Fusarium Yellows and Turnip Mosaic Virus Resistance in *Brassica rapa* and *B. juncea*

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Abstract. Thirty-seven *Brassica rapa* L. and *B. juncea* L. lines from nine subspecies were tested for their reaction to two pathotypes of *Fusarium* yellows (*Fusarium oxysporum* Schlecht. f. sp. *conglutinans* (Wr.) Snyder & Hans. race 1 and *F.o.* f. sp. *raphani* Kend. & Snyder). A subset of 16 lines from these same vegetable types were tested for their reaction to four strains of turnip mosaic virus (TuMV-C1, C2, C3, and C4). Resistance to both *Fusarium* pathotypes was widespread in these *Brassica* subspecies, whereas resistance to any strain of TuMV was uncommon. The broad availability of resistance to *Fusarium* yellows and scarcity of resistance to TuMV necessitate different approaches to obtain disease-resistant cultivars.

Fusarium yellows, caused by *Fusarium oxysporum* f. spp. *conglutinans* and *raphani*, and turnip mosaic virus (TuMV) are common diseases of *Brassica* crops (Shatuck, 1992; Walker, 1969). Although the seriousness of *Fusarium* yellows on *B. rapa* (syn. *B. campestris* L.) and *B. juncea* has not been systematically documented, the importance of this disease in other crucifers (*B. oleracea* L. and *Raphanus sativus* L.; Walker et al., 1958) gives reason for concern about its potential for damaging these *Brassica* crops. Susceptibility of *B. rapa* and *B. juncea* to TuMV, however, is known to be costly. TuMV causes widespread devastation within plantings of these vegetables (Faan and Ko, 1957; Nui et al., 1983; Sako, 1981; Wu et al., 1964).

Information on resistance to these diseases within the economically important oriental vegetable subspecies of *B. rapa* and *juncea* is relatively scarce. Only one subspecies, *B. rapa* ssp. *pekinensis* (Lour.) Olsson, has been well characterized for the possession of TuMV resistance (Green and Deng, 1983; Provvidenti, 1980) and only two cultivars have been examined for resistance to yellows (Bosland and Williams, 1988; Ramirez-Villupadua et al., 1985). Thus, as part of an ongoing program of crucifer pathology research, we undertook an evaluation of *Fusarium* yellows and TuMV resistance in a set of *B. rapa* and *B. juncea* cultivars. This survey of eight *B. rapa* and one *B. juncea* subspecies for resistance against two pathotypes of *F. oxysporum* and four strains of TuMV provides information concerning the prevalence of disease resistance in these crops.

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Materials and Methods

Pathogen and cultivar sources. Isolates of *F. oxysporum* f. sp. *conglutinans* race 1 (FOC) and *F.o.* f. sp. *raphani* (FOR) were obtained from the collection of P. H. Williams, Dept. of Plant Pathology, Univ. of Wisconsin, Madison (isolates PHW81 and 699, respectively). Isolates of TuMV-C1, C2, C3, and C4 were obtained from R. Provvidenti, Dept. of Plant Pathology, New York State Agr. Expt. Sta., Geneva. Eight subspecies of *B. rapa*, ssp. *chinensis* L. (pakchoy, tai-tsai, etc.), *parachinensis* (Bailey) T. & L. (choy sum), *pekinensis* (Chinese cabbage), *perviridis* Bailey (komatsuna or tendergreen), *narinosa* Bailey (chizimina, vitamin greens, etc.), *nipposinica* Bailey (mizuna and mibuna), *rapifera* (Metzg.) Sinsk. (turnip), and *utilis* T. & L. (hong-tai-tsai), and one subspecies of *B. juncea*, ssp. *crispifolia* Bailey (mustard greens), were obtained from various sources (Table 1).

