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Reaction of durum wheat cultivars to mixed SBWMV and WSSMV infection in central Italy

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Summary. Forty-three cultivars of durum wheat (*Triticum durum* Desf.) were grown during the 1998–99 growing season in a field near Rome with natural inoculum sources of *Soilborne wheat mosaic virus* (SBWMV) and *Wheat spindle streak mosaic virus* (WSSMV), to evaluate their resistance to the mixed infection. Leaf extracts from twelve cultivars had relatively low ELISA values for WSSMV, and thirteen had low ELISA values for SBWMV. Results confirmed the high level of resistance to SBWMV of the cultivars Colorado, Ionio and Neodur. The reactions of the cultivars to SBWMV were consistent with those recorded in previous trials near Bologna, northern Italy, indicating that the SBWMV strains at the two test sites were pathogenically similar. Disease severity was significantly correlated with grain yield, thousand-kernel weight, heading date and the SBWMV-ELISA value, but not with the WSSMV-ELISA value. Regression analysis showed that, as a result of the mixed infection, the four cultivars with the most severe disease symptoms headed about 5 days later than normal, and suffered grain yield and kernel weight reductions of about 56 and 10% respectively. Cultivars with milder symptoms were also severely affected.

Key words: *Triticum durum* Desf., *Polymyxa graminis* Led., *Soilborne wheat mosaic*, *Wheat spindle streak mosaic*, resistance.

Introduction

In Italy, *Soilborne wheat mosaic virus* (SBWMV, genus *Furovirus*) and *Wheat spindle streak mosaic virus* (WSSMV, genus *Bymovirus*, family *Potyviridae*), both vectored by *Polymyxa graminis* Led. (Canova, 1966; Slykhuis and Barr, 1978), were first reported in 1960 and 1987 respectively (Canova and Quaglia, 1960; Rubies-Autonell and Vallega, 1987). SBWMV is widespread on both common wheat (*Triticum aestivum* L.) and durum wheat (*Triticum durum* Desf.), especially in northern and central Italy (Corino and Grancini, 1975; Rubies-Autonell and Vallega, 1985; Vallega and Rubies-Autonell, 1989; Rosciglione, 1991). WSSMV has been identified only in about twenty wheat fields in Emilia-Romagna, Marche, Toscana and Lazio, in northern and central Italy, often in mixed infection with SBWMV (Rubies-Autonell and Vallega, 1987, 1991). Mixed infections with SBWMV and WSSMV are not easily recognized in the field because symptoms of the mixed virus are very similar to those of a single virus except for the transient appearance of the characteristic spindle-shaped dashes caused by WSSMV. Despite these diagnostic difficulties, mixed infections are known to be widespread around the world (Hariri *et al.*, 1987; Kendall and Lommel, 1988; Chen, 1993). Mixed infections are of concern because reports

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suggest that the presence of WSSMV may cause a breakdown of resistance to SBWMV (Brakke *et al.*, 1982; Lommel *et al.*, 1986; Kendall and Lommel, 1988).

It should be noted that, based on the results of nucleotide sequence analysis, several authors (Chen *et al.*, 1999; Koenig and Huth, 2000) suggest that these two soilborne wheat viruses, both reported also in other European countries (Signoret *et al.*, 1977; Proeseler and Stanarius, 1983; Hariri *et al.*, 1987; Clover and Henry, 1999; Koenig and Huth, 2000) and hitherto generally referred to as SBWMV and WSSMV, are different from the SBWMV present in North America and the WSSMV present in far east Asia, and should be treated as distinct viruses.

