Inheritance of Resistance to the Florida Strain of Zucchini Yellow Mosaic Virus in Watermelon

R. Provvidenti

Cornell University, New York State Agricultural Experiment Station,
Department of Plant Pathology, Geneva, NY 14456

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Abstract. A high level of resistance to zucchini yellow mosaic virus (ZYMV) was found in four landraces of *Citrullus lanatus* (Thunb.) MatSum. & Nakai (PI 482322, PI 482299, PI 482261, and PI 482308) originally collected in Zimbabwe. This resistance is specific to the Florida strain of the virus (ZYMV-FL), which prevails in the United States. Inheritance studies were conducted by using a single-plant selection (PP261-I) of PI 482261 and the ZYMV-susceptible watermelon cultivar New Hampshire Midget. In F₁, F₂, and reciprocal backcross populations, resistance was conferred by a single recessive gene to which the symbol *zym* is assigned. There was no linkage between *zym* and one of the three homodimer bands of the isozyme phosphoglucosomerase (*Pgi-2b*), which was found in PP261-1, and in other ZYMV-FL resistant plants.

Since its discovery and characterization in 1981, zucchini yellow mosaic virus (ZYMV) has been found in many countries on five continents and is considered one of the most important viruses affecting the Cucurbitaceae (Lisa and Lecoq, 1984). Sources of heritable resistance to this virus in cucumber (*Cucumis sativus*), melon (*C. melo*), and squash (*Cucurbita* spp.) have been found (Pitrat and Lecoq, 1984; Provvidenti, 1987,

1990); breeding programs are underway in the United States and other countries for the development of resistant cultivars. ZYMV has also caused losses to watermelon, and, in the Middle East, particularly in Egypt, this virus has caused devastating epidemics in the last decade (Provvidenti et al., 1984b). A good level of resistance to ZYMV is available in some accessions of Egusi (*Citrullus colocynthis* Schrad.), a wild relative of the cultivated watermelon from Nigeria (Provvidenti, 1986a). Although this resistance is currently being used in the United States and Egypt, the acquisition of additional germplasm of *C. lanatus* with resistance to ZYMV would be useful for breeding programs. In

1986, we obtained from the U.S. Dept. of Agriculture Germplasm Resources part of a large collection of landraces of *C. lanatus* gathered in Zimbabwe in 1982 by Toll and Gwarazimba (1983). The purpose of our study was to identify sources of resistance to three diverse strains of ZYMV and to elucidate the mode of inheritance.

Seeds of 57 plant introductions (PI) were supplied by V. Gwarazimba of the Harare Research Station, Causeway, Zimbabwe, and those of several watermelon cultivars were obtained from commercial sources and the Central Florida Research and Education Center, Leesburg. In screening for resistance, 20 plants of each line were tested with each of the following strains: ZYMV-Connecticut (ZYMV-CT), ZYMV-Florida (ZYMV-FL), and ZYMV-Egypt (ZYMV-E). Viral strains were routinely maintained in plants of 'Seneca Zucchini' squash, which were also used as the source of inoculum. Inocula were prepared by macerating young symptomatic leaves with 0.05 M phosphate buffer at pH 8.5. Extracts were rubbed individually on the cotyledons and the first fully expanded leaves of test plants previously dusted with Carborundum. All plants were maintained in an insect-free greenhouse at 25 to 30°C. ZYMV-inoculated plants, regardless of their reaction, were assayed for virus infection using enzyme-linked immunosorbent assay (ELISA). A ZYMV antiserum was available from a previous study (Provvidenti et al., 1984a).

All plants of the 57 PIs and 11 commercial cultivars were found to be susceptible to ZYMV-CT and ZYMV-E. Similarly, plants of all the cultivars and 53 of 57 PI were susceptible to ZYMV-FL, but the following accessions yielded many resistant plants: PI 482261 (45%), PI 482299 (60%), PI 482308

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Table 1. Inheritance of resistance to zucchini yellow mosaic virus, Florida strain (ZYMV-FL), in progenies from the cross *Citrullus lanatus* PP261-1 (from PI 482261) with the susceptible cultivar New Hampshire Midget (NHM).

Progeny	Plants (no.)		Expected ratio	χ^2	P
	Resistant	Susceptible			
PP261-1	70	0			
NHM	0	47			
PP261-1 × NHM					
F ₁	0	23			
F ₂	25	89	1:3	0.573	0.46
NHM × PP261-1					
F ₁	0	28			
F ₂	24	80	1:3	0.205	0.63
BC (F ₁ × NHM)	0	60			
BC (F ₁ × PP261-1)	22	27	1:1	0.510	0.48

(80%), and PI 482322 (90%). Resistant plants of these four lines were selfed and their progenies were confirmed to be resistant to ZYMV-FL. No local or systemic infection was detected by ELISA or by using zucchini squash as an indicator host. As expected, the same selections were susceptible to ZYMV-CT and to ZYMV-E, indicating that resistance was viral strain specific.

A single plant selection PP 261-1 (from PI 482261) was used as the seed parent in crosses with 'Crimson Sweet', 'Charleston Gray', 'Dixie Queen', 'Dixie Lee', 'Florida Giant', 'Kleckley Sweet', 'Jubilee', 'Mick-eylee', 'Minilee', 'New Hampshire Midget', and 'Sugar Baby' watermelon. Fifteen plants each of the resulting F₁ hybrids were tested with ZYMV-FL and all showed systemic symptoms associated with ZYMV infection: severe mosaic, leaf distortion, and plant stunting. Identical results were obtained when PP261-1 was used as the pollen parent, indicating that resistance was inherited recessively. Because plants were grown exclusively under greenhouse conditions, the early maturing cultivar 'New Hampshire Midget' (NHM) was chosen for further inheritance studies.

The F₂ populations from crosses PP 261-1 × NHM and the reciprocal NHM × PP261-1 segregated in the ratio 1 resistant : 3 susceptible (Table 1). Plants of the backcross to the susceptible parent, (NHM × PP261-1) × NHM, were all susceptible, whereas those of the backcross to the resistant parent, (NHM × PP261-1) × PP261-1, segregated in the ratio 1 resistant : 1 susceptible. Consequently, the high level of resistance to ZYMV-FL in PP261-1 is conditioned by a single recessive gene, to which the symbol *zym* is assigned.

Navot and Zamir (1986) investigated the linkage relationship of 19 isozyme genes in *C. lanatus* and *C. colocynthis* and found two loci for the isozyme phosphoglucosomerase, *Pgi-1* and *Pgi-2*. In a preliminary study using the methods of Wendel and Weeden

(1989), we confirmed the presence of *Pgi-1* and *Pgi-2* in the 11 commercial cultivars and in the ZYMV-FL resistant selections. All lines appeared to be monomorphic for *Pgi-1*, but there were three different banding patterns for *Pgi-2*. The fast homodimer band (*aa*) was confined to several plants of PI 482308, the intermediate homodimer (*bb*) was noted in plants of PI 482261, PI 482299, PI 482308 and 482322, whereas the slow homodimer (*cc*) was present in all commercial cultivars tested (R.P., unpublished data). The association of ZYMV-FL resistance and *Pgi-2b* prompted me to explore the possibility of using *Pgi-2b* as a marker in breeding for resistance to ZYMV-FL. Each plant of the backcross PP261-1 × (PP261-1 × NHM) was analyzed for the presence of *Pgi-2b* and then inoculated with ZYMV-FL. The 49 plants of this test cross segregated as follows: 14 were homozygous for both *zym* and *Pgi-2b*; eight plants possessed *zym/zym* and *Pgi-2b/+*; 16 plants contained *zym/+* and *Pgi-2b/Pgi-2b*; and 11 plants were heterozygous *zym/+* and *Pgi-2b/+*. Analyses of these data for linkage showed that the two genes are independently inherited ($P = 0.38$). However, *Pgi-2b* was a valuable marker in determining whether some of the populations were the result of true crosses.

The center of origin of the watermelon is considered to be the Kalahari (Toll and Gwarazimba, 1983), and this is reflected in the wide genetic diversity found in landraces of *C. lanatus* from that region of Africa. A range of plant size, leaf types, fruit characteristics, and maturity occurred in the Zimbabwe collection. Some lines produced fruits with sweet, red flesh, while in others the flesh was yellowish, very firm, and low in sugar. In Zimbabwe, these latter types are stored for months and used for cooking and animal feed (Toll and Gwaranzimba, 1983). Plants of PI 482261, PI 482299, PI 482308, and PI 482322 possess these last characteristics and may be considered as primitive

forms (landraces) of the cultivated watermelon.

At present, there are two sources of resistance for the control of ZYMV; both inherited recessively. The first is not viral strain-specific and is available in some accessions of the Nigerian Egusi (e.g. PI 494528 and PI 494532) (Provvidenti, 1986a). However, this resistance is temperature-dependent and it is best expressed in warm or hot climates. The second reported herewith confers a very high level of resistance at any temperature, but is specific for ZYMV-FL. My surveys have indicated that this strain prevails in the continental United States and Hawaii (Provvidenti, 1986b); hence, *zym* can be very useful in the development of resistant cultivars. Future work will determine whether these two types of resistance can be combined to achieve a more durable, wide-spectrum resistance to ZYMV in watermelon.

Literature Cited

- Lisa, V. and H. Lecoq. 1984. Zucchini yellow mosaic virus. Descriptions of plant viruses no. 282. Cmwlt. Mycol. Inst./Assn. Applied Biol. Kew, Surrey, England.
- Navot, N. and D. Zamir. 1986. Linkage relationships of 19 protein coding genes in watermelon. Theor. Applied Genet. 72:274-278.
- Pitrat, M. and H. Lecoq. 1984. Inheritance of zucchini yellow mosaic virus resistance in *Cucumis melo* L. Euphytica 33:57-61.
- Provvidenti, R. 1986a. Reactions of accessions of *Citrullus colocynthis* to zucchini yellow mosaic virus and other viruses. Cucurbit Genet. Coop. Rpt. 9:82-83.
- Provvidenti, R. 1986b. Occurrence of zucchini yellow mosaic virus in the United States in 1985. Cucurbit Genet. Coop. Rpt. 9:96.
- Provvidenti, R. 1987. Inheritance of resistance to a strain of zucchini yellow mosaic virus in cucumber. HortScience 22:102-103.
- Provvidenti, R. 1990. Viral diseases and genetic sources of resistance in *Cucurbita* species, p. 427-435. In: D.M. Bates, R.W. Robinson, and C. Jeffrey (eds.). Biology and utilization of the Cucurbitaceae. Comstock Publ. Assoc. and Cornell Univ. Press.
- Provvidenti, R., D. Gonsalves, and H.S. Humaydan. 1984a. Occurrence of zucchini yellow mosaic virus in cucurbits from Connecticut, New York, Florida, and California. Plant Dis. 68:443-446.
- Provvidenti, R., H.M. Munger, and A.O. Paulus. 1984b. Epidemics of zucchini yellow mosaic virus in Egypt in the Spring of 1983. Cucurbit Genet. Coop. Rpt. 7:78-79.
- Toll, J. and V. Gwaranzimba. 1983. Collecting in Zimbabwe. Plant Genet. Resources Nwsl. ACP:PGR/53:2-5.
- Wendel, J.F. and N.F. Weeden. 1989. Visualization and interpretation of plant isozyme, p. 5-45. In: D.E. Soltis and P.S. Soltis (eds.). Isozymes in plant biology. Dioscorides, Portland, Ore.