Reactions of Italian *Triticum durum* Cultivars to Soilborne Wheat Mosaic

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ABSTRACT

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The presence of soilborne wheat mosaic virus (SBWMV) in durum wheats (*Triticum durum*) in Central Italy is reported. The most widely grown durum cultivars in Italy are resistant to SBWM, but many of the new, higher-yielding, semidwarf types were found extremely susceptible. Yield losses as high as 70% have been estimated in the more susceptible cultivars. Grain number per square meter (51%) rather than kernel weight (8%) reductions accounted for most of the yield reduction. SBWM also affected test weight, plant height, and weediness. Visual disease assessments made very early in the season were highly correlated with losses, but some cultivars appeared to possess efficient "tolerance" mechanisms.

In Italy, soilborne wheat mosaic (SBWM) was first reported in 1960 but was known to occur only on bread wheats (*Triticum aestivum* L.) grown in the northern regions of the country (4). The disease often decreases the yield of susceptible bread wheat cultivars by more than 50% (1,7,13,15), also affecting test weight and plant height (3,6,12,16).

The SBWM virus (SBWMV) is also able to attack *T. durum* Desf. cultivars (4,11), yet no reports regarding its effects on this species have been published before. The behavior of Italian durum wheats with regard to SBWM is also unknown, and the same may be said about *T. durum* germ plasm in general.

In bread wheats, resistance to the most characteristic symptoms of SBWM, such as mottling, stunting, and rosetting, is simply inherited (5,9,10). Moreover, in SBWMV-infested soils, yield is also affected by recovery (1,3,10) and possibly other unidentified "tolerance" mechanisms. Both symptom expression and yield, as well as their relationship, have therefore been considered in this study.

MATERIALS AND METHODS

The durum wheat cultivar trials organized in Central Italy (2) by the Istituto Sperimentale per la Cerealicoltura (ISC) during 1982 afforded an excellent opportunity to compare the yields of 25 cultivars grown in a naturally SBWMV-infested field near Rome with those obtained from 14 disease-free soils. The trials, each consisting of 25 cultivars grown in 10-m^2 plots with three replicates, were planted on 12 November 1981 at Rome and during the following 2 wk at the other sites. Eleven new semidwarf lines (Norin 10 derivatives) were also grown in the infested field. Randomized-block and triple-lattice designs were used, respectively, in the infested and disease-free trials.

In February 1982, severe yellowing and stunting were observed in one of the two trials grown on the experimental farm of the ISC. Through immunoelectron microscopy, the causal agent was identified as SBWMV. On 25 March, at growth stage 3 on the Feekes-Large scale (8), plots were rated for disease on a scale of 0–4, where 0–1 = resistant, slight or no symptoms; 1.1–2 = mildly resistant, mild mottling and stunting; 2.1–3 = mildly susceptible, mottling and stunting; and 3.1–4 = susceptible, severe mottling and stunting, with virus-killed plants. Ratings were based on overall appearance, which included mottling, stunting, and stand loss. Disease ratings varied among replicates, but symptom severity on individual plants within each plot was quite uniform. Susceptible cultivars showed 100% disease incidence.

Grain yield (adjusted to 13% moisture) was recorded as kilograms obtained from the whole plot and expressed in quintals per hectare. Grain number, calculated by dividing total grain yield by average kernel weight, was expressed as number of kernels obtained from 1 m^2. Plant height was measured from the ground to the base of the spike. Weediness was estimated visually and expressed as the percentage of the plot infested with undesirable plants.

Plant height, kernel weight, test weight, and kernel number reductions attributable to SBWM were estimated for each cultivar using the following formula:

$$L_x = (\bar{X}_n - X_i) - (\bar{R}_n - \bar{R}_i),$$

where L_x = loss of cultivar X due to SBWM; X_n and X_i = average performance of cultivar X in 14 disease-free trials and in the infested field, respectively; $\bar{R}_n$ and $\bar{R}_i$