In Italy, SBWMV may cause grain yield reductions of up to 50–70% (Toderi, 1969; Vallega and Rubies-Autonell, 1985; Vallega *et al.*, 1999a, 1999b, 2002; Rubies-Autonell *et al.*, 2000), and the same applies to WSSMV (Vallega and Rubies-Autonell, unpublished results). The only economic means of avoiding such damage is by growing resistant cultivars (Merkle and Smith, 1983; Van Koevering *et al.*, 1987; Wiese, 1987; Rumjuan *et al.*, 1996). Most of the wheats currently grown in Italy have been evaluated for resistance to SBWMV, but their reaction to WSSMV remains unknown, mainly because fields infected solely with this virus are not available for testing. In the current study we evaluated the response to WSSMV of a number of durum wheat cultivars using an experimental field harbouring both viruses, and took the opportunity to estimate the agronomic effects caused by the mixed infection. To our knowledge, this is the first report on the reaction of *T. durum* cultivars to WSSMV.

Materials and methods

The trial comprised forty-three cultivars of durum wheat sown November 10 (1998) in a field naturally infected with both SBWMV and WSSMV, situated near Rome. Twenty-five of these cultivars had been previously tested for SBWMV-resistance in northern Italy (Vallega *et al.*, 1999a, 1999b). The cultivars were planted at a rate of 4500 seeds/m^2 in plots of 10 m^2 distributed in the field according to a randomized-block design with two replicates. Symptom severity was evaluated on March 8, March 18 and April 6, 1999 using a 0–4 scale where 0–1, slight or no symptoms; 1.1–2, mild mottling and stunting; 2.1–3, mottling and stunting; and 3.1–4, severe mottling and stunting, with virus-killed plants. In what follows, scores given are the means of the symptom scores recorded on these three dates. Fifteen plants were collected from each plot on March 18 to perform DAS-ELISA according to the procedure of Clark and Adams (1977), modified as follows: sap extracted from leaves was diluted 1:6 in a phosphate saline buffer (pH 7.2) containing 0.05% Tween-20, 2% polyvinylpyrrolidone (MW 24,000), 0.2% powdered chicken-albumin and 0.5 mol l^{-1} urea. Extracts were from the apical half of the youngest leaf of each plant.

Agronomic performance was evaluated in terms of grain yield, thousand-kernel weight, test weight and heading date. The effects of the mixed SBWMV-WSSSMV infection on the cultivars assayed were estimated on the basis of simple linear regression equations between symptom severity and those agronomic characters which were significantly correlated (*P*=0.05) with the disease scores.

Results

Foliar mosaic became evident from about mid-February and remained visible until about the end of May. None of the cultivars remained asymptomatic throughout the season (Table 1), but a few expressed very mild symptoms, particularly cv. Ceedur (mean disease score, 0.3), Claudio (0.5) and Rusticano (0.6). Symptom expression was highest in 'Varano' (2.5), 'Ionio' (2.4), 'Lloyd' (2.2) and 'Bronte' (2.1).

ELISA absorbance values of the cultivars ranged from 0 to 0.729 for WSSMV, and from 0.012 to 1.733 for SBWMV. For brevity, and based on the results of previous trials (Rubies-Autonell *et al.*, 2000; Vallega *et al.*, 1999a, 1999b, 2002), cultivars with ELISA values lower than 0.091 for WSSMV and lower than 0.067 for SBWMV will, in what follows, be termed resistant, and the others susceptible.

Relatively low WSSMV titers (ELISA =0.091) were recorded for 'Arcobaleno', 'Dupri', 'Ofanto, 'Provenzal', 'Rusticano', 'Simeto', 'Solex', 'Svevo', and especially (ELISA =0.010) for 'Claudio', 'Iride', 'Italo' and 'San Carlo'.

Low SBWMV titers (ELISA =0.066) were record-

Table 1. Symptom severity, ELISA values, grain yield, test weight, days to head and thousand-kernel weight for 43 cultivars of durum wheat grown in a field infected with both SBWMV and WSSMV near Rome, Italy, during 1998–99.