***Fusarium* disease screen.** Seeds of the 37 cultivars to be screened for resistance to FOC and FOR were sown in silica sand in 30 × 60 × 8 cm steel pans, grown under continuous illumination of 400 μmol·m⁻²·s⁻¹ from mixed (1:1) Sylvania cool-white and Gro-lux fluorescent lamps (GTE, Danvers, Mass.) in a 28 ± 5 °C greenhouse, and watered daily. *Fusarium* isolates were stored in soil at 4 °C. Isolates were grown in 50 mL of potato dextrose broth in 250-mL flasks. Cultures were incubated at 20 °C on a gyrating shaker for 3 to 5 d, then filtered through two layers of cheesecloth. The fungal mat collected on top of the cheesecloth was rinsed with distilled water, transferred to a Waring blender containing 50 mL of distilled water per culture flask, and macerated at the highest speed setting for 1 min. The resulting mixture of hyphae and spores became the primary inoculum for the disease screen.

Fifty 7-d-old seedlings were inoculated by first removing them from sand using a steel spatula, dipping the roots into water to wash off excess sand, blotting the roots on paper toweling, and submerging the roots in the

inoculum suspension for 5 to 10 min. The inoculated seedlings were transplanted into another steel pan of sand in randomly arranged groups of 25 (10 groups per pan, two replications per cultivar). The pans were held in Wisconsin soil temperature tanks (Williams, 1981) set at 24 ± 1 °C. Plants were kept in a 20 ± 1 °C greenhouse, continuously illuminated, as for the seedling germination, and irrigated daily with 0.5× modified Hoagland solution (Jacobson, 1950).

Two weeks after inoculation, the plants were gently removed from the sand and rated for their disease reaction on a scale from 0 to 9 (0 = no symptoms; 3 = some stunting of shoot and root growth; 5 = noticeable stunting of shoot and root growth, with leaves turning yellow and roots dark; 7 = severe stunting of shoot and root growth, with yellowing and necrosis of leaves, browning and necrosis of roots; 9 = death of the plant; Williams, 1981). Plants rated from 0 to 3 on this scale were considered to be resistant and 4 to 9 to be susceptible. The percentage of resistant plants and mean disease reaction for each cultivar were then calculated. Twenty-five resistant and 25 susceptible control plants were included in each screening pan. 'Wisconsin Golden Acre' and 'Golden Acre' cabbage for FOC and 'Fancy Red' and 'White Icicle' radish for FOR were the resistant and susceptible controls, respectively.

TuMV disease screen. Seeds of the 16 cultivars to be screened for resistance to TuMV-C1, C2, C3, and C4 were sown in greenhouse potting soil in plastic multipot 96 cell trays (39 × 28 × 53 mm/cell), fertilized once weekly with a soluble 20 N-20 P-20 K fertilizer, and grown under natural illumination in a shaded 28 ± 5 °C glasshouse.

The TuMV strains were maintained in turnip plants ('Presto') isolated in aphid-proof cages. TuMV inoculum was prepared by grinding 4 cm² of systemically infected turnip leaf with a pestle in a mortar containing 5 mL of 0.03 M phosphate (K⁺) buffer at pH 7.0 and 0.2 g of 200 mesh (72 μm particle size) carborundum.

Forty-eight 14-d-old plants of each cultivar were randomized into four replications of 12 plants/replication/cultivar, lightly dusted with 200 mesh carborundum, and inoculated by rubbing the first two true leaves with inoculum. Inoculated plants were covered with wetted newspaper for 20 h after inoculation. Plants were observed for mosaic symptoms 10 d after the initial inoculation and, at this time, symptomless plants were reinoculated on their third and fourth true leaves. Ten and 20 d after the second inoculation, plants were rated for their disease reaction on a scale from 0 to 9 (0 = no symptoms; 1 = symptoms restricted to small chlorotic and necrotic lesions on the inoculated leaves; 3 = chlorotic or necrotic lesions on the inoculated leaves plus slight mottling on new growth; 5 = 3 + increased mottling and chlorosis on new growth, no leaf deformation; 7 = 3 + severe chlorotic mottling, deformation and stunting of new growth; 9 = progressive chlorotic mottling and deformation to the death of the plant). Plants rated from

0 to 3 on this scale were considered to be resistant and 4 to 9 to be susceptible. Percentage of resistant plants and mean disease reaction for each cultivar were then determined. Susceptible 'Presto' turnip control plants were distributed among the groups of 12 plants inoculated with TuMV.

Results

Fusarium tests. In general, the majority of cultivars were resistant to FOC and FOR (Table 2). Of the 37 cultivars screened against FOC and FOR, 19 and 21 cultivars, respectively, had a 50% or higher frequency of resistant plants. The overall average resistance frequency of the *B. rapa* cultivars was 74.3% to FOC and 76.4% to FOR and the average was 83.3% and 22.3%, respectively, for the *B. juncea* cultivars. No correlation ($r = 0.08$) existed between the resistance frequencies of FOC and FOR. There was a high correlation ($r = -0.985$) between the frequency of resistant plants and mean disease reaction.

The *B. rapa* ssp. *pekinensis* cultivars had the highest average (pooled among all cultivars within a subspecies) combined frequencies of plants resistant to the two pathotypes of *F. oxysporum* (82.3% and 86.0% to FOC and FOP, respectively). *B. rapa* ssp. *chinensis*, ssp. *rapifera*, ssp. *narinosa*, and ssp. *utilis* cultivars also had relatively high (>60%) average resistant frequencies to the two pathotypes. A >50% average frequency of resistance against one pathotype, but not against the other, occurred in the *B. rapa* ssp. *parachinensis*, ssp. *perviridis*, ssp. *nipposinica*, and *B. juncea* ssp. *crispifolia* cultivars. The *B. rapa* ssp. *nipposinica* cultivars were relatively susceptible (22.0% average resistance frequency) to FOC and the *B. rapa* ssp. *parachinensis*, *perviridis*, and *B. juncea* ssp. *crispifolia* cultivars were relatively susceptible (36.0%, 26.0%, and 22.3% average resistance frequencies, respectively) to FOR.

Despite the relatively common occurrence of resistance, the cultivars were quite heterogeneous in their disease reaction to the *Fusarium* pathotypes. Only five of the 35 cultivars were uniformly ($\geq 95\%$) resistant to FOC and only two were uniformly resistant to FOR. None were uniformly resistant to both pathotypes.

TuMV tests. Resistance against any of the strains of TuMV (C1, C2, C3, and C4) was uncommon (Table 3). Out of 64 total cultivar-strain combinations tested, there were only four combinations that showed a cultivar having a 50% or higher frequency of resistant plants to any one strain of the virus. Cultivars having >5% frequency of resistant plants occurred in only 11 of the 64 combinations. 'Southern Giant Curled', of *B. juncea* ssp. *crispifolia*, was the only cultivar having >50% frequencies of resistant plants against more than one strain of TuMV (having 72% and 81% frequencies of resistance against strains C1 and C2, respectively).

Resistance against any one strain of the virus generally had low correlation (absolute value $r < 0.16$) with resistance to any other

strain. The highest correlations were between C1 and C2 resistance and C1 and C3 resistance, being 0.566 and 0.542, respectively. The correlation of resistance frequency to mean disease reaction was only moderately high ($r = -0.63$). Resistance frequencies >5% to the various TuMV strains were found among cultivars of *B. rapa* ssp. *pekinensis*, ssp. *chinensis*, and ssp. *rapifera*. Cultivars belonging to the other *B. rapa* subspecies tested had <5% resistant plants. *B. juncea* ssp. *crispifolia* cultivars had resistance against C1 and C2, but no resistance against C3 and C4.

Discussion

The two pathotypes of *Fusarium oxysporum* we studied are those most widely recognized to infect *Brassica* crops in the field (Bosland and Williams, 1988). Resistance to both pathotypes of *F. oxysporum* exists in many cultivars of *B. rapa* and *juncea*. Since these vegetables are mainly grown during cool seasons when soil temperatures are unfavorable for the expression of Fusarium yellows, it could be argued that there may be no real threat

of this disease against *B. rapa* and *B. juncea* crops. However, cultivars are increasingly being bred and grown for production during warmer seasons, and the *Fusarium* resistance identified in this research should be of value. The Chinese cabbage lines 'Gingetsu', 'Saladeer', 'Summer Sowing', 'Summer Winner', 'Tropicana', and AVRDC #58 and #62, which have been bred to possess heat tolerance for production in hot tropical summers, were specifically examined for *Fusarium* resistance and resistance was found in all of these cultivars.

Of major concern with Fusarium yellows is the relative susceptibility of *B. juncea* to FOR. Nevertheless, the resistance to FOR identified within 'Giant Savoy Leaved' should be readily transferable to other *B. juncea* cultivars. Though susceptibility of the *B. rapa* ssp. *nipposinica* cultivars to FOC is high, resistance is available in other *B. rapa* subspecies.

Resistance to TuMV is generally lacking in the *B. rapa* and *juncea* cultivars surveyed. Each of the subspecies of *B. rapa* studied lacked resistance to at least one of the strains

Table 1. Scientific designation, Univ. of Wisconsin (PHW) accession number, commercial name, and seed source of *Brassica rapa* and *B. juncea* accessions used in disease screens of *Fusarium oxysporum* f. sp. *conglutinans* and *raphani* and turnip mosaic virus strains C1, C2, C3, and C4.

Species and subspecies	PHW accession no.	Commercial name	Seed source ^a
<i>B. rapa</i> ssp. <i>chinensis</i>	64254	Late Shirona	Takii
	64261	Santoh Round	Takii
	64264	Tai-tsai	Takii
	64290	Pak-choy	Takii
<i>B. rapa</i> ssp. <i>parachinensis</i>	64292	Shirona	Takii
	64073	Chizimina	AVRDC
	64266	Vitamin-Sai	Watanabe
	64242	Mizuna	Takii
<i>B. rapa</i> ssp. <i>nipposinica</i>	64294	Mibuna	Takii
	64145	Choy Sum	CRGC
	64147	Flowering Cabbage	Wong Yuen Shin
	64169	Chee Foo	Takii
<i>B. rapa</i> ssp. <i>pekinensis</i>	64179	Kurihara	Takii
	64184	R-55	Mikado
	64193	Tropicana	Takii
	64207	Saladeer	Takii
<i>B. rapa</i> ssp. <i>perviridis</i>	64218	Summer Sowing	Watanabe
	64480	Gingetsu	Kaneko
	64609	#58	AVRDC
	64610	#62	AVRDC
<i>B. rapa</i> ssp. <i>rapifera</i>	64612	Chi Bei Tsai	CRGC
	64614	Siao Bei-Sing	CRGC
	64615	Fu-Shan	CRGC
	64616	Jias-Bei	CRGC
<i>B. rapa</i> ssp. <i>utilis</i>	64621	Huang-Jin-Bei	CRGC
	64643	Summer Winner	Hungnong
	64721	Ning Sing Chin	CRGC
	MIC	Michihili	Olds
<i>B. juncea</i> ssp. <i>crispifolia</i>	64248	Komatsuna	Takii
	64253	Late Komatsuna	Takii
	64275	Purple Top White Globe	Takii
	64657	Shogoin	Kaneko
<i>B. juncea</i> ssp. <i>crispifolia</i>	64630	Hong-Tai-Tsai	CRGC
	43153	Red Leaved Mustard	Takii
	43154	Giant Savoy Leaved	Takii
	43155	Miike Giant	Takii
	43452	Southern Giant Curled	Olds

^aAVRDC = Asian Vegetable Research and Development Center, Tainan, Taiwan; CRGC = Crucifer Genetics Cooperative, Dept. of Plant Pathology, Univ. of Wisconsin, Madison, Wis.; Hungnong = Hungnong Seed Co., Seoul, Korea; Kaneko = Kaneko Seeds Co., Maebashi City; Mikado = Mikado Seed Growers, Chiba City, Japan; Olds = Olds Seed Co., Madison, Wis.; Takii = Takii and Co., Kyoto, Japan; Watanabe = Watanabe Seed Co., Tokyo, Japan; Wong Yuen Shin = Wong Yuen Shin Seed Co., Hong Kong.

of TuMV, and many lacked resistance to all four strains. Resistance to TuMV in *B. rapa* ssp. *pekinensis* cultivars was not emphasized in this study since thorough examinations of TuMV resistance in these vegetable types have been reported (Green and Deng, 1985; Provvidenti, 1980). This study included the most common Chinese cabbage cultivar, 'Michihili', which was not tested by Provvidenti (1980), who tested the selections 'Michihili 75' and 'Michihili 85' instead. *Brassica rapa* ssp. *pekinensis* has sources of resistance to each of the four strains of TuMV tested (Provvidenti, 1980), as well as resistance to a fifth TuMV strain (Green and Deng, 1985) that was not studied by us. The ability to readily transfer TuMV resistance from one subspecies to another within *B. rapa* vegetables (Leung and Williams, 1983) suggests that TuMV resistance, lacking in most *B. rapa* vegetable subspecies, could be acquired from *B. rapa* ssp. *pekinensis* sources of resistance. *B. juncea* cultivars lacked any resistance to strains C3 and C4. Thus, the transfer of resistance from *B. rapa* ssp. *pekinensis* into *B. juncea* through interspecific hybridization may be the only alternative for obtaining such resistance in this crop species.

Because numerous strains of TuMV are known to exist worldwide (Green and Deng, 1985; Provvidenti, 1980; Shattuck, 1992), the use of strain-specific resistance genes may only be a temporary solution to the control of TuMV. Whereas durable sources of resistance to this highly variable virus may be difficult to identify, their detection would be of obvious value.

Using differing pathogen isolates, inoculum concentrations, seed sources, or growing conditions could alter disease phenotypes. The results of Ramirez-Villupadua et al. (1985) demonstrate that disease reactions to *F. oxysporum* on crucifer cultivars were not entirely consistent in comparing greenhouse tests conducted in California and Wisconsin when using similar isolates. While the classification of cultivars as resistant or susceptible did not vary between the two locations, their disease reaction varied considerably. Bosland and Williams (1988) also showed that FOR can be more variable than what was traditionally thought, with some strains being much more virulent on *B. rapa* ssp. *pekinensis* 'Michihili' than others (mean disease reaction ranging from 1.2 to 6.6). Although *Fusarium* yellows and turnip mosaic resistance displayed in green-

house tests emulates resistance seen in the field (Ramirez-Villupadua et al., 1985; Shattuck, 1992; Walker, 1969), resistant cultivars identified in our study may prove susceptible to untested isolates in a variety of field conditions and warrant further testing for sources of resistance.

Literature Cited

- Faan, H.C. and C. Ko. 1957. A preliminary study on the mosaic virus of crucifers in the vicinity of Canton. *Acta Phytopathol. Sinica* 3:155-168.
- Bosland, P.W. and P.H. Williams. 1988. Pathogenicity of geographic isolates of *Fusarium oxysporum* on crucifers on a differential set of crucifer seedlings. *J. Phytopathol.* 123:63-68.
- Green, S.K. and T.C. Deng. 1985. Turnip mosaic virus strains in cruciferous hosts in Taiwan. *Plant Dis.* 69:28-31.
- Jacobson, L. 1951. Maintenance of iron supply in nutrient solutions by a single addition of ferric potassium ethylenediamine tetra-acetate. *Plant Physiol.* 26:411-413.
- Nui, X.K., H. Leung, and P.H. Williams. 1983. Sources and nature of resistance to downy mildew and turnip mosaic in Chinese cabbage (*Brassica campestris* ssp. *pekinensis*). *J. Amer. Soc. Hort. Sci.* 108:775-778.
- Provvidenti, R. 1980. Evaluation of Chinese cabbage cultivars from Japan and the People's Re-

Table 2. Disease expression of *Brassica rapa* and *B. juncea* cultivars among Univ. of Wisconsin (PHW) accessions inoculated with *Fusarium oxysporum* f. spp. *conglutinans* (FOC) and *raphani* (FOR).

Species and subspecies	PHW accession no.	<i>Fusarium</i> race			
		FOC		FOR	
		Resistant plants (%)	Mean disease reaction ²	Resistant plants (%)	Mean disease reaction
<i>B. rapa</i> ssp. <i>chinensis</i>	64254	54	4.4 (0.8)	47	4.6 (0.6)
	64261	88	2.1 (0.3)	88	2.3 (0.1)
	64264	52	4.5 (0.2)	80	2.5 (0.1)
	64290	54	3.6 (0.7)	88	1.8 (0.5)
	64292	90	2.2 (0.3)	74	2.7 (0.7)
ssp. <i>narinosa</i>	64073	78	2.1 (0.2)	81	2.4 (0.9)
	64266	83	2.2 (0.3)	44	5.1 (0.3)
ssp. <i>nipposinica</i>	64242	29	5.5 (0.6)	47	4.0 (0.4)
	64294	5	7.9 (0.4)	69	3.5 (0.4)
ssp. <i>parachinensis</i>	64145	92	2.1 (0.4)	45	4.9 (0.2)
	64147	80	2.5 (0.7)	26	6.6 (0.2)
ssp. <i>pekinensis</i>	64169	71	2.1 (0.5)	86	2.2 (0.2)
	64179	99	1.2 (0.1)	68	3.2 (0.8)
	64184	100	1.0 (0.0)	92	1.4 (0.2)
	64193	98	1.5 (0.1)	83	2.2 (0.3)
	64207	91	1.7 (0.2)	79	1.9 (0.1)
	64218	88	1.9 (0.6)	87	1.7 (0.1)
	64480	84	1.8 (0.1)	92	1.8 (0.1)
	64609	92	1.6 (0.1)	88	1.7 (0.3)
	64610	90	1.7 (0.5)	86	1.9 (0.1)
	64612	56	3.9 (0.6)	92	1.6 (0.1)
	64614	90	2.0 (0.7)	90	1.7 (0.1)
	64615	83	2.3 (0.3)	92	1.6 (0.2)
	64616	78	2.7 (0.2)	98	1.2 (0.1)
	64621	65	3.0 (0.3)	88	1.6 (0.3)
	64643	78	2.1 (0.3)	76	2.4 (0.4)
	64721	46	4.0 (0.2)	90	1.9 (0.2)
	MIC	80	2.2 (0.2)	72	3.2 (0.0)
ssp. <i>perviridis</i>	64248	61	3.5 (0.5)	37	5.8 (0.6)
	64253	80	2.8 (0.5)	50	5.3 (0.7)
ssp. <i>rapifera</i>	64275	38	5.5 (0.4)	54	4.8 (0.2)
	64657	84	2.4 (0.2)	67	3.5 (0.5)
ssp. <i>utilis</i>	64630	60	4.0 (0.3)	96	1.3 (0.1)
<i>B. juncea</i> ssp. <i>crispifolia</i>	43153	95	1.3 (0.3)	14	7.1 (0.3)
	43154	98	1.1 (0.6)	50	4.8 (0.5)
	43155	83	2.0 (0.5)	16	7.2 (0.5)
	43452	57	4.3 (0.5)	8	8.3 (0.3)

²Mean disease reaction based on a scale of 0 to 9, where 0 to 3 = resistant and 4 to 9 = susceptible, with SE of two replications in parentheses.

Table 3. Disease expression of *Brassica rapa* and *B. juncea* cultivars among Univ. of Wisconsin (PHW) accessions inoculated with turnip mosaic virus (TuMV) strains C1, C2, C3, and C4.

Species and subspecies	PHW accession no.	TuMV strain							
		C1		C2		C3		C4	
		Resistant plants (%)	Mean disease reaction ^a	Resistant plants (%)	Mean disease reaction	Resistant plants (%)	Mean disease reaction	Resistant plants (%)	Mean disease reaction
<i>B. rapa</i> ssp. <i>chinensis</i>	64261	0	5.5 (0.9)	2	6.9 (1.7)	0	5.6 (1.1)	0	8.1 (1.0)
	64264	0	5.5 (0.9)	9	5.1 (1.2)	0	5.0 (0.0)	0	7.3 (1.3)
	64290	2	5.1 (0.6)	0	5.9 (1.1)	0	5.3 (0.7)	19	5.3 (1.5)
	64292	0	5.3 (0.7)	0	6.3 (1.5)	0	5.3 (0.8)	0	8.0 (1.2)
ssp. <i>narinosa</i>	64073	0	5.0 (0.6)	0	5.6 (1.6)	2	5.0 (0.3)	0	6.8 (1.6)
	64266	4	5.3 (0.6)	0	5.6 (1.4)	4	5.4 (0.8)	0	6.2 (1.2)
ssp. <i>nipposinica</i>	64242	1	5.6 (1.0)	0	5.5 (1.2)	0	5.6 (1.4)	0	6.0 (1.5)
	64294	0	5.3 (0.7)	0	7.5 (1.6)	0	5.5 (1.0)	0	7.5 (0.9)
ssp. <i>parachinensis</i>	64147	4	5.1 (0.5)	0	5.9 (0.9)	3	5.2 (0.7)	0	6.7 (2.1)
ssp. <i>pekinensis</i>	MIC	67	3.6 (1.1)	2	4.7 (0.5)	26	4.6 (1.1)	2	6.9 (1.7)
ssp. <i>perviridis</i>	64248	2	5.4 (0.8)	0	5.8 (1.6)	0	5.6 (0.9)	0	7.3 (1.8)
ssp. <i>rapifera</i>	64275	2	5.6 (1.6)	7	5.9 (1.8)	9	4.9 (0.7)	12	5.9 (1.7)
	64657	1	5.3 (1.3)	0	5.7 (1.3)	0	5.4 (0.9)	0	7.1 (1.9)
ssp. <i>utilis</i>	64630	0	5.0 (0.0)	4	5.7 (1.5)	4	4.9 (0.4)	4	6.8 (1.2)
<i>B. juncea</i> ssp. <i>crispifolia</i>	43153	21	4.8 (1.9)	90	2.7 (0.4)	0	5.5 (1.0)	0	5.8 (1.6)
	43452	72	2.9 (0.7)	81	3.1 (1.8)	0	6.7 (1.1)	0	6.0 (1.3)

^aMean disease reaction based on a scale of 0-9, where 0-3 = resistant and 4-9 = susceptible, with SE of four replications in parentheses.

- public of China for resistance to turnip mosaic virus and cauliflower mosaic virus. J. Amer. Soc. Hort. Sci. 105:571-573.
- Ramirez-Villupadua, J., R.M. Endo, P. Bosland, and P.H. Williams. 1985. A new race of *Fusarium oxysporum* f. sp. *conglutinans* that attacks cabbage with type A resistance. Plant Dis. 69:612-613.
- Sako, N. 1981. Virus diseases of Chinese cabbage in Japan, p. 129-142. In: N.S. Talekar and T.D. Griggs (eds.). Chinese cabbage. Asian Veg. Res. Dev. Ctr., Shanhua, Taiwan.
- Shattuck, V.I. 1992. The biology, epidemiology, and control of turnip mosaic virus. Hort. Rev. 14:199-238.
- Walker, J.C. 1969. Cabbage yellows, p. 291-298. In: J.C. Walker. Plant pathology. McGraw-Hill, New York.
- Walker, J.C., R.H. Larson, and A.L. Taylor. 1958. Diseases of cabbage and related plants. U.S. Dept. Agr. Handbook 144. U.S. Govt. Print. Off., Washington, D.C.
- Williams, P.H. 1981. Screening crucifers for multiple disease resistance. Dept. Plant Pathology, Univ. of Wisconsin, Madison.
- Wu, C.S., T. Tang, S.W. Li, and Z.T. Wang. 1965. Some factors influencing the epiphytotics of mosaic disease of Chinese cabbage in Urumchi, Sinkiang. Acta Phytopythologica Sinica 4:177-183.