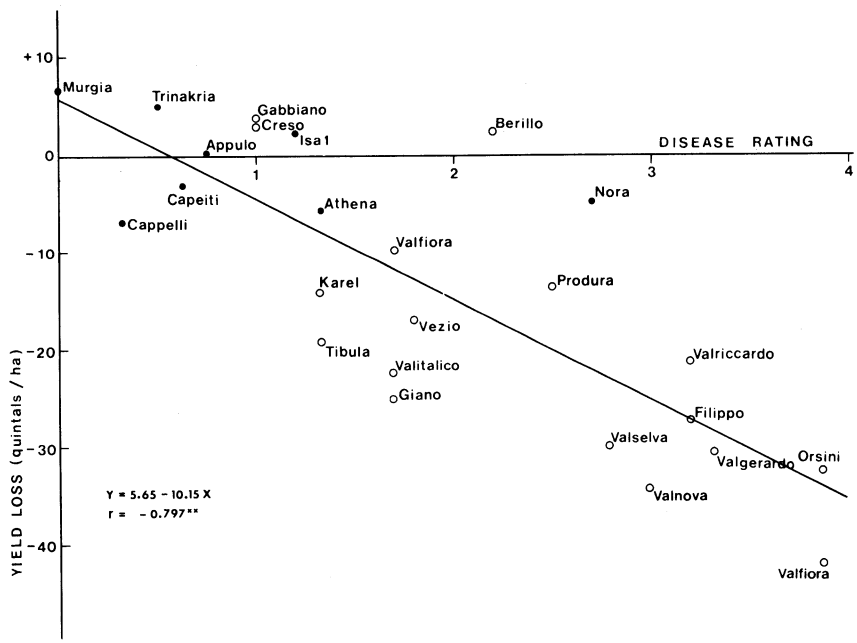

Fig. 1. Relationship between estimated yield loss (q/ha) and disease severity (scale of 0–4, where 0 = slight or no symptoms and 4 = severe mottling and stunting) observed in 25 durum wheat cultivars grown in a field infested with soilborne wheat mosaic virus. Yield loss estimates were obtained by comparing the performance of each genotype in the infested field and in 14 disease-free trials. Hollow circles indicate dwarf types (Norin 10 derivatives); solid circles indicate tall cultivars.

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= average performance of the five most resistant cultivars in 14 disease-free trials and in the infested field, respectively. Because the average yield of the resistant controls was identical in diseased and healthy soils, the second term of the equation was omitted when computing yield reductions. For all characters, losses were estimated with the assumption that resistant controls were not affected by SBWMV in the infested field.

RESULTS

The data collected in the infested field on the various cultivars and breeding lines provided a wide range in yield, disease severity ratings, and plant characteristics (Tables 1 and 2). Statistically significant differences ($P = 0.05$) were observed among genotypes for all the characters examined.

Most tall cultivars showed a resistant (R) or moderately resistant (MR) reaction to SBWM, except Nora, which was moderately susceptible (MS). No SBWM symptoms were observed on Murgia. Among semidwarfs, only Creso and Gabbiano were classified as resistant, whereas several others—especially Valforte and Orsini—were extremely susceptible.

The mean yield of the five most susceptible cultivars (22.7 q/ha) was only half of that obtained from the five most resistant ones (44.1 q/ha). However, SBWM-damage was undoubtedly greater because the yielding ability of the tall, resistant genotypes is known to be lower than that of semidwarfs. Differences in test weight (6 kg/hl), thousand-kernel weight (4.4 g), and especially in grain number (4,260 kernels per square meter) between the resistant and susceptible groups of cultivars were also relatively high. Weediness, reported as one of the serious indirect effects caused by SBWM (14), was much worse in plots sown with the more susceptible cultivars (35 vs. 14%). Highly significant ($P = 0.01$) linear correlations were found between disease ratings and most of the variables examined (Tables 1 and 2). It is to be noted, however, that the grain yields of the moderately susceptible cultivars Berillo (56.8 q/ha) and Nora (47.2 q/ha) were notably higher than those expected from the regression (+19.6 q/ha and +13.9 q/ha, respectively), whereas that of resistant Cappelli (29.8 q/ha) was 22.2 q/ha lower. Moreover, relatively high test weights were displayed by Nora (80.4 kg/hl) and Cappelli (79.4 kg/hl) but not by Berillo (74.6 kg/hl).

A more precise estimate of the damage caused by SBWM and of its relationship with disease symptoms was obtained by comparing the performance of each cultivar in healthy and diseased fields (Tables 1 and 2). In the latter, the average grain yield of the five most resistant cultivars was exactly the same as in the uninfested trials, whereas mean test weight (−1.54 kg/hl), kernel weight (−1.7 g), and plant height (−12 cm) were somewhat lower. Symptomless Murgia and six other cultivars—most of them classified as resistant—yielded slightly more in the infested field than in the other trials. The mean estimated damage caused by SBWM on the five most susceptible cultivars was 30.4 q/ha (yield), 5.3 g (thousand-kernel weight), 5,940 grains per square meter, 3.8 kg/hl (test weight), and 13 cm (plant height). In susceptible cultivars, grain number (51%) rather than kernel weight (8%) reductions accounted for most of the damage. The greatest estimated yield loss was observed in Valforte (70%).

Correlations between disease symptoms and estimated losses were highly significant ($P = 0.01$) for all the variables examined, particularly for yield loss (Fig. 1) and grain number reduction (Table 2). Nora and Berillo, however, apparently suffered very little or no yield loss, and in the case of Nora, only a very slight test weight reduction (−0.2 kg/hl). The good performance displayed by these moderately susceptible cultivars in a heavily SBWMV-infested soil may therefore be tentatively attributed to tolerance mechanisms, perhaps similar to those already reported (1,3,10) for some bread wheats.

DISCUSSION

The most widely grown durum cultivars in Italy (Capeiti, Appulo, Creso, and Trinakria), as well as the formerly popular Cappelli, are all highly resistant to SBWM, and this probably explains

Table 1. Disease severity, grain yield, and thousand-kernel weight for 36 Italian durum wheat cultivars and lines grown in a field infested with soilborne wheat mosaic virus (SBWMV) near Rome, Italy, in 1982 and estimates[v] of losses caused by the disease

Cultivar or line	Disease severity[w]	Grain yield (q/ha)		Thousand-kernel weight (g)	
		Actual performance	Estimated loss	Actual performance	Estimated loss
Murgia[x]	0.0 a[y] (R)	51.2 abcd	6.2	47.2 abcd	1.7
Cappelli[x]	0.3 ab (R)	29.8 ghijk	−7.9	47.7 abc	−1.3
Trinakria[x]	0.5 abc (R)	42.1 abcdefgh	4.8	46.0 abcde	1.0
Capeiti[x]	0.7 abcd (R)	46.6 abcdefg	−3.4	41.9 cdefghij	−0.5
Appulo[x]	0.8 abcde (R)	50.8 abcde	0.3	41.6 cdefghij	−1.0
Creso	1.0 abcde (R)	54.6 abc	2.9	44.4 bcdefgh	−0.6
Gabbiano	1.0 abcde (R)	57.7 a	3.6	38.5 hijk	−1.4
Isa I[x]	1.2 abcdef (MR)	45.6 abcdefg	2.4	48.5 ab	2.1
V. 1082	1.2 abcdef (MR)	57.2 a	···	47.6 abc	···
V. 1108	1.2 abcdef (MR)	55.5 ab	···	40.6 efghij	···
Athena	1.3 abcdefg (MR)	43.7 abcdefg	−5.7	38.6 hijk	−1.1
Karel	1.3 abcdefg (MR)	44.3 abcdefg	−14.1	36.0 jk	−3.7
Tibula	1.3 abcdefg (MR)	38.0 cdefghij	−19.0	45.5 abcdef	−2.0
V. 1095	1.3 abcdefg (MR)	43.6 abcdefg	···	46.8 abcd	···
Giano	1.7 bcdefgh (MR)	30.8 ghijk	−24.6	41.6 cdefghij	−4.4
Valfiora	1.7 bcdefgh (MR)	38.2 cdefghij	−9.8	50.7 a	0.3
Valitalico	1.7 bcdefgh (MR)	30.8 ghijk	−22.1	41.6 cdefghij	−3.7
V. 1038	1.8 cdefghi (MR)	49.3 abcdef	···	44.3 bcdefgh	···
Vezio	1.8 cdefghi (MR)	37.8 cdefghij	−16.8	34.5 k	−5.0
V. 1111	2.0 defghij (MR)	31.9 fghijk	···	41.6 cdefghij	···
Berillo	2.2 efghij (MS)	56.8 a	2.5	38.9 efghijk	−2.6
V. 981	2.2 efghij (MS)	48.8 abcdef	···	47.2 abcd	···
V. 1040	2.2 efghij (MS)	39.4 bcdefghij	···	44.9 abcdefg	···
Produra	2.5 fghijk (MS)	41.0 abcdefghi	−13.2	42.1 cdefghi	−0.6
Nora[x]	2.7 ghijk (MS)	47.2 abcdefg	−4.7	44.4 bcdefgh	0.4
V. 978	2.7 ghijk (MS)	39.0 cdefghij	···	47.4 abc	···
V. 1002	2.7 ghijk (MS)	39.1 cdefghij	···	42.3 cdefghi	···
V. 941	2.8 hijk (MS)	33.8 efghij	···	45.2 abcdef	···
Valselva	2.8 hijk (MS)	23.6 hijk	−29.5	38.9 ghijk	−6.7
V. 804	3.0 hijk (MS)	23.2 jk	···	36.9 ijk	···
Valnova	3.0 hijk (MS)	25.2 hijk	−33.8	38.6 hijk	−9.1
Filippo	3.2 ijk (S)	19.3 k	−27.7	42.6 bcdefghi	−4.6
Valriccardo	3.2 ijk (S)	36.6 defghij	−20.7	41.3 defghij	−6.2
Valgerardo	3.3 jk (S)	23.5 ijk	−30.2	36.7 ijk	−6.8
Orsini	3.8 k (S)	16.9 k	−31.8	42.2 cdefghi	−0.3
Valforte	3.8 k (S)	17.4 k	−41.5	39.7 fghijk	−8.5
Mean	1.9	39.2	−16.7	42.6	−3.2
Coefficient of variation	37.9	22.6	···	7.2	···
Correlation coefficient	···	−0.661 **[z]	−0.797**	−0.325*	−0.635**

[v] Losses were estimated for each cultivar and character using the equation $L_x = (\bar{X}_n - X_i) - (\bar{R}_n - \bar{R}_i)$, where L_x = loss of cultivar X due to SBWM; $\bar{X}_n$ and X_i = average performance of cultivar X in 14 disease-free trials and in the infested field, respectively; $\bar{R}_n$ and $\bar{R}_i$ = average performance of five resistant cultivars in 14 disease-free trials and in the infested field, respectively.

[w] Disease rating based on a scale of 0–4, where 0–1 = resistant (R), slight or no symptoms; 1.1–2 = mildly resistant (MR), mild mottling and stunting; 2.1–3 = mildly susceptible (MS), mottling and stunting; and 3.1–4 = susceptible (S), severe mottling and stunting, with virus-killed plants.

[x] Tall genotypes.

[y] Within columns, means followed by the same letters are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

[z] Simple correlation coefficients between disease ratings and various plant characters (on 36 genotypes) and between disease ratings and estimated losses (on 25 genotypes): * = significant at $P = 0.05$ and ** = significant at $P = 0.01$.

Table 2. Field reaction, grain number, test weight, and plant height for 36 Italian durum wheat cultivars and lines grown in a field infested with soilborne wheat mosaic virus (SBWMV) near Rome, Italy, in 1982 and estimates[v] of losses caused by the disease

Cultivar or line	Field reaction[w]	Grain number ($\times 10^2/m^2$)		Test weight (kg/hl)		Plant height (cm)	
		Actual performance	Estimated loss	Actual performance	Estimated loss	Actual performance	Estimated loss
Murgia[x]	R	108 bcdefg[y]	9	81.4 a	1.3	104 b	1
Cappelli[x]	R	62 ijk	−16	79.4 abcde	0.0	117 a	−6
Trinakria	R	92 cdefghi	8	79.1 abcde	0.0	105 b	7
Capeiti[x]	R	111 bcde	−6	80.2 abc	−0.6	100 bc	3
Appulo[x]	R	122 abc	4	79.5 abcde	−0.9	90 cd	−5
Creso	R	123 abc	8	78.8 abcdef	−2.4	74 efghi	4
Gabbiano	R	150 a	16	79.3 abcde	−0.2	79 def	0
Isa I[x]	MR	94 cdefghi	0	79.7 abcd	0.1	98 bc	1
V. 1082	MR	120 abcd	···	79.8 abcd	···	68 efghijk	···
V. 1108	MR	137 ab	···	76.4 efghijk	···	80 de	···
Athena[x]	MR	113 bcde	−10	78.0 bcdefgh	−2.7	79 def	−12
Karel	MR	123 abc	−18	70.9 p	−6.3	78 defg	4
Tibula	MR	84 efghi	−36	74.0 jklmn	−4.8	63 hijk	−11
V. 1095	MR	93 cdefghi	···	78.4 abcdefg	···	77 defgh	···
Giano	MR	74 ghij	−46	77.8 bcdefghi	−2.1	66 efghijk	−14
Valfiora	MR	75 ghij	−21	77.0 cdefghij	−1.0	70 efghijk	−9
Valitalico	MR	74 ghij	−43	75.4 ghijklmn	−3.2	63 hijk	−7
V. 1038	MR	111 bcde	···	77.7 bcdefghi	···	70 efghijk	···
Vezio	MR	110 bcdef	−27	76.6 defghijk	−3.9	72 efghij	−6
V. 1111	MR	77 f	···	75.2 ghijklmn	···	72 efghij	···
Berillo	MS	146 a	17	74.6 ijklmn	−3.6	76 efgh	−7
V. 981	MS	103 cdefg	···	76.7 defghijk	···	72 efghij	···
V. 1040	MS	88 defghi	···	75.2 ghijklmn	···	64 ghijk	···
Produra	MS	97 cdefgh	−29	74.7 ijklmn	−5.1	64 ghijk	−6
Nora[x]	MS	106 bcdefg	−12	80.4 ab	−0.2	74 efghi	−23
V. 978	MS	82 efghi	···	75.8 fghijkl	···	65 jk	···
V. 1002	MS	92 cdefghi	···	75.5 ghijklmn	···	65 fghijk	···
V. 941	MS	75 ghij	···	74.7 ijklmn	···	66 efghijk	···
Valselva	MS	61 ijk	−55	75.7 fghijklm	−2.5	67 efghijk	−12
V. 804	MS	63 ijk	···	71.9 op	···	58 jk	···
Valnova	MS	65 hijk	−58	72.6 lmnop	−4.6	59 jk	−17
Filippo	S	45 jk	−55	73.4 klmnop	−4.0	57 k	−14
Valriccardo	S	89 defghi	−31	75.2 ghijklmn	−3.3	66 efghijk	−9
Valgerdo	S	64 hijk	−59	73.6 klmnop	−4.7	61 ijk	−17
Orsini	S	40 k	−74	72.4 nop	−3.6	59 jk	−7
Valforte	S	44 jk	−78	74.9 hijklmno	−3.2	61 ij	−16
Mean		92	−31	76.4	−3.1	74	−9
Coefficient of variation		18.3	···	2.2	···	9.6	···
Correlation coefficient		−0.524**[z]	−0.783**	−0.693**	−0.575**	···	−0.691**

[v] Losses were estimated for each cultivar and character using the equation $L_x = (\bar{X}_n - X_i) - (\bar{R}_n - \bar{R}_i)$, where L_x = loss of cultivar X due to SBWMV; $\bar{X}_n$ and X_i = average performance of cultivar X in 14 disease-free trials and in the infested field, respectively; $\bar{R}_n$ and $\bar{R}_i$ = average performance of five resistant cultivars in 14 disease-free trials and in the infested field, respectively.

[w] R = resistant, MR = mildly resistant, MS = mildly susceptible, and S = susceptible.

[x] Tall genotypes.

[y] Within columns, means followed by the same letters are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

[z] Simple correlation coefficients between disease ratings and various plant characters (on 36 genotypes) and between disease ratings and estimated losses (on 25 genotypes); ** = significant at $P = 0.01$.

why the virus had not been observed previously on this crop. The disease, however, may become a limiting factor for durum wheat production in Italy if the new semidwarf material presently being released is not carefully selected for SBWM resistance. Our results, in fact, clearly indicate that durum wheat yield losses caused by SBWM (as high as 70%) can be of the same magnitude as those reported for bread wheats and that most of the new Italian Norin 10 derivatives are quite susceptible to the disease.

Visual disease assessments made at a very early growth stage have been found to be highly correlated with yield loss and should therefore be very helpful in selecting resistant material in segregating populations. Their value in predicting actual loss under different environmental conditions, however, is probably much lower because of the influence exerted by the latter on the persistence of symptoms (12) as well as on yield itself. A few susceptible cultivars appear to possess efficient tolerance mechanisms, so that, in the case of advanced breeding material or in promising crosses between susceptible genotypes, both disease severity and yield in the presence of SBWMV should be evaluated.

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