	Disease severity (scale 0–4)[a]													
Ceedur*[b]	0.3	i[c]	0.121	de	0.27	af	3.46	a	76.6	aj	205	fl	32.4	gi
Claudio	0.5	hi	0.126	de	0.004	f	1.92	af	79.4	ab	205	fl	39.8	ad
Rusticano*	0.6	gi	0.281	ce	0.037	df	0.85	ef	72.8	ik	202	kn	34	di
Colorado	0.7	fi	0.056	e	0.114	bf	2.94	ac	79	ae	207	di	38.1	ag
Ofanto*	0.7	fi	1.211	ac	0.032	ef	2.44	ae	72.2	jk	204	hm	38.1	ag
Simeto*	0.8	di	1.611	a	0.053	def	1.47	bf	72.9	hk	202	kn	39.1	af
Solex*	0.8	ei	0.013	e	0.091	cf	0.99	ef	74.5	dk	206	ej	36.7	bg
Dupri	0.9	di	0.041	e	0.039	df	3.08	ab	76.1	bj	209	bf	41.4	ac
Gianni*	0.9	ci	0.016	e	0.114	bf	1.71	bf	75.8	bk	199	n	38.3	ag
Duilio*	1	ci	0.847	ae	0.272	af	2.01	af	74.9	bk	201	ln	39.3	ae
Giemme*	1	ci	0.805	ae	0.267	af	1.98	af	79.5	ab	202	jn	42.3	ab
Creso*	1.1	bi	0.154	de	0.11	bf	2.01	af	79.1	ad	207	di	43	a
Fortore	1.1	bi	1.038	ad	0.221	bf	2	af	74	gk	205	fl	36.9	bg
Ixos*	1.1	ci	1.525	a	0.227	bf	1.62	bf	71.4	k	205	gm	33.3	ei
Gargano	1.2	bi	1.57	a	0.348	af	1.32	cf	72.1	jk	199	n	35.2	dh
Valbelice	1.2	ai	1.542	a	0.509	ae	0.95	ef	77.6	ah	202	kn	33.1	fi
Iride*	1.3	ai	0.029	e	0	f	2.06	af	74.3	fk	201	mn	34.3	di
Italo*	1.3	ai	0.025	e	0.010	f	1.58	bf	75.9	bk	205	fl	33.1	fi
Poggio	1.4	ai	0.868	ae	0.406	af	0.84	ef	74.4	ek	210	ae	37.5	ag
San Carlo*	1.4	ai	0.012	e	0	f	1.73	bf	77.3	ai	206	ej	37.8	ag
Svevo*	1.4	ai	0.013	e	0.039	df	1.98	af	75.8	bk	201	ln	35.1	dh
Neodur*	1.5	ai	0.066	e	0.523	ad	2.74	ad	78.4	ag	211	ad	39.3	ae
Mongibello	1.6	ai	0.304	ce	0.295	af	1.31	cf	73.3	hk	207	di	34.6	dh
Parsifal*	1.6	ai	0.089	de	0.409	af	1	ef	74.4	ek	209	bg	35.4	cg
Baio	1.7	ah	0.898	ae	0.42	af	1.48	bf	77.3	ai	208	ch	39.3	ae
Ciccio*	1.7	ah	1.553	a	0.729	a	1.31	cf	76.1	bj	201	ln	36	cg
Flaminio	1.7	ah	0.168	de	0.272	af	1.14	df	76.5	aj	204	hm	40.1	ad
Nefer	1.7	ah	0.061	e	0.15	bf	1.93	af	76.3	bj	207	di	39.6	ad
Tresor*	1.7	ah	0.062	e	0.134	bf	1.12	df	77.5	ah	205	fl	32.2	gi
Platani*	1.8	ag	1.464	a	0.285	af	1.02	ef	73	hk	199	n	28.6	i
Cirillo*	1.9	af	1.599	a	0.594	ab	1.45	bf	78.8	af	206	ej	36.5	bg
Colosseo*	1.9	ag	0.103	de	0.418	af	0.78	ef	75.5	bk	207	di	36.5	bg
Grazia*	1.9	af	1.350	ab	0.344	af	1.58	bf	81	a	206	ej	35	dh
Saadi'	1.9	ag	0.480	be	0.444	af	0.89	ef	74.1	gk	212	ac	33	fi
Arcobaleno	2	ae	1.733	a	0.046	df	1.36	cf	75.4	bk	205	fl	34.5	di
Elios	2	ae	1.186	ac	0.21	bf	0.77	ef	74.6	ck	207	di	32.6	gi
Nerone	2	ae	1.295	ab	0.544	ac	2.15	af	79.2	ac	214	a	35.9	cg
Provenzal	2	ae	0.264	ce	0.054	df	1.31	cf	73.1	hk	207	di	29.2	hi
Valnova	2	ae	1.308	ab	0.478	af	1.05	df	74.7	ck	206	fk	37.9	ag
Bronte*	2.1	ad	1.711	a	0.351	af	1.3	cf	74.4	dk	203	in	36.9	bg
Lloyd*	2.2	ac	0.043	e	0.526	ad	1.72	bf	74.3	fk	213	ab	36.7	bg
Jonio* = Ares	2.4	ab	0.024	e	0.471	af	1.64	bf	75.7	bk	205	fl	35	dh
Varano	2.5	a	1.607	a	0.522	ae	0.52	f	74	gk	206	fk	32.4	gi
Mean	1.4		0.681		0.265		1.59		75.6		205		36.2	

[a] Disease ratings based on a scale of 0–4; values are the means of ratings made on March 8, March 18, and April 6, 1999.
[b] Cultivars marked with an asterisk (*) were assayed for SBWMV resistance in 1995–96 and/or 1996–97.
[c] Within columns, means followed by the same letters are not significantly different (*P*=0.05) according to Duncan's multiple range test.

ed for 'Colorado', 'Dupri', 'Gianni', 'Ionio' (i.e. 'Ares'), 'Iride', 'Italo', 'Lloyd', 'Nefer', 'Neodur', 'San Carlo', 'Solex', 'Svevo' and 'Tresor'. In other trials (Vallega *et al.*, 1999a, 1999b, 2002; Rubies-Autonell *et al.*, 2000), all these cultivars, except 'Colorado', 'Ionio' and 'Neodur'**,** were only moderately resistant to this virus; 'Dupri' was tested only in the present experiment. Among the other wheats assayed, thirty had relatively high SBWMV titers.

The twenty-five cultivars previously tested for resistance to SBWMV in northern Italy (Vallega *et al.*, 1999a, 1999b) ranked in nearly the same way in the Rome trial. On the other hand, a number of cultivars that had shown moderately high ELISA values in northern Italy showed values close to zero in Rome, indicating that disease pressure here was relatively low, and that the reaction to SBWMV of the cultivars tested for the first time needs to be verified under more stringent conditions.

Symptom severity was significantly correlated (P=0.01 or 0.05) with grain yield, days to head, thousand-kernel weight and the WSSMV ELISA value, but not with test weight or the SBWMV-ELISA value (Table 2). Correlations between ELISA values and agronomic characters were not significant, except for that between SBWMV ELISA and grain yield.

Regression analysis showed that the four cultivars expressing the most severe symptoms (disease scores 2.1–2.5) suffered a mean grain yield loss of about 56% and a reduction in kernel weight of about 10%. Cultivars with somewhat milder symptoms (disease scores 1.1–2) suffered a mean grain yield loss of about 39% and a thousand-kernel weight reduction of about 9%. Regression analysis also showed that cultivars with disease scores of 1.1 and over headed, on average, 4–5 days later than normal as a result of the mixed infection.

Discussion

Based on the DAS-ELISA readings, twenty-four of the cultivars tested were classified as susceptible to both SBWMV and WSSMV, and thirteen others as susceptible to at least one of these viruses.

Relatively low WSSMV ELISA values were recorded on twelve cultivars, especially on 'Claudio', 'Iride', 'Italo' and 'San Carlo'. Although the resistance of these wheats to WSSMV needs to be confirmed, the data are of interest in that they provide a first indication regarding the best cultivars to be grