A Dominant Gene Conferring Resistance to Fusarium Wilt in Cucumber

D. Netzer, S. Niego, and E. Galun

Research Plant Pathologist, Agricultural Research Organization, Bet Dagan, Israel; Plant Breeding Assistant, and Irene and David Schwartz Professor of Plant Genetics, respectively, Weizmann Institute of Science, Rehovot, Israel.

This research was supported in part by the Ministry of Agriculture, Israel.

We thank Chaim Weintal for technical assistance.

Contribution No. 207-E (1976 Series) from the Agricultural Research Organization, The Volcani Center, Bet Dagan, Israel.

Accepted for publication 28 October 1976.

ABSTRACT

NETZER, D., S. NIEGO, and E. GALUN. 1977. A dominant gene conferring resistance to Fusarium wilt in cucumber. Phytopathology 67:525-527.

A single-spore culture of an isolate of *Fusarium oxysporum* f. sp. *cucumerinum* from a wilted cucumber plant in the Samaria area, was utilized to test wilt resistance in cucumber lines and cultivars. Only one inbred line, WIS-248, from the introduction collection at the Weizmann Institute of Science, showed resistance. This line also was resistant to additional isolates of *F. oxysporum* f. sp. *cucumerinum*. Analysis of progenies of crosses between the resistant WIS-248 line and a susceptible inbred cultivar (Shimshon) as well as of backcross progenies to the susceptible parental cultivar indicated that resistance to Fusarium wilt is controlled by a dominant gene tentatively designated *Foc*.

Additional key words: *Cucumis sativus*, breeding for disease resistance.

Fusarium wilt and foot-rot of cucumber (*Cucumis sativus* L.) have been described in many parts of the world. In several countries; e. g., Japan [cited by Komada and Ezuka (7)], The Netherlands (14), United States (9), England (4), and Israel (3, 11), cucumber wilt causes serious economic damage. The cucumber wilt pathogen, *Fusarium oxysporum* f. sp. *cucumerinum* (Schlecht.) Owen, is specific to this host (1, 10).

Tests of *F. oxysporum* isolates from wilted melon, watermelon, and cucumber, collected from various locations in Israel and used for cross-inoculation experiments, verified that only those isolates from cucumber, were *F. oxysporum* f. sp. *cucumerinum* (3).

In heavily infested fields, profitable cucumber production is not possible unless resistant cultivars are used. In the course of breeding such cultivars, we investigated the inheritance of resistance to Fusarium wilt in cucumber. Our main findings are reported below.

MATERIALS AND METHODS

The inoculum was derived from a single-spore culture of *F.* oxysporum f. sp. *cucumerinum* No. 706, which was isolated from a wilted cucumber plant collected in the summer of 1970 in northern Samaria. This isolate previously was found (3) to be highly specific to its respective host (*C. sativus*).

Cultures were grown in a liquid medium as suggested by Komada and Ezuka (7) and consisting of the following components (grams per liter of tap water): K_2HPO_4, 1; $MgSO_4 \cdot 7H_2O$, 0.5; KCl, 0.5; Fe-EDTA, 0.01; yeast extract, 1; L-aspargine, 2; D-glucose, 30. To 20 ml of this medium dispensed in 100-ml Roux bottles, 0.5 ml of a dense spore suspension was added. The bottles were kept stationary for 7-8 days at 25 C. The growth of each bottle was macerated in 100 ml of sterile tap water. The suspension then was mixed with 3 kg of sieved, air-dried, and heat-sterilized sandy loam soil. This infested soil contained hyphal fragments as well as micro- and macro-conidia, and had approximately 1.3×10^6 propagules/ml.

The infested soil was placed either in asbestos flats ($24 \times 12 \times 7$ cm) or in Jiffy pots ($10 \times 10 \times 8$ cm) in which 18-20 plants of six or seven lines or one line, respectively, were sown. The plants were maintained in a greenhouse kept at about 28 C air and 26 C soil temperature. Soil moisture was kept optimal for vegetative growth of the cucumber seedlings.

Daily records were kept of the number of wilted plants. Wilt symptoms in susceptible plants began to appear 12 days after sowing and final assessment was made on the 20th day.

Sections of wilted plants were placed on PDA plates for re-isolation of *F. oxysporum* f. sp. *cucumerinum* . The surviving plants were transplanted after an additional 7 days (i. e., on the 27th day after sowing) and grown to maturity for either self- or cross-pollinations.

RESULTS

The following commercial cultivars and breeding line of cucumber were tested for resistance: China, Harris Double Yield (Harris Seed Co., Rochester, NY 14624); Ashley, Chipper, Galaxy (Asgrow Seed Co., Kalamazoo, MI 49001); Aofushinari N=2, Chojitsu-Ochiai N=2, Kagafushinari, Karihafushinari, Natsufushinari, Peking, Saganihanjiro, Shimoshirazu, Taisen-Kema (Nishi Seed Co., Tokyo, Japan); Aodai, Jihai (Takii Seed Co., PO 7, Kyoto, Japan); Ben-Shemen, Bet-Alpha (Hazera Seed Co., Haifa, Israel); and WIS-248. All were maintained by selfing at the Department of Plant Genetics of the Weizmann Institute of Science (WIS). Only the inbred line, WIS-248, was resistant. It also was resistant when tested with five isolates of *F. oxysporum* f. sp. *cucumerinum* obtained from wilted cucumber plants in three regions of Israel (the Esdralon Valley, the coastal region, and the southern Negev Desert). None of the progeny from self-pollination of the WIS-248 line wilted after inoculation with isolate 706. We then crossed WIS-248 with several susceptible cultivars and, in all cases, the F_1 progeny was as resistant as WIS-248. The inheritance of resistance to Fusarium wilt was further tested using the inbred cultivar Shimshon as the susceptible parent (Table 1). The F_2 progeny of the cross WIS-248 × Shimshon segregated in a 3:1 ratio (resistant:susceptible), indicating a single dominant gene for resistance. To obtain further information, F_1 plants of this cross were backcrossed to the susceptible parent (cultivar Shimshon). The F_1 progeny of this backcross segregated in a 1:1 ratio (resistant:susceptible). The same ratio was obtained when either a plant of cultivar Shimshon or the F_1 plant served as the female parent. To test the mode of wilt resistance further, F_2 plants were self-pollinated and the progenies were tested by inoculation with isolate 706. Self-pollination was performed in F_2 plants which had not been inoculated, as well as F_2 plants that had been inoculated, but did not wilt. Eleven and seven progenies of such plants, respectively, were obtained. Of the 11 F_3 progenies of noninoculated F_2 plants, two progenies consisted of susceptible plants only, five of both susceptible and resistant plants, and four of resistant plants only. The five F_3 segregating progenies contained a total of 111 resistant and 40 susceptible plants, approximating a 3:1 ratio (χ^2 = 0.13, P = 0.70-0.80). Three F_3 progenies out of the seven resistant self-pollinated F_2 plants contained resistant plants only, and the four segregating progenies consisted of a total of 161 resistant and 43 susceptible plants, approximating a 3:1 ratio (χ^2 = 1.67, P = 0.10-0.20). When resistant plants of nonsegregating F_3 progenies were self-pollinated, only resistant F_4 plants resulted.

DISCUSSION

The results of inoculation of F_1, F_2, and backcross progenies support the hypothesis that a single dominant gene in WIS-248 controls wilt resistance to isolate No. 706 of *Fusarium oxysporum* f. sp. *cucumerinum*. We propose to designate the alleles controlling resistance and susceptibility as *Foc* and *Foc*$^+$, respectively. Our data indicate further that, when *Foc*/*Foc*$^+$ F_2 plants are self-pollinated, a 3:1 ratio of resistant:susceptible F_3 progeny is obtained and that self-pollination of *Foc*/*Foc* F_3 plants (i.e., resistant plants of nonsegregating F_3 progenies) results in resistant F_4 plants only. A survey of the pathogenicity of *F. oxysporum* f. sp. *cucumerinum* isolates in Israel (Netzer, *unpublished*) did not reveal any isolate that caused a reaction different from that of isolate No. 706 in either susceptible cucumber cultivars or in the resistant WIS-248 line. This does not exclude the possible existence of other isolates in Israel or other countries. When cultivars of the Aofushinari group were inoculated with isolate No. 706, wilting was observed although these cultivars are resistant to Japanese isolates of *F. oxysporum* f. sp. *cucumerinum* (7). Except for a single, short report (13), which suggests that resistance is controlled by three genes, there is no previous information on the inheritance to Fusarium wilt on cucumber. Risser (12) reported on a dominant gene (*Fom 1.2*) for resistance to both races 1 and 2 of the melon wilt pathogen (*F. oxysporum* f. sp. *melonis*). Either one or two dominant genes for resistance to muskmelon wilt had been reported previously by Mortensen (8). Bennett (2) reported that in watermelon Fusarium wilt resistance in F_1 progeny was intermediate between the resistant and the susceptible parent. Henderson et al. (6) studied the

TABLE 1. Tests for resistance to *Fusarium oxysporum* f. sp. *cucumerinum* in progenies of crosses of a resistant inbred line (WIS-248) and susceptible inbred cucumber cultivar Shimshon

Parents and crosses	Plants tested (no.)	Phenotypic segregation (R:S)[a] Expected ratio	Observed number	χ^2	P
WIS-248 (resistant line)	59	all R	59:0	. . .	. . .
Shimshon (susceptible line)	50	all S	0:50	. . .	. . .
F_1 (WIS-248 × Shimshon)	58	all R	58:0	. . .	. . .
F_2 (WIS-248 × Shimshon)					
1[b]	95	3:1	66:29	1.55	.20-.30
2[c]	101	3:1	76:25	0.002	.95-.98
Total	196	3:1	142:54	0.68	.30-.50
BC$_1$ (WIS-248 × Shimshon) × Shimshon					
1[b]	59	1:1	29:30	0.02	.80-.90
2[c]	60	1:1	34:26	1.07	.30-.50
Total	119	1:1	63:56	0.41	.50-.70

[a]Symbols: R = resistant, and S = susceptible.
[b]With Shimshon as the female parent.
[c]With WIS-248 as the female parent.
[d]With F_1 plant as the female parent.

inheritance of Fusarium wilt resistance in several watermelon cultivars and suggested that in cultivar Summit wilt resistance was controlled by a single dominant gene.

Fusarium wilt of cucumber may result in complete loss of the crop. In some locations, grafting of individual plants on a resistant species (*Cucurbita ficifolia* Bouchë) was suggested as the only means of avoiding wilting (5). The finding that a cucumber line has a single dominant gene for resistance to *F. oxysporum* f. sp. *cucumerinum* could be of great economic significance.

LITERATURE CITED

1. ARMSTRONG, G. M., and J. K. ARMSTRONG. 1968. Formae speciales and races of Fusarium oxysporum causing a tracheomycosis in the syndrome of disease. Phytopathology 58:1242-1246.
2. BENNETT, L. S. 1936. Studies on the inheritance of resistance to wilt (F. niveum) in watermelon. J. Agric. Res. 53:295-306.
3. DISHON, I., and D. NETZER. 1971. Pathogenicity tests of Fusarium on cucurbits. Hassadeh 51:833-835. (in Hebrew).
4. FLETCHER, J. T., and H. G. KINGHAM. 1966. Fusarium wilt of cucumbers in England. Plant Pathol. 15:85-89.
5. GROENEWEGEN, J. H. 1953. Het enten van Komkommers en Meloenen. Meded. Dir. Tuinbouw. 16:169-183.
6. HENDERSON, W. R., S. F. JENKINS, JR., and J. O. RAWLINGS. 1970. The inheritance of Fusarium wilt resistance in watermelon, Citrullus lanatus (Thunb.) Mansf. J. Am. Soc. Hortic. Sci. 95:276-282.
7. KOMADA, H., and A. EZUKA. 1974. Varietal resistance to Fusarium wilt in cucumber. I. Relation between the resistance reaction of adult plants in field and that of seedlings in greenhouse. Bull. Veg. Ornam. Crops Res. Stn., Japan, Ser. A., 1:233-245.
8. MORTENSEN, J. A. 1959. The inheritance of Fusarium resistance in muskmelons. Diss. Abstr. 19:2209.
9. OWEN, J. H. 1955. Fusarium wilt of cucumber. Phytopathology 45:435-439.
10. OWEN, J. H. 1956. Fusarium wilt, caused by Fusarium oxysporum f. cucumerinum n.f. Phytopathology 46:153-157.
11. PALTI, J., and A. Z. JOFFÉ. 1971. Causes of the Fusarium wilts of cucurbits in Israel and conditions favouring their development. Phytopathol. Z. 70:31-42.
12. RISSER, G. 1973. Étude de l'hérédité de la resistance du melon (Cucumis melon) aux races 1 et 2 de Fusarium oxysporum f. melonis. Annals Amél. Plantes 23:259-263.
13. TOSHIMITSU, Y., and T. NOGUCHI. 1975. Inheritance of resistance to Fusarium wilt in cucumber. Pages 150-151 *in* Proc. Mtg. Japn. Hortic. Soc. (in Japanese). [Summarized *in* T. Kawaide, 1975. Breeding for disease resistance in vegetable crops in Japan. Part I. Cucurbit. Japn. Agric. Res. Quart. 9 (4):181-246]:212-216.
14. VAN KOOT, Y. 1943. Enkele onderzoekingen betreffende de Fusariumziekte bij de komkommer. Tijdschr. Plantenziekt. 49:52-72.