flight'	6	3.7 de	381802	6	26.5 f-h
381775	6	3.9 de	179914	6	27.0 f-h
183304	6	4.1 de	164331	5	27.9 f-h
'HY-Mark'	6	4.4 c-e	183052	6	28.7 e-h
WI 298	6	4.5 c-e	WI 298	6	28.7 e-h
266931	6	4.6 c-e	'BUS'	6	29.3 e-h
WI 242	6	4.6 c-e	'Laguna'	6	30.5 e-h
164825	6	5.0 c-e	164825	6	30.7 e-h
'Explorer'	6	5.3 c-e	183047	6	33.2 e-h
179894	6	6.0 c-e	183304	6	34.5 e-h
'Magnum-45'	6	6.0 c-e	'Grande Gold'	6	36.7 d-h
390452	6	6.1 c-e	'Top Flight'	6	37.8 d-h
182941	6	6.3 c-e	234607	6	38.5 d-h
'Grande Gold'	6	6.4 c-e	182949	6	39.8 d-h
266936	1	6.8 c-e	183307	6	41.3 d-h
183307	6	7.2 c-e	'Easy Rider'	6	41.3 d-h
183046	6	7.4 c-e	182941	6	41.8 d-h
182938	6	7.5 c-e	'HY-Mark'	6	42.3 d-h
'CHI'	6	7.7 c-e	390452	6	43.0 d-h
'Hiline'	5	7.8 c-e	179894	6	43.2 d-h
'Laguna'	6	8.3 b-e	'Hiline'	5	43.3 d-h
179914	6	9.3 a-e	WI 242B	6	44.3 d-h
'Mission'	6	9.5 a-e	'Voyaguer'	6	46.0 d-h
'Easy Rider'	6	9.5 a-e	182951	6	48.5 c-h
'Perlita'	6	9.5 a-e	WI 297	6	52.2 b-h
164331	5	10.4 a-e	'Explorer'	6	53.3 b-h
182951	6	10.4 a-e	WI 210	6	54.5 b-h
WI 297	6	10.5 a-e	'Magnum-45'	6	61.0 b-g
381802	6	10.6 a-e	183046	6	63.0 b-f
WI 210	6	12.8 a-e	266931	6	63.7 b-e
'Voyaguer'	6	18.1 a-d	'Perlita'	6	70.8 a-d
182949	6	19.1 a-c	'Mission'	6	71.2 a-d
266935	6	22.5 ab	266936	1	81.0 a-c
'Sunshine'	6	23.3 a	381775	6	82.2 ab
			266935	6	97.3 a

Means in a column followed by the same letter are not significantly different (P > 0.05, Duncan's NMRT).

Table 3. Results from greenhouse mass screening trial 3.

PI/Line	N	Eggs/ Female	PI/Line	N	Females/ Leaf
122847	5	1.0 d	164343	5	24.6 k
116915	6	1.6 cd	116915	6	27.3 k
116917	6	2.5 cd	102077	6	28.2 jk
116828	6	2.7 cd	116917	6	34.5 i-k
93779	6	3.6 cd	109479	6	39.2 h-k
11716	6	4.2 b-d	116736	6	40.7 g-k
164343	5	4.3 b-d	122847	5	40.8 g-k
116824	6	4.6 b-d	116826	6	42.2 g-k
116666	6	4.7 b-d	164856	6	42.7 f-k
116916	5	4.8 b-d	93779	6	42.8 f-k
164856	6	4.9 b-d	116487	6	43.7 f-k
179915	6	5.2 b-d	116824	6	44.3 f-k
131396	6	5.5 b-d	179915	6	45.2 e-k
109479	6	5.6 b-d	118584	6	45.5 e-k
116666	6	5.6 b-d	116827	5	47.0 d-k
116489	6	5.7 b-d	116738	6	47.8 d-k
164569	6	6.6 b-d	313969	6	48.2 d-k
296345	6	6.6 b-d	116660	6	49.7 c-k
93438	6	6.7 b-d	116828	6	50.7 c-k
'Magnum-45'	6	6.7 b-d	93438	6	51.5 c-k
323498	6	6.8 b-d	296345	6	51.7 c-k
116736	6	7.0 b-d	116490	6	52.3 b-k
116661	6	7.3 b-d	116479	6	53.2 b-k
116659	6	7.3 b-d	183256	6	53.3 b-k
183256	6	7.7 b-d	164330	6	53.8 b-k
174175	6	7.8 b-d	'Magnum-45'	6	54.0 b-k
116490	6	8.0 b-d	174175	6	54.0 b-k
'Perlita'	6	8.0 b-d	116916	5	56.4 b-k
108902	6	8.3 b-d	108902	6	61.5 b-j
116487	6	8.4 b-d	117162	6	63.0 b-i
116664	6	8.5 b-d	116661	6	63.2 b-i
164750	6	8.7 b-d	117158	6	63.7 b-i
116738	6	8.7 b-d	116664	6	63.7 b-i
116479	6	8.7 b-d	179903	6	64.7 b-i
179903	6	8.8 b-d	'Perlita'	6	66.8 b-i
117158	6	9.7 b-d	116659	6	67.5 b-i
164330	6	10.2 b-d	164750	6	69.5 a-h
116826	6	10.3 b-d	116489	6	74.2 a-g
93800	6	10.6 b-d	116482	6	76.5 a-f
118584	6	11.5 bc	93800	6	78.8 a-e
116482	6	11.6 bc	116666	6	80.7 a-d
116827	5	12.0 bc	323498	6	83.3 a-c
116667	6	14.5 ab	164569	6	86.0 ab
102077	6	21.5 a	116667	6	102.5 a

Means in a column followed by the same letter are not significantly different ($P > 0.05$, Duncan's NMRT).

Table 4. Results from greenhouse mass screening trial 4.

PI/Line	N	Eggs/ Female	PI/Line	N	Females/ Leaf
167044	6	6.1 c	179895	6	14.3 e
183675	6	6.7 bc	182186	6	14.7 e
174814	6	7.6 bc	174169	6	15.3e
181749	5	7.8 bc	183223	6	16.2 e
176504	6	8.3 bc	183676	6	17.2 e
179916	5	8.4 bc	183675	6	19.5 e
174169	6	9.6 bc	176504	6	20.5 e
183223	6	9.7 bc	169355	3	21.0 e
'Magnum-45'	6	9.9 bc	182943	6	22.0 e
182940	6	10.7 bc	183444	6	22.2 e
179887	5	10.9 bc	'Magnum-45'	6	22.8 de
172817	6	11.1 bc	172814	6	23.7 de
183228	6	11.1 bc	179887	5	24.4 de
167057	6	11.2 bc	172817	6	26.0 de
179912	6	11.2 bc	181749	5	26.4 de
183676	6	11.5 bc	183027	6	27.3 c-e
169355	3	12.1 bc	179912	6	27.8 c-e
183444	6	12.2 bc	174156	5	28.4 c-e
172814	6	13.9 bc	182956	6	28.5 c-e
183227	6	14.0 bc	183043	6	29.3 c-e
183049	6	14.9 bc	183025	6	29.8 c-e
183048	6	15.1 bc	169379	5	30.2 c-e
182187	6	15.4 bc	177353	6	31.0 c-e
179245	6	15.6 bc	182940	6	31.3 c-e
182186	6	15.6 bc	179905	6	32.3 b-e
'Perlita'	5	15.6 bc	169325	6	33.3 b-e
183043	6	15.7 bc	164635	5	34.8 a-e
177353	6	15.8 bc	182187	6	36.0 a-e
174156	5	15.8 bc	177351	6	37.0 a-e
182773	6	15.9 bc	167057	6	37.3 a-e
182956	6	16.1 bc	167044	6	37.7 a-e
179895	6	16.4 bc	183227	6	38.5 a-e
174157	6	16.4 bc	183049	6	39.0 a-e
177351	6	16.9 bc	183228	6	39.3 a-e
183443	6	17.2 bc	179916	5	40.0 a-e
183027	6	19.4 bc	183048	6	40.5 a-e
169325	6	20.2 bc	'Perlita'	5	42.6 a-e
179905	6	21.5 bc	167221	6	43.3 a-e
169379	5	22.3 bc	174157	6	47.0 a-e
167221	6	22.9 bc	182773	6	47.0 a-e
183025	6	24.3 bc	179669	6	55.5 a-d
179669	6	27.3 a-c	179245	6	59.5 a-c
182943	6	30.6 ab	174814	6	63.5 ab
164635	5	45.8 a	183443	6	66.3 a

Means in a column followed by the same letter are not significantly different (P > 0.05, Duncan's NMRT).

Table 5. Results from greenhouse mass screening trial 5.

PI/Line	N	Eggs/ Female		PI/Line	N	Females/ Leaf	
124101	6	4.0	f	123689	6	23.8	k
124107	6	4.7	ef	124101	6	25.0	jk
212895	6	5.1	ef	211937	6	32.3	i-k
'Magnum-45'	6	5.2	d-f	124100	6	36.3	h-k
124098	6	5.3	d-f	124113	6	37.7	g-k
124106	6	5.4	d-f	179891	6	38.8	f-k
123683	6	5.7	c-f	123493	3	39.7	e-k
123682	5	5.8	c-f	123494	6	41.2	e-k
123684	6	5.9	c-f	123187	6	42.0	e-k
123680	6	6.0	c-f	123501	6	42.5	e-k
124099	6	6.3	b-f	212895	6	42.5	e-k
124092	6	6.7	b-f	216030	6	43.5	d-k
124108	6	6.9	b-f	124099	6	44.2	d-k
123501	6	6.9	b-f	124114	6	44.3	d-k
123517	6	7.1	b-f	124102	6	45.0	d-k
211937	6	7.2	b-f	123504	6	45.7	d-k
211726	6	7.3	b-f	124109	6	46.7	d-k
123685	6	7.4	b-f	124106	6	47.2	d-k
123825	6	7.5	b-f	211726	6	49.5	d-k
124102	6	7.6	b-f	123685	6	49.7	d-k
'Perlita'	6	7.8	b-f	123502	6	49.8	d-k
123493	3	7.8	b-f	123823	6	50.2	d-k
179891	6	7.9	b-f	123684	6	50.7	d-k
123689	6	9.0	a-f	124105	6	51.7	d-k
123188	6	9.0	a-f	123822	6	53.5	d-k
124114	6	9.3	a-f	123505	6	53.8	d-k
124109	6	9.5	a-f	123683	6	53.8	d-k
124105	6	9.6	a-f	124108	6	55.7	d-k
123494	6	9.6	a-f	123821	6	56.5	d-k
123496	6	9.6	a-f	123499	6	57.2	c-k
123822	6	9.7	a-f	124096	6	58.0	b-k
123821	6	9.7	a-f	123680	6	59.7	b-k
216030	6	9.7	a-f	123824	6	63.8	a-k
123504	6	9.9	a-f	'Magnum-45'	6	64.0	a-j
124113	6	10.2	a-f	124107	6	64.8	a-j
217599	6	10.3	a-f	123188	6	66.0	a-i
124103	6	10.3	a-f	124103	6	68.0	a-i
124096	6	10.5	a-f	123500	4	68.7	a-i
123505	6	10.6	a-f	123496	6	69.4	a-i
124112	6	11.4	a-f	124098	6	72.7	a-h
123499	6	11.6	a-f	123495	6	73.2	a-h
123823	6	12.3	a-e	123498	6	73.7	a-g
124100	6	12.9	a-d	124092	6	78.2	a-f
123498	6	13.1	a-c	123682	5	79.2	a-e
123187	6	13.2	a-c	123517	6	82.7	a-d
123495	6	13.8	ab	124112	6	95.5	a-c
123500	4	13.9	ab	217599	6	96.3	ab
123502	6	16.0	a	'Perlita'	6	99.8	a

Table 6. Results from greenhouse mass screening trial 6.

PI/Line	N	Eggs/ Female Mite		PI/Line	N	Female Mites/ Leaf	
125877	2	1.2	d	125877	2	24.0	g
124429	6	1.6	cd	125896	6	24.5	g
124431	6	2.3	cd	124431	6	26.2	fg
125878	5	2.6	cd	124432	6	31.5	e-g
125863	6	2.8	b-d	124439	6	34.8	d-g
125885	3	3.3	b-d	125887	3	35.0	d-g
125887	2	3.5	b-d	125886	6	36.2	d-g
124443	6	4.0	b-d	125869	6	38.5	d-g
125895	6	4.0	b-d	124443	6	39.8	d-g
125884	6	4.5	b-d	124441	6	41.5	c-g
125886	5	4.7	b-d	124207	6	41.7	c-g
125893	6	4.9	b-d	125866	1	42.0	c-g
125866	1	5.1	b-d	125895	6	44.5	c-g
124430	6	5.1	b-d	125874	2	46.0	c-g
125882	6	5.2	b-d	125876	5	48.0	c-g
124432	6	5.3	b-d	125879	6	48.8	b-g
125896	6	5.6	b-d	125862	6	51.7	b-g
124436	2	5.7	b-d	125880	6	52.0	b-g
125862	6	5.9	b-d	124433	6	52.7	b-g
124441	6	6.0	b-d	125878	5	54.0	b-g
124550	6	6.3	b-d	124553	6	56.0	b-g
125876	5	6.3	b-d	125863	6	57.3	b-g
125868	6	6.6	b-d	124430	6	58.2	b-g
125875	6	6.7	b-d	124429	6	59.5	b-g
125860	5	6.7	b-d	125861	6	59.7	b-g
125874	2	6.9	b-d	'Magnum-45'	6	60.7	a-g
124435	6	6.9	b-d	124550	6	61.8	a-g
124439	6	7.0	b-d	125884	6	62.0	a-g
125890	6	7.1	b-d	125893	6	62.8	a-g
124440	6	7.2	b-d	125860	5	63.2	a-g
125869	6	7.4	b-d	125868	6	63.7	a-g
124208	6	7.6	b-d	124214	6	65.5	a-g
124206	6	7.7	b-d	125890	6	66.0	a-g
125861	6	7.7	b-d	124210	6	66.0	a-g
124207	6	7.8	b-d	125885	3	68.3	a-g
124433	6	8.1	b-d	125875	6	69.3	a-g
125870	6	8.1	b-d	124436	2	70.0	a-g
124214	6	8.4	b-d	125882	6	71.3	a-g
'Magnu-45'	6	8.4	b-d	125892	6	74.0	a-f
125879	6	9.0	b-d	125870	6	74.2	a-f
124449	6	9.1	b-d	124552	6	77.3	a-e
124553	6	9.3	b-d	'Perlita'	6	80.2	a-e
125892	6	9.5	b-d	124206	6	83.3	a-d
124210	6	9.6	b-d	125891	6	89.0	a-c
'Perlita'	6	12.5	bc	124440	6	90.2	a-c
124552	6	12.6	bc	124208	6	90.2	a-c
125891	6	13.9	ab	124435	6	97.0	ab
125880	6	22.6	a	124449	6	107.8	a

Table 8. Results from greenhouse mass screening trial 7.

PI/Line	N	Eggs / Female Mite		PI/Line	N	Female Mites/ Leaf	
125935	5	0.9	b	125956	2	8.0	e
125951	5	1.2	b	125918	4	9.7	de
125960	6	1.4	b	125951	5	12.4	c-e
125913	6	1.4	b	125922	6	12.5	c-e
125922	6	1.8	b	125952	6	14.0	c-e
125911	6	1.9	b	125933	6	14.7	c-e
125918	4	2.0	b	125897	6	14.8	c-e
125927	6	2.3	b	125910	6	15.5	c-e
125909	6	2.5	b	125960	6	15.8	c-e
125910	6	2.6	b	125901	6	16.5	c-e
125937	6	2.7	b	125913	6	16.8	c-e
125904	6	2.7	b	125920	4	19.2	b-e
125915	4	2.9	b	125915	4	19.5	b-e
125949	5	3.3	b	125928	6	19.7	b-e
125931	5	3.6	b	125931	5	20.8	b-e
125921	3	3.8	b	125927	6	21.3	b-e
125933	6	4.0	b	125904	6	22.0	b-e
125939	6	4.0	b	125924	5	22.4	b-e
125940	6	4.3	b	125902	6	23.3	b-e
125952	6	4.4	b	125929	3	25.3	b-e
125953	6	4.5	b	125961	6	25.8	b-e
125963	5	4.9	b	125940	6	26.2	b-e
125906	6	5.2	b	125955	6	26.5	a-e
125928	6	5.2	b	125930	6	26.7	a-e
125924	5	5.3	b	125908	3	26.7	a-e
125901	6	5.3	b	125914	5	27.2	a-e
125956	2	5.4	b	125937	6	29.2	a-e
125964	6	5.5	b	125911	6	29.2	a-e
125957	6	5.8	b	125957	6	29.5	a-e
125902	6	6.1	b	125948	6	30.0	a-e
125929	3	6.3	b	125942	2	31.0	a-e
125930	6	6.5	b	125926	3	31.7	a-e
125961	6	6.7	b	125944	6	31.7	a-e
125942	2	6.8	b	125939	6	32.7	a-e
125903	6	6.9	b	125953	6	33.0	a-e
125923	6	7.0	b	125949	5	34.8	a-e
125908	3	7.0	b	125906	6	36.0	a-e
125921	3	7.0	b	125921	3	36.0	a-e
125919	5	7.5	b	125903	6	37.2	a-e
125914	5	7.7	b	125923	6	37.5	a-d
'Magnum-45'	6	8.0	b	125919	5	38.0	a-d
125944	6	8.2	b	125935	5	39.2	a-c
'Perlita'	6	10.9	b	'Perlita'	6	39.3	a-c
125955	6	11.7	b	125909	6	40.2	a-c
125948	6	11.9	b	125964	6	41.2	a-c
125897	6	14.5	b	125943	6	41.3	a-c
125943	6	14.7	b	'Magnum-45'	6	48.0	ab
125920	4	36.6	a	125963	5	55.2	a

Table 9. Results from greenhouse mass screening trial 8.

PI/Line	N	Eggs/ Female Mite		PI/Line	N	Female Mites/ Leaf	
126012	3	1.7	d	126027	4	24.2	e
126013	6	2.3	cd	126021	6	24.5	e
125972	3	2.6	cd	126051	2	25.0	de
126021	6	3.1	cd	125986	6	27.8	c-e
126040	6	3.2	cd	126057	6	28.5	c-e
125969	2	3.2	cd	126024	6	31.3	b-e
126045	6	3.2	cd	126019	6	31.3	b-e
126018	1	3.3	cd	126058	6	31.7	b-e
126051	2	3.3	cd	125987	5	36.0	a-e
'Perlita'	6	3.3	cd	126054	6	36.8	a-e
126032	6	3.4	cd	125981	6	38.5	a-e
126034	3	3.4	cd	126020	6	38.8	a-e
126027	4	3.5	cd	126059	5	39.4	a-e
126059	5	3.5	cd	125970	6	40.2	a-e
125982	4	3.6	b-d	125997	6	40.2	a-e
126019	6	3.6	b-d	126012	6	40.3	a-e
126024	6	4.1	b-d	126036	6	40.8	a-e
125986	6	4.2	b-d	126018	1	42.0	a-e
126016	6	4.7	b-d	126034	3	43.0	a-e
125981	6	5.0	a-d	126042	6	43.7	a-e
125976	6	5.0	a-d	126044	4	45.7	a-e
126020	6	5.0	a-d	126040	6	46.7	a-e
125967	6	5.0	a-d	126013	6	46.7	a-e
125992	6	5.0	a-d	126008	6	48.3	a-e
125973	6	5.1	a-d	126053	6	48.5	a-e
126054	6	5.2	a-d	125972	3	48.7	a-e
126036	6	5.3	a-d	126016	6	50.0	a-e
125970	6	5.3	a-d	'Perlita'	6	52.8	a-e
126033	6	5.5	a-d	126045	6	53.3	a-e
125997	6	5.6	a-d	126037	6	53.3	a-e
125971	6	5.7	a-d	125992	6	55.3	a-e
Magnum45	6	5.7	a-d	126032	6	56.3	a-e
125991	3	5.8	a-d	'Magnum-45'	6	56.0	a-e
126053	6	5.9	a-d	125976	6	58.2	a-e
126037	6	6.2	a-d	125994	6	58.2	a-e
125974	6	6.4	a-d	125982	4	58.2	a-e
125994	6	6.4	a-d	126056	6	58.7	a-e
126044	4	6.6	a-d	125974	6	58.8	a-e
126056	6	6.7	a-d	125969	2	59.5	a-e
126012	6	7.4	a-d	125973	6	64.8	a-e
126058	6	7.8	a-d	125971	6	66.3	a-d
126042	6	8.0	a-d	125967	6	66.7	a-c
126008	6	8.3	a-d	126033	6	67.3	a-c
126057	6	8.4	a-d	125993	6	67.3	a-c
125987	5	9.5	a-c	126000	3	72.7	ab
125993	6	10.7	ab	126030	6	73.8	a
126030	6	11.9	a	125991	3	75.3	a

Table 9. Results from greenhouse mass screening trial 9.

PI/Line	N	Eggs/ Female Mite	PI/Line	N	Female Mites/ Leaf
126129	1	0.0 b	126129	1	0.0 g
126126	5	1.7 b	126126	6	4.0 fg
126063	1	1.9 b	126076	6	4.0 fg
126076	6	2.1 b	126136	4	5.0 fg
126071	6	2.3 b	126073	6	5.5 fg
'Magnum-45'	6	2.3 b	126084	6	5.7 fg
126096	6	2.5 b	126088	6	6.2 e-g
126084	6	2.8 b	126079	2	7.0 e-g
126113	6	3.0 b	126096	6	7.0 e-g
126140	5	3.2 b	126060	6	7.0 e-g
126077	2	3.5 b	126072	6	7.5 e-g
126130	6	3.7 b	126117	6	8.8 e-g
126081	6	3.9 b	126116	6	9.3 d-g
126133	6	4.2 b	126113	6	9.3 d-g
126134	6	4.2 b	126134	6	9.3 d-g
126118	2	4.3 b	126065	2	9.5 d-g
126069	4	4.3 b	126081	6	10.0 d-g
126101	6	4.4 b	126101	6	10.2 d-g
126068	6	4.4 b	126112	5	10.8 d-g
126117	6	4.7 b	126063	1	11.0 c-g
126138	5	4.8 b	126114	6	11.3 c-g
126095	5	5.1 b	126138	5	11.6 c-g
126082	6	5.3 b	126125	6	11.8 c-g
126073	6	5.5 b	126068	6	12.3 c-g
126086	6	5.5 b	126111	6	12.8 c-g
126060	6	5.6 b	126123	6	13.2 c-g
126088	6	5.7 b	126083	4	14.2 c-g
126125	6	6.2 b	126071	6	14.5 c-g
126079	2	6.3 b	126086	6	14.8 c-g
126123	6	6.3 b	126069	4	15.0 c-g
126080	4	6.7 b	126064	6	15.3 c-g
126106	1	6.8 b	126077	2	15.5 c-g
126072	6	7.0 b	126080	4	16.2 c-g
126116	5	7.0 b	126132	2	16.5 c-g
126105	3	7.0 b	126099	5	17.0 c-g
126111	6	7.1 b	126106	1	18.0 c-g
126064	6	7.1 b	126082	6	18.2 c-g
126127	6	7.4 b	126095	5	21.6 b-g
126114	6	7.7 b	'Magnum-45'	6	22.3 b-g
126112	5	9.5 b	126140	5	24.4 a-g
126090	2	10.5 b	126090	2	27.5 a-f
'Perlita'	6	15.8 b	126127	6	28.0 a-f
126099	5	16.0 b	126118	2	31.5 a-e
126083	4	20.1 b	126130	6	34.5 a-d
126065	2	21.3 b	126133	6	36.3 a-c
126136	4	28.6 b	126105	3	44.3 ab
126132	2	141.2 a	'Perlita'	6	47.7 a

Table 10. Results from greenhouse mass screening trial 10.

PI/Line	N	Eggs/ Female Mite	PI/Line	N	Female Mites/ Leaf
126169	3	1.3 g	127532	1	17.0 f
127575	6	1.5 g	126190	4	24.0 ef
126165	6	2.3 fg	126198	6	26.8 d-f
127565	6	2.8 fg	127546	6	28.0 d-f
127519	3	3.2 fg	127570	6	28.8 d-f
127535	2	3.6 fg	126185	6	30.0 c-f
126190	4	3.8 fg	127565	6	30.5 c-f
127540	6	4.2 fg	127567	6	31.2 b-f
126202	5	4.3 fg	127566	6	33.2 a-f
126198	6	4.4 fg	127530	4	34.0 a-f
'NY'	6	5.2 e-g	126176	6	36.5 a-f
126150	4	5.2 e-g	126141	6	37.0 a-f
127570	6	5.4 e-g	126169	3	37.7 a-f
126176	6	5.5 e-g	127535	2	38.5 a-f
126167	6	5.7 e-g	126179	6	39.8 a-f
127577	6	5.9 e-g	126160	6	40.2 a-f
126174	6	6.1 e-g	127540	6	40.7 a-f
127566	6	6.2 e-g	127544	6	40.8 a-f
126162	6	6.2 e-g	127575	6	42.7 a-f
127546	6	6.3 e-g	127577	6	45.7 a-f
126166	6	6.4 e-g	126165	6	46.3 a-f
126197	6	6.5 e-g	126167	6	48.2 a-f
126185	6	6.8 e-g	127528	6	49.2 a-f
126180	6	7.0 d-g	126146	6	52.0 a-f
127538	6	7.2 d-g	126151	6	52.2 a-f
127528	6	7.5 d-g	126180	6	52.2 a-f
127544	6	7.5 d-g	'NY'	6	52.7 a-f
126151	6	7.7 d-g	127538	6	53.5 a-f
126145	6	7.9 d-g	126172	6	53.7 a-f
126199	3	8.0 d-g	126200	6	55.2 a-f
127560	6	8.7 c-g	126202	5	55.2 a-f
126200	6	8.9 c-g	127519	3	56.3 a-f
127536	6	9.6 c-g	'Perlita'	5	58.6 a-f
126172	6	10.1 c-g	126145	6	59.8 a-f
126153	6	11.0 c-g	126162	6	60.5 a-f
127534	6	11.1 c-g	126197	6	60.5 a-f
'Perlita'	5	11.8 c-g	126153	6	60.7 a-f
126179	6	15.1 b-g	127536	6	62.0 a-f
126141	6	15.4 b-g	126150	4	68.0 a-e
126152	6	16.4 b-f	126166	6	69.3 a-e
126160	6	18.7 b-e	126199	3	70.7 a-d
126195	6	20.8 b-d	126195	6	74.5 a-c
126146	6	20.9 b-d	126152	6	75.0 a-c
127567	6	21.8 bc	127560	6	76.3 ab
127530	4	25.8 b	127534	6	76.7 ab
127532	1	47.6 a	126174	6	78.7 a

Table 11. Results from greenhouse mass screening trial 11.

PI/Line	N	Eggs/ Female Mite	PI/Line	N	Female Mites/ Leaf
128901	6	1.4 d	136223	5	9.8 i
136227	6	1.9 cd	127578	6	13.3 hi
136229	6	2.5 cd	136192	6	17.5 g-i
136197	4	2.5 cd	136197	4	17.5 g-i
136228	6	2.6 cd	136208	6	18.7 g-i
127578	6	2.8 cd	136202	6	20.5 f-i
136204	6	3.4 cd	134196	6	21.5 f-i
136220	6	3.4 cd	136171	6	21.8 f-i
136215	6	3.5 cd	136213	6	22.8 e-i
136186	6	3.6 cd	136201	6	23.5 d-i
136184	6	3.6 cd	134200	5	25.2 d-i
136182	6	3.7 cd	136220	6	26.0 d-i
137834	6	3.8 cd	136173	6	26.3 d-i
136225	6	3.8 cd	136229	6	28.0 d-i
136206	6	4.1 cd	136205	6	28.2 d-i
136211	6	4.3 b-d	136228	6	28.2 d-i
136180	6	4.6 b-d	136204	6	30.7 c-i
134200	5	4.6 b-d	136218	6	31.7 c-i
136205	6	4.8 b-d	136203	6	32.0 c-i
'NY'	6	4.8 b-d	137837	6	32.2 c-i
136203	6	4.8 b-d	136215	6	33.5 b-i
136187	5	4.8 b-d	136177	6	34.0 b-i
134196	6	5.0 b-d	136196	6	35.0 b-i
136202	6	5.4 b-d	136211	6	35.5 b-i
136198	6	5.5 b-d	136200	6	35.7 b-i
136173	6	5.6 b-d	136206	6	38.3 a-i
136224	6	6.2 b-d	136184	6	39.2 a-i
136223	5	6.3 b-d	136181	6	40.3 a-i
136218	6	6.6 b-d	136191	6	40.3 a-i
136191	6	6.6 b-d	136221	6	40.7 a-i
136210	6	6.8 b-d	136225	6	41.3 a-i
136177	6	6.9 b-d	136182	6	41.3 a-i
136214	6	7.2 b-d	136214	6	41.5 a-i
136208	6	7.2 b-d	128901	6	43.2 a-i
136171	6	7.3 b-d	137834	6	43.5 a-i
136195	6	7.4 b-d	'NY'	6	45.2 a-h
134199	4	7.5 b-d	136224	6	46.0 a-h
136219	6	7.9 a-d	136195	6	47.7 a-h
136181	6	8.1 a-d	136219	6	50.7 a-g
'Perlita'	6	8.2 a-d	'Perlita'	6	50.8 a-g
137837	6	8.7 a-d	136227	6	51.8 a-g
136192	6	9.3 a-d	136180	6	54.3 a-f
136213	6	9.5 a-d	136187	5	57.2 a-e
136201	6	10.2 a-d	136210	6	57.7 a-d
136209	6	10.6 a-c	134199	4	58.0 a-d
136221	6	12.9 ab	136209	6	64.3 a-c
136200	6	16.1 a	136198	6	67.5 ab
136196	6	16.2 a	136186	6	71.0 a

Table 12. Results from the intensive screening trial.

PI/Line	N	Eggs/ Female Mite	PI/Line	N	Female Mites/ Leaf
'CHI'	20	6.2 c	164343	36	35.5 c
164343	36	7.3 c	'BUS'	25	37.9 c
179859	53	7.6 c	179895	53	43.6 c
123689	51	9.9 bc	'CHI'	20	44.1 c
'Perlita'	17	11.3 bc	123689	51	48.1 bc
BB 1036	52	14.5 ab	'Perlita'	17	61.0 ab
'BUS'	25	18.2 a	BB 1036	52	64.8 a

Means in a column followed by the same letter are not significantly different ($p > 0.05$, Duncan's NMRT).

Table 13. Comparison of field and greenhouse results on selected lines from greenhouse mass screening trial 5.

Line	N	Mites/cm² (field)	Mites/leaf (greenhouse)	Eggs/Mite (greenhouse)
'Perlita'	30	0.1937 a	99.8	7.8
'Magnum-45'	30	0.1752 ab	64.0	5.2
PI 123689	30	0.1733 ab	23.8	9.0
PI 124101	30	0.0698 b	25.0	4.0

Means in a column followed by the same letter are not significantly different ($p > 0.05$, Duncan's NMRT).

Table 14. Comparison of field and greenhouse results on selected lines from greenhouse mass screening trial 6.

Line	N	Mites/cm² (field)	Mites/leaf (greenhouse)	Eggs/Mite (greenhouse)
PI 124449	20	0.2084 a	107.8	9.1
'Perlita'	30	0.1910 a	80.2	12.5
PI 124431	20	0.0613 b	26.2	2.3
PI 125896	10	0.0512 b	24.5	5.6

Means in a column followed by the same letter are not significantly different ($p > 0.05$, Duncan's NMRT).

Table 15. Comparison of field and greenhouse results on selected lines from greenhouse mass screening trial 7.

Line	N	Mites/cm² (field)	Mites/leaf (greenhouse)	Eggs/Mite (greenhouse)
'Perlita'	30	0.2983 a	39.3	10.9
PI 125963	30	0.2765 a	55.2	4.9
PI 125930	30	0.2402 a	26.7	6.5
PI 125951	30	0.1872 ab	12.4	1.2
PI 125956	10	0.0969 b	8.0	5.4

Means in a column followed by the same letter are not significantly different ($p > 0.05$, Duncan's NMRT).

B. Resistance of melon to the carmine spider mite, Tetranychus cinnabarinus (Boisduval) (Acari: Tetranychidae)*

Introduction

Melon (Cucumis melo) is an important horticultural crop of high economic value in Israel and world wide. High market value is dependent on the production of superior quality fruits. The carmine spider mite, Tetranychus cinnabarinus (Boisduval), is a major pest of species of Cucurbitaceae, including melon, causing serious damage and reducing yield and quality of fruits (Avidov & Harpaz, 1969).

Tulisalo (1972) reported that T. urticae Koch may lead to economic losses by causing as little as 30% defolation of leaves. Management of tetranychid mites on melons at present relies on chemical and biological control measures, but these have not always been effective. Chemical control is difficult due to the prostrate growth habit of plants, preventing efficient penetration by acaricides to the lower leaf survaces where the mites are most commonly found. Additionally, severl of the more efficacious acaricides are phytotoxic to cucurbits. Control is also complicated by the mite's propensity for becoming resistant to pesticides (Mansour & Plaut, 1979).

The introduction of synthetic pyrethroids has complicated control due to the induction of mite population outbreaks by increasing its fecundity or by the selective destruction of its natural enemy complex (Plaut & Mansour, 1980). The use of pesticides has therefore caused additional problems in the case of mite pests rather than alleviating them. Therefore, tests of alternative methods of control, such as the production of resitant cultivars, are needed.

Research throughout the world is focused on breeding melons for insect resistance, but mostly to aphids. Resistance of C. melo to the melon aphid, Aphis gossypii Glover, has been identified (Kishaba et al. 1971), and the mechanism of resistance and genetic aspects of antibiosis to the aphid have been studies (Bohn et al., 1972; Kishaba et al., 1976). Little research, however, has been conducted to determine whether or not resistance factors to mites exist in C. melo.

De Ponti (1978) conducted work on resistace to mites in cucumbers. He developed techniques for evaluation of resistance and determined the role of heritability of the resistance and other characteristics. His work indicated that resistance to tetranychids occurs within the genus Cucumis.

Knipping et al. (1975) investigated resistance to mites in various cucurbits, including two lines of C. melo. Their results indicated that the two lines tested had little or no resistance, although there were some indications of tolerance in one line. The object of the present study was to evaluate a wide range of melon germplasm for its resistance to spider mites.

Materials and methods

The C. melo material tested had been introduced from all over the world, and included breeding lines and commercial varieties from various countries, all from the C. melo germplasm bank in Newe Ya'ar.

Maintenance of the mite stock culture

The mites were reared in a controlled climate room at 25-27°C, 60±5% RH and 16 h light from a series of fluorescent lamps, yielding a light intensity of ca. 2000 lux. The strain of the spider mites T. cinnabarinus used originated from infested leaves of cotton collected in Newe Ya'ar. Rearing was done on 2-3 week-old kidney bean (Phaseolus vulgaris) plants in 25 x 32 x 8-cm pots. To ensure a continuous supply of host-plants, pots were seeded at seven-day intervals. Mites were always transferred from aging plants to the younger ones by placing old leaves infested with mites on 7-10 day-old seedlings. The 20 individual mites used for bioassays were collected and transferred to the plants by means of a fine hair brush.

Preparation of melon plants and screening for resistance

In all experiments, seeds were germinated in 7 x 7 x 17-cm pots using a peat; vermiculite (1:1) growth medium, watered with nutrient solution. The environmental conditions in the rearing room wer 26±1°C, 50-55% RH, and 16 h light form Brolus lamps. The screening tests of the plant material were conducted using a modified de Ponti (1978) technique. Seven to ten seedlings from each of the 32 different lines of melon were grown and tested. To prevent outside infestation, plants were placed in tin trays covered with a 4-mm film of water and spaced to avoid contact between plants. At the fourth-leaf stage, five adult female mites from the laboratory colony were placed on each leaf, so that each plant was infested with 20 mites.

Ten days after the inoculation, the first, second and third true leaves were detached from each plant. Then, four leaf-tissue discs 1 cm in diameter were punched from each leaf and all mobile stages of mites found on each disc were counted. When no mites were found on the discs, the whole leaf was searched.

From each line that had a significantly low mena number of mites, three plants were chosen for future study: two plants with the lowest and one with the highest mite population. These plants were transplanted to larger plots and placed in a greenhouse for observation at the flowering stage, when four leaf-tissue discs 1 cm in diameter were punched out from the fourth, fifth and sixth leaves from the stem apex. The mobile stages of mites found on each disc were counted.

Results

The average number of mites on each of the 32 melon lines at the fourth-leaf stage of growth is shown in Table 1. The numbers differed significantly. Counts ten days after infestation ranged from 3-5 to 57 mites per four leaf discs (an 11-fold increase over the initial number). Out of the 32 entries tested, six lines (BUS, CHI, COR2, COR4, CON and CRO) had a count as low or lower than the number with which they were infested. As no dead mites were observed on the leaf discs, it is likely that the mites were, for an unknown reason, repelled by plants and/or had a very low reproduction rate.

Fourteen lines were included in the flowering stage test, and the mite counts at this stage are given in Table II. On tow of the lines, BUS and CHI, no mites could be found on any of the leaves sampled. Another line, FAC, had low counts on all three plants (3-1, 1-0 and 0-0 mites on four leaf discs). All the three lines had also had low mite counts at the fourth-leaf stage of growth. The remaining lines had high counts, indicating that the mites flourished and reproduced on the leaves.

Discussion

The results suggest there is definite variation among C. melo germplasm as to mite resistance. In two lines, CRE and CHT, plants with the highest mite counts did not survive to the flowering stage because of defoliation caused by the heavy infestation. Generally, younger plants have a stonger mite-repelling factor than older flowering plants, which are more attractive to mite survival and reproduction. The three lines that maintained a high level of resistance to mite both at the fourth-leaf and flowering stages are genetically of interest. However, clarification of the phenomenon necessitates further studies, and its rate of heritability requires progency testing; both are currently under way.

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Table 1. The mean number of mobile stages of Tetranychus cinnabarinus on 32 melon lines at the fourth-leaf stage

Line	Mean no. of mobile mites on 4 leaf discs each 1 cim in diam. *
ENZ	56.7 a
CM	52.2 ab
BEL	45.8 bc
EBE	45.3 bc
NY	39.7 cd
ERG	32.1 dc
ENZB	26.9 cf
CORI	23.8 cfg
BUST	19.0 fgh
DUD	18.9 fgh
BES	18.7 fgh
BUH	18.7 fgh
CBE	17.2 ghi
CH6	14.8 ghij
CHT	11.9 hijk
CHF	11.9 hijk
DOU	11.8 hijk
DEL	11.7 hijk
CRH	11.6 hijk
CDW	11.3 hijk
CRE	10.3 hijk
EDI	9.6 hijk
FAC	8.3 ijk
COR3	8.1 ijk
CHII	7.5 jk
ERZ	7.1 jk
CHI	6.0 jk
BUS	5.0 k
COR2	4.8 k
COR4	4.5 k
CON	4.4 k
CRO	3.5 k

*Means with the same letter are not significantly different at the 5% level, according to Duncan's multiple range test.

Table 2. The mean numbers of mobile stages of Tetranychus cinnabarinus on 14 melon lines at the fourth-leave and flowering stages[t]

Line	Plant no.	No.	Variation range*	s.c.	No.	Variation range*	s.c.
CHI	7	0-7	1	0-1	0-1	1	0-12
	8	0-3	1	0-1	0-0	0	0-0
	3	7-7	2	0-2	0-0	0	0-0
BUS	3	2-0	2	0-2	0-0	0	0-0
	7	2-0	2	0-2	0-0	0	0-0
	9	9-7	3	0-3	0-0	0	0-0
CRE	1	2-0	2	0-2	12-9	34	4-25
	3	3-2	4	0-4	23-1	50	6-25
	2	5-0	5	0-5	--	--	--
CORI	4	2-8	3	0-3	12-0	14	1-75
	8	4-0	4	0-4	16-0	13	1-62
	6	16-0	9	0-9	6-5	13	1-62
CRO	1	0-8	2	0-2	22-3	21	2-6
	3	2-4	5	0-5	24-6	21	2-6
	9	0-0	0	0-0	35-8	54	6-75
COR3	1	0-8	1	0-1	21-7	20	2-5
	8	1-6	2	0-2	29-6	55	6-87
	10	4-3	4	0-4	7-9	14	1-75
CDW2	2	2-0	2	0-2	32-6	43	5-38
	9	0-8	1	0-1	18-0	31	3-87
	7	11-7	6	0-6	54-7	69	8-62
COR4	1	0-32	1	0-1	13-9	11	1-38
	8	0-8	1	0-1	25-2	24	3-0
	6	4-3	5	0-5	14-1	15	1-87
CHT	8	2-8	2	0-2	5-1	11	1-38
	10	1-2	1	0-1	2-9	8	1-0
	2	9-3	3	0-3	--	--	----
CR75	3	2-0	2	0-2	6-8	12	1-5
	7	3-0	3	0-3	---	--	----
	6	5-2	4	0-4	19-7	33	4-12
CHF2	4	2-0	1	0-1	6-7	10	1-25
	6	2-8	2	0-2	12-3	26	3-25
	1	6-3	3	0-3	11-5	13	1-62
EBZ	4	0-8	2	0-2	5-8	10	1-25
	5	0-32	1	0-1	4-7	10	1-25
	2	6-3	7	0-7	10-1	26	3-25
FAC	5	0-8	1	0-1	3-1	5	0-62
	6	0-8	1	0-1	1-0	3	0-37
	9	8-0	5	0-5	0-9	4	0-5
ED147	3	1-5	2	0-2	31-0	56	7-0
	6	4-5	4	0-4	9-0	17	2-12

[t] Studies were on the two plants of each line that at the fourth-leaf stage, had the lowest mite numbers and the one plant that at that stage, had the highest mite number.
* Variation range = the highest number minus the lowest number.
- Plants did not survive to the flowering stage because of defoliation as a result of heavy infestation with mites.

C. The evaluation of antibiosis for selected lines for resistance of melon to the carmine spider mite, Tetranychus cinnabarinus (Acari: Tetranychidae)

Introduction

Tetranychus cinnabarinus (Boisduval) is a major pest of many commercial Cucurbitaceae (including melon) causing serious damage and reductions in yield and quality of fruits (Avidov & Harpaz, 1969). Difficulties in controlling spider mites in different row crops are well known world-wide (Hussey & Scopes, 1985; Van de Vrie, 1985; Wysoki, 1985). During recent years, efforts have therefore been intensified to develop new methods for spider mite control, including the development of resitant lines (De Ponti, 1982).

The resistance of 32 melon lines to T. cinnabarinus was studied in Israel (Mansour et al., 1987). At the four-leaf and flowering stages, two lines had significantly fewer mites than the other lines. Since selection for resistance to spider mites and other pests is restricted mainly to evaluating plant effect on oviposition (De Ponti, 1982), the object of the present study was to evaluate antibiosis of these two selected muskmelon lines to the pest.

Materials and Methods

Maintenance of mite stock culture and preparation of melon plants and environmental conditions were described by Mansour et al. (1987). Twenty-five to 40 melon plants per line of the five lines selcted to provide resistance to mites (CHI, BUS) and of the susceptible line (NY) wre prepared. The progenies tested resulted from self pollination of plants selected in a previous generation for a high level of antibiosis level to mites.

The BUS line has short internodes, hairy leaves, a very compact growth and small fruit. The CHI line has a prostrate growth habit, longer internodes, and almost glabrous stems and leaves. The NY line used as a susceptible control is an Israeli line, homozygous for plant and fruit characteristics.

At the four-leaf stage, five to eight discs 20 mm in diameter were punched from the leaves of each plant and placed upside down, on filter paper. A ring of 'Tanglefoot' glue was applied to the cut edges. One single mite, three to five days old, was transferred from a colony kept on bean leaves and placed on each disc. Five experiments were made with a total of 203 mites tested for each line. In the individual experiments, the numbers of mites per line were, respectively 8, 15, 40, 100. Each experiment had a completely randomized design. In subsequent analyses of varience of the data, the five experiments were taken as five 'blocks' and all of each experiment's discs for a particular line were taken as constituting a 'plot', in the analyses, plot values were weighed by the number of discs per plot. Each filter paper was placed on a

sheet of foam plastic, floating on water, in a petri dish (90 mm diamter). Dishes with mites were kept in a controlled climate room at 25-27° C, 60 ± 5% RH and 16 h light, the latter from a series of Growlux and fluorescent tubes, yielding light intensity of ca. 2000 lux.

Records on live, dead and/or trapped mites and oviposition data were taken seven days following inoculation. In addition, another experiment was conducted as described above, except that records on live mites, on those dead or trapped in the glue, and on oviposition were made daily for four days. Sixteen mites were used for each line in four replicates in a randomized block design.

Results and discussion

Results from a laboratory evaluation of several variates measuring antibiosis to spider mites in resitant and susceptible melon lines are presented in Table 1. Even though data were collected only seven days after inocluation, the values of most variates were less for the BUS and CHI lines than for NY. The lines CHI-8, BUS-7, and BUS-3 caused significant reductions in number of live mites, an increase in the number of dead mites and significant repellence of mites, trapping them in the glue rings. The increased number of mites caught in the glue is the result of a greater level of activity - this is quite likely to be a repellent effect but it may not be.

All the BUS and CHI lines exhibited more resitance than NY did. The effect of the resistant lines was most pronounced on mite fecundity. All lines, except CHI-3, caused significant reduction in the average number of eggs per female produced in the seven day period, compared with the susceptible lines NY. Accordingly, there was significant reduction in the average total number of juveniles produced by each female. All resistant lines caused a significantly lower average daily fecundity, compared with the susceptible NY line. On lines CHI-8, BUS-7, and BUS-3, daily mite fecundity was reduced to 49% , 40% and 33% respectively of that on NY (based on results in table 1).

A similar resistance reaction by mites to plants with a distinctly different growth habit may indicate that the nature of this resistance is not related to plant form and shape, but rather to a common cause, physiological or biochemical in nature.

Oviposition records on a day-to-day basis during four-day periods are summarized in Table 2. On the susceptible NY line, the initial number of eggs/female/day (E/F/D) was highest and increased by an average of ca. 80% during the third and fourth days. On BUS-7 the E/F/D on day one was only slightly less than on NY line. The initial number of E/F/D in all resistant lines (except BUS-3) was significantly lower, and remained lower throughout the four-day experimental period. However, the rate of oviposition on consecutive days was considerably reduced, as on other resistant lines. The initial high count on a BUS-3 plant may be an experimental error.

Oviposition rates on all resistant lines were apperciably less in experiment 2 (Table 2) than in experiment 1 (Table 1); this could be the result of environmental factors and experimental errors. Mites on lines CHI-8 and CHI-3 had specially low oviposition rates, 0.05 and 0.07 E/F/D respectively.

The oviposition data in Table 2 are corroborated by the data on mite mortality and the mites trapped in glue (Table 2). These effects were evident in all lines on the second experimental day, resulting in an increase of over 80% in mites dead or trapped. These data explain in part the greater reduction of rates of reproduction, 76-97%, on resistant lines than on the susceptible NY. The nature of the resistance implies three main effects on mites, namely starvation and mortality caused by unsuitable cell sap, repellence and reduction in fecundity.

Plants of P-1 and S-1 of the resistant BUS and CHI and the susceptible NY lines are classified into E/F/D classes in Table 3. In the original P-1 BUS and CHI population, 48% and 44% of the plants, respectively had counts of more than 2.0 E/F/D and only 15% and 22% of the BUS and CHI plants, respectively, led to the production of fewer than 1.0 E/F/D. These data closely resemble those for the behavior of mites on the susceptible NY line. Selfing the resistant parents resulted, in all progenies, in a dramatic increase in the number of plants with fewer that 1.0 E/F/D ranging from 37% to 85% (Table 3).

These data emphasize the heritable nature of the resistance in our melon lines in terms of mite mortality repellence and fecundity, and suggest that, in the course of time, this character might be used in breeding programmes.

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Table 1. Laboratory evaluation of antibiosis to the mite Tetranychus cinnabarinus of selected melon lines at 4-leaf growth stage, 7 days following inoculation of detached leaf discs with one/F/disc.

Melon line	Live	Dead	Trapped in glue	'Female/7 days'		
				Eggs	Juvenile	Fecundity
	%	%	%			
NY	40.4 a	8.6 b	48.1 b	9.71 a	3.79 a	1.93 a
CHI-3	31.0 ab	18.0 ab	50.9 b	7.92 ab	2.97 b	1.56 b
CHI-7	27.8 b	21.4 a	0.7 b	4.65 bc	2.48 bc	1.02 bc
CHI-8	26.6 b	8.0 b	65.7 a	4.47 bc	2.12 c	0.94 bc
BUS-7	26.1 b	21.4 a	62.5 a	3.96 c	1.41 d	0.77 c
BUS-3	22.7b	15.7 ab	61.6 a	3.38 c	1.12 d	0.64 c

Mean separation within columns, by Duncan's multiple range test (D.F. for error = 20). Figures followed by the same letter are not significantly different at 5% level. The analyses for percentages were carried out after angular transformation.

Table 2. Reproduction characteristcs (recorded daily) of females Tetranychus cinnabarinus on melon lines with different levels of resistance.

	*Eggs/Female/Day					
			Proport.			
Period	1	2	3	4	Average	diff.
line						
NY	1.43a	1.38a	2.65a	2.43a	1.97	
BUS-7	1.18a	0.13a	0.18b	0.38b	0.47	-76%
BUS-3	0.68ab	0.25ab	0.13b	0.44b	0.37	-81%
CHI-7	0.50bc	0.19b	0.18b	0.44b	0.33	-83%
CHI-8	0.13c	0.00	0.06b	0.00	0.05	-97%
CHI-3	0.13c	0.00	0.00	0.13b	0.07	-96%

** mortality + trapped in glue (counts out of 16)

NY	7	8	9
BUS-7	13	14	14
BUS-3	13	14	14
CHI-8	13	14	16
CHI-3	13	13	13
CHI-7	14	14	14

* mean separation, within columns, by Duncan's Multipe Range Test at Test at P = 0.05. Differences between figures not followed by the same letter are statistically significant. The analysis for the E/F/D was carried out after log transformation in order to stabilize the variance which depends upon the mean. ** For each column, a chi squared test with 1 d.f. showed that the proportion dead and trapped differed significantly, at the 1% level, between NY and the other lines.

Table 3. Distribution to oviposition classes, of plants from the susceptible cultivar, the original open-pollinated resistant lines, and their self pollinated progenies.

		Classes of number of eggs/female/day					
		2.0		1.5-2.0	1.5-1.0	1.0	
Generation	Line	no.	%	no.	no.	no.	%
Original	NY	14	50	2	4	7	26
Open Pollination	BUS	13	48	3	7	4	15
	CHI	12	44	3	6	6	22
Self Pollination	CHI-3	2	7	5	10	10	37
	CHI-7	0	0	4	5	18	67
	CHI-8	3	11	2	5	17	63
	BUS-3	0	0	1	3	23	85
	BUS-7	2	7	1	4	20	74

D. Evaluation of Watermelon Cultivars for Resistance to Spider Mites

Introduction

Watermelons are one of the major commercial horticultural crops produced in Oklahoma. As with most horticultural crops the successful marketing of melons is dependent upon growing high quality fruit with little pest damage. Various insect and mite pests feed on and affect watermelon yield and quality.

Spider mites, including Tetranychus urticae Koch, feed on leaves and fruit and may cause damage by reducing plant photosynthate available for production of fruit or 'russetting' of fruit. Current management of mites is dependent upon application of pesticides. Development of an IPM program for watermelon production should incorporate evaluation of host plant resistance. Therefore, tests were conducted to screen available commercial cultivar resistance levels to mites.

Methods and Materials

Mite Colony. A colony of the twospotted spider mite, Tetranychus urticae Koch, was maintained at the Wes Watkins Agricultural Research and Extension Center (WWAREC) on bean, Phaseolus vulgaris L. Mites were originally collected from cotton in south Texas and had been maintained on bean plants in a culture for 2 years prior to these tests. Bean plants with mites were grown in screen cages with 24 hr photophase. Temperatures ranged between 70 and 85° F.

Field Screening of Watermelon cultivars. Seven watermelon (Citrullus lunatus) cultivars, 'American Sun Triploid' (seedless), 'All-Sweet', 'Black Diamond', 'Calhoun Gray', 'Charleston Gray', 'Crimson Sweet' and 'Jubilee' were transplanted to field plots at the 2-3 true leaf stage on May 25, 1989. The experimental design was a randomized complete block with 5 replicates. Plots were 32 ft long with 15 ft center spacing and 4 ft plant spacing. Plants were drip irrigated.

Watermelon plants were inoculated with spider mites from the laboratory colony on June 20, June 30, and July 10, 1989. Plots were inoculated by placing 2-3 mite infested lima bean plants in the center of each watermelon plant. Weekly applications (June 23 through July 31) of Asana (0.0125 lb ai./acre) and Bravo 720 (1.5 pts/acre) were made to all plots to induce mite outbreaks.

Surveys of field plots were conducted July 18 and August 3 to determine mite abundance. Plots were sampled by randomly selecting 3 vines per plot; one in the middle and each end of each plot. The first fully expanded leaf on each vine was removed, then the 7th, 14th and 21st leaf down that vine was removed. All adult female mites on the upper and lower surface of each leaf were counted and the area of the leaf measured with a Li-Cor 3000 area meter. The number of female mites per cm^2 was calculated.

Results and Discussion

Cultivar resistance to mites was evaluated by determining mite populations on leaves under field conditions. Relative resistance among common cultivars was based on differences in density of mite populations per unit leaf area. An assumption made in using this relative measure of resistance is that some inherent 'resistance' factor in the cultivars results in reduced abundance of mites indicated by the survey methods.

Mites were abundant and observations indicated that damage from mite feeding was causing significant leaf senescence by August 3. Results of surveys of mite populations on July 18 and August 3 are indicated in Table 1. Mite densities were significantly greater on 'Jubilee' than on the other cultivars on both survey dates. Mite densities on July 18 were lower on 'Black Diamond' and 'Crimson Sweet' than on the other cultivars. By August 3 mite populations had increased on 'Crimson Sweet' but remained the same on 'Black Diamond'. Densities among cultivars on August 3 ranged from 0.035/cm² to 0.008/cm² which is a 44X difference.

Repeated and more closely controlled laboratory and greenhouse studies should be conducted to determine whether these differences are due to inherent stable factors of the cultivars. This large scale field screening for resistance to mites indicates that variability in resistance to mites occurs among commercially available cultivars of watermelons. If future evaluations result in similar differences in mite populations and subsequent differences in profits, then cultivars should be ranked in terms of resistance as a producer aid.

Table 1. Mean number of adult female twospotted spider mites on seven cultivars of watermelon, Lane, OK, 1989.

Cultivar	Leaves	Mites/cm² July 18	Mites/cm² August 3
'Jubilee'	60	0.038 a	0.035 a
'All-Sweet'	60	0.014 b	0.022 bc
'Calhoun Gray'	60	0.014 b	0.020 bc
'Charleston Gray'	60	0.012 b	0.014 cd
'American Sun'	60	0.010 b	0.026 b
'Black Diamond'	60	0.008 b	0.008 d
'Crimson Sweet'	60	0.006 b	0.017 bc

Means in a column followed by the same letter are not significantly different (P = 0.05; Duncan's NMRT).

IV. Description of cooperation

Germplasm was exchanged between locations with watermelon plant introductions sent to Israel and muskmelon breeding lines sent to the U.S.A. Similar techniques were used in evaluation of all lines for resistance and lines exhibiting resistance were exchanged between locations. Resistant germplasm was evaluated in each location under pressure from mite populations used at each research location.

The two Israeli P.I.'s visited the U.S.A. to confer with the U.S.A. scientists in 1988. Two of the U.S.A. scientists visited Israel to observe production and to confer with Israeli scientists.

A proposal was developed and submitted to BARD in 1989 to continue the research and to initiate the development of resistant germplasm based on results of this project that was focused on identification of resistance. The second proposal was rejected in 1989 but will be revised and submitted in 1991.

V. Evaluation of achievements

An objective of the research was to determine methods of evaluating melon germplasm for resistance to mites. Several laboratory and greenhouse methods were evaluated and found to be valid in terms of projecting results under field conditions. The techniques can thus be used to conduct mass screening under controlled conditions throughout the year.

A second objective of the research project was to evaluate and identify melon germplasm with resistance to spider mites. Approximately 500 muskmelon lines and 7 cultivars of watermelon were evaluated and a large range of resistance to mites was noted.

A third objective of the project was to determine mechanisms of resistance and heritability of the characteristics. This objective was accomplished.

In summary, all objectives were accomplished and manuscripts prepared for publication. Two peer reviewed manuscripts have been published, one is in peer review and two technical reports were published. A continuation proposal has been developed to focus on incorporation of the resistance characteristics into melon cultivars for commercial use.

VI. List of publications

East, D.A., J.V. Edelson, E.L. Cox and M. K. Harris. 1989. Search for resistance in muskmelon to spider mites. Texas Agric. Expt. Stn. Progress Report, PR-4677, 10 pp.

East, D.A. and J.V. Edelson. 1990. Evaluation of watermelon cultivars for resistance to spider mites. Oklahoma Agric. Expt. Stn., Research Report, P-914, 8 pp.

East, D.A., J.V. Edelson, E.L. Cox and M.K. Harris. (In Review). Evaluation of screening methods and search for resistance in muskmelon, Cucumis melo L., to the twospotted spider mite, Tetranychus urticae, Koch. Crop Protection.

Mansour, F., Z. Karchi and N. Omari. 1987. Resistance of melon to the carmine spider mite, Tetranychus cinnabarinus (Boisduval) (Acari: Tetranychidae). Bull. ent. Res. 77:603-607.

Mansour, F., and Z. Karchi. 1990. The evaluation of antibiosis for selected lines of resistance of melon to the carmine spider mite Tetranychus cinnabarinus (Acari: Tetranychidae). Bull. ent. Res. 80:

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