Inheritance of Resistance to Watermelon Mosaic Virus 2 in Phaseolus vulgaris

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ABSTRACT

Resistance to watermelon mosaic virus 2 (WMV-2) was found to be widespread in *Phaseolus vulgaris*. Of 280 bean accessions tested, 229 were resistant, 22 developed a local reaction, 21 were systemically infected (susceptible), and 8 were heterogeneous populations. Among resistant lines, a few responded with a severe necrotic hypersensitive reaction when graft-inoculated, or when mechanically inoculated and incubated at 35 C. In F_1, F_2, and reciprocal F_1 backcross progenies of resistant × susceptible and hypersensitive-resistant × susceptible lines, resistance was monogenically dominant. On susceptible genotypes, foliar and pod symptoms incited by WMV-2 were similar to those caused by some strains of bean yellow mosaic virus.

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Watermelon mosaic virus 2 (WMV-2) was first found to affect cucurbits in central New York State in 1969 (9). Since then, the virus has been recovered from naturally infected plants of several leguminous species, including *Phaseolus vulgaris* L. and *Pisum sativum* L. WMV-2 continues to be an important economic factor in cucurbit production, but losses to bean and pea crops appear negligible. Resistance to WMV-2 in pea is conditioned by the same factor that confers resistance to bean yellow mosaic virus (BYMV) (13). Presently, most of the leading commercial cultivars are resistant to both viruses. In bean, natural infection with WMV-2 has been confined to a few cultivars and breeding lines. Experimentally, a number of cultivars were found to be resistant (9).

This paper reports the reaction of 280 bean accessions of domestic and foreign origins to WMV-2, and presents data on the inheritance of resistance.

MATERIALS AND METHODS.—Bean seeds of domestic cultivars and breeding lines were obtained from several commercial sources. Plant introductions were secured from the Northeast Regional Plant Introduction Station, Geneva, New York. Three isolates of WMV-2 from cucurbits were used: NY69-81B, from New York; 69-109, obtained from D. E. Purcifull, Florida; and 70-1, supplied by K. A. Kimble, California. These isolates were maintained in a WMV-2-susceptible selection of the bean cultivar Black Turtle (B. Turtle 2), which also served as the source of inoculum. In screening for resistance, 16 to 20 plants of each line were inoculated with each isolate of WMV-2. Mechanical transmissions usually were made when plants were in the primary-leaf stage; those which did not show symptoms were inoculated a second time.

Genetic populations were derived from crosses and reciprocal F_1 backcrosses of WMV-2-susceptible B. Turtle 2, with WMV-2-resistant B. Turtle 1, or Great Northern 1140 (G. Northern 1140). All plants used in this study were kept in a greenhouse maintained at 27 C. Tests requiring lower or higher temp were conducted in climatic chambers. All inoculated plants were assayed for WMV-2 on *Cucurbita pepo* L. 'Zucchini', which reacted with systemic infection, and on *Chenopodium amaranticolor* Coste & Reyn., which responded with chlorotic local lesions.

RESULTS.—*Symptoms of WMV-2 in bean.*—All three isolates of WMV-2 incited identical symptoms on susceptible genotypes. Initially, they consisted of epinasty of primary leaves, which later developed chlorotic spots and some veinal browning. Systemic infection appeared as a marked mosaic of contrasting yellow-green and dark-green areas on the trifoliate leaves, which were smaller than normal and slightly malformed (Fig. 1,A). Infected plants were stunted and bushy due to the proliferation of lateral branches. Pods were mottled and distorted (Fig. 1,B). These symptoms were similar, in many respects, to those incited by some strains of BYMV (10, 11).

Varietal reaction to WMV-2.—Bean accessions representing 160 domestic cultivars and breeding lines, and 120 plant introductions of globally widespread origins were tested for reaction to three WMV-2 isolates. Of these accessions, 229 were resistant, 22 developed a local reaction, 21 were systemically infected (susceptible), and eight were a mixture of resistant and susceptible individuals. Susceptibility to WMV-2 occurred in the following lines: Black Turtle, Canadian Wonder, Limelight, Pioneer, P.I. 136681, P.I. 136692, P.I. 353521, and P.I. 353615 (U.S.A. and Canada); P.I. 340987 (Australia); P.I. 288019 (Costa Rica); P.I. 353535 (East Africa); P.I. 264784 (France); P.I. 261135 (Germany); P.I. 353529 (India); P.I. 304749 (Italy); P.I. 281556 (Japan); P.I. 165426, P.I. 165435, P.I. 203598, P.I. 203958, and P.I. 313528 (Mexico); P.I. 302467 (Netherlands); P.I. 209480 (Nicaragua); P.I. 250165 (Pakistan); P.I. 296319 (Philippines); P.I. 306170 (Sweden); P.I. 226922 (Ukraine); and P.I. 109859 and P.I. 353497 (Venezuela). In Black Turtle, the number of susceptible individuals varied from 30% to 70%, depending upon the seed lot tested. Lines which responded with local, but no systemic, reactions expressed inconspicuous chlorotic spots and mild veinal chlorosis. This group included the cultivars Bountiful, Kinghorn Wax, Red Kidney, and 19 other lines. A complete list of the lines tested and their reaction is available on request.

Resistance to WMV-2 in bean.—Resistant lines were free of symptoms, and no virus was recovered from them. However, under certain conditions following inoculation, a few of these lines responded with a severe systemic necrotic reaction which caused the premature death of the

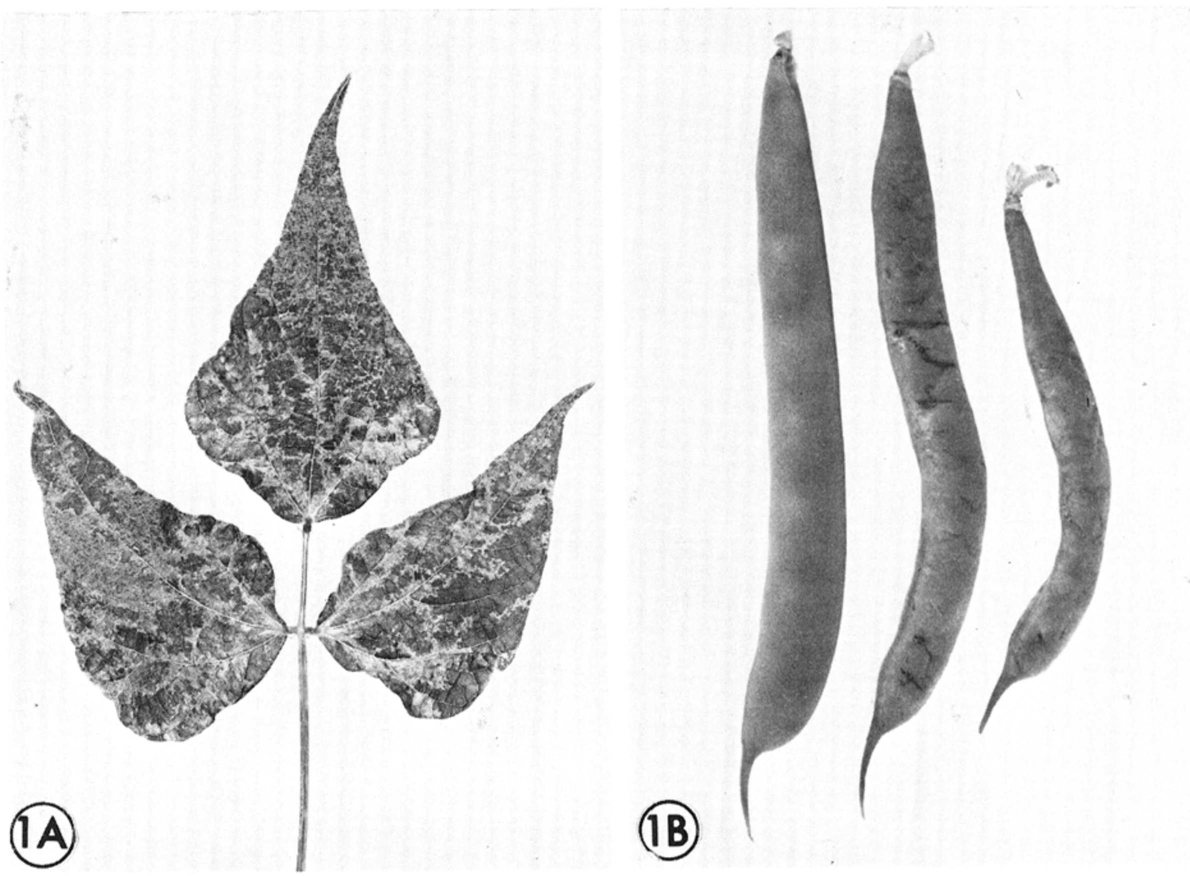

Fig. 1-(A,B). Symptoms incited by watermelon mosaic virus 2 in *Phaseolus vulgaris* 'Black Turtle 2'. **A**) Foliar mottle; **B**) Pod distortion; at left, healthy control.

affected plants. In the greenhouse at 27 C, only an occasional plant of the cultivars B. Turtle 1, Scotia, Tempo, and a few others developed these symptoms. In contrast, when 25 plants of each of these cultivars were incubated at 25 and 35 C, all the plants at 35 C were severely affected by necrosis within ten days, whereas those at 25 C remained unaffected. Apparently, the high temp was a determining factor only in mechanically inoculated plants, because when plants of the same cultivars were approach-grafted to systemically infected plants and incubated at 25 and 35 C, the apical and stem necrosis appeared on all the plants regardless of the ambient temp. The lower temp merely delayed the appearance of the symptoms. Cultivars such as G. Northern 1140, Roma, Cascade, Tendercrop, Michelite and others, when treated in a similar manner, remained unaffected. Thus, WMV-2-resistant bean lines can be classified into two types, highly resistant and hypersensitive resistant.

A systemic hypersensitive reaction is known to occur in bean lines possessing the dominant type of resistance to bean common mosaic virus (3).

Genetics of resistance to WMV-2 in bean.—In studying the inheritance of resistance to WMV-2 in bean, the susceptible line B. Turtle 2 was crossed with the hypersensitive resistant line B. Turtle 1, and with the highly resistant line G. Northern 1140. Plants were inoculated with the virus isolate NY69-81B, and incubated at 25 C. All the F_1 plants of both crosses were resistant (Table 1). Populations of F_2 families of these crosses segregated in a ratio of three resistant:one susceptible. In addition, backcrosses of F_1 to the resistant parents were all resistant, whereas F_1 backcrosses to the susceptible parents segregated one resistant:one susceptible. The results clearly established that resistance to WMV-2 in *Phaseolus vulgaris* L. is monogenically dominant. Whether a common factor is responsible for both types of resistance is under investigation.

DISCUSSION.—Resistance in many commercial cultivars has prevented widespread infection with WMV-2, thus minimizing losses to the bean crop in New York State. However, the ubiquity of overwintering hosts and the presence of an efficient vector (9) make this virus a potential threat. Although susceptibility to WMV-2 was found in only 10% of the lines tested, there is a constant danger of introducing new susceptible cultivars. For example, Limelight, a recently introduced cultivar which has been suggested as a substitute for baby lima bean, was susceptible in our tests. It derived from P.I. 136681 (G. A. Kemp, *personal communication*) a heterogeneous line.

TABLE 1. Segregation in F_1, F_2, and reciprocal F_1 backcrosses for resistance in *Phaseolus vulgaris* 'Black Turtle 1' (B. Turtle 1) and 'Great Northern 1140' (G. N. 1140) to watermelon mosaic virus 2 at 25 C

Cross	Families (no.)	Individuals: Resistant (no.)	Individuals: Susceptible (no.)	Expected ratio	Goodness of fit (P)	Heterogeneity (P)
(B. Turtle 1 × B. Turtle 2) F_1	8	45	0			
(B. Turtle 1 × B. Turtle 2) F_2	2	210	78	3:1	.43	.62
(B. Turtle 1 × B. Turtle 2) F_1 × B. Turtle 1	11	75	0			
(B. Turtle 1 × B. Turtle 2) F_1 × B. Turtle 2	12	42	37	1:1	.59	.97
(G. N. 1140 × B. Turtle 2) F_1	6	41	0			
(G. N. 1140 × B. Turtle 2) F_2	3	261	80	3:1	.52	.95
(G. N. 1140 × B. Turtle 2) F_1 × G. N. 1140	9	57	0			
(G. N. 1140 × B. Turtle 2) F_1 × B. Turtle 2	8	28	22	1:1	.41	.89

Also, P.I. 109859, P.I. 165426, P.I. 165435, P.I. 203598, and P.I. 203958 which are widely used as sources of root-rot resistance, were susceptible to WMV-2. Hence, without adequate testing it is likely that lines developed for resistance to root-rot may be susceptible to this virus. Thus, resistance to WMV-2 in bean, or to any other disease which may appear to be of minor importance, must be maintained in order to decrease the genetic vulnerability of the crop.

Very little is known about the presence and distribution of WMV-2 throughout the bean-producing areas of the world. Inouye (5) reported its occurrence in Japan, and described the reaction of some local cultivars (4). Our study indicates that susceptibility occurs in plant introductions from 17 countries. Susceptibility in a plant introduction does not necessarily correlate with the presence of the pathogen in its place of origin. However, it is possible that WMV-2 infection occurs in the bean crop of several countries such as Australia, India, Mexico, and Venezuela, where the virus is known to infect cucurbits (2, 6, 7, 8). The similarity of WMV-2 symptoms to those of BYMV in bean could have precluded an accurate diagnosis, particularly if based solely upon symptomatology.

In *Pisum sativum* L., the *mo* gene is able to confer resistance to both BYMV and WMV-2 (13). In bean, resistance to WMV-2 appears to be distinct from that conferred by *By*, *By-2* and *by-3*, the genes conditioning resistance to specific strains of BYMV (1, 10, 12). Of the two WMV-2-resistant lines used in the inheritance study, B. Turtle 1 is susceptible to all strains of BYMV (10, 12), and G. Northern 1140 possesses gene *by-3*, which conditions resistance to the severe strain of the virus (10). The obvious question is whether any of the genes which condition resistance to BYMV in bean also confer resistance to WMV-2, or whether they may modify the hypersensitive resistance thus conferring a higher degree of resistance to the genotype. Interestingly, all the lines which responded with a systemic hypersensitive reaction are known to lack any resistance to BYMV (R. Provvidenti, *unpublished*). This study will be continued to elucidate this and other points, particularly the unusual range of susceptibility possessed by WMV-2-susceptible lines, which also succumb to bean common mosaic, bean yellow mosaic, soybean mosaic and to a cowpea seed-borne virus (14).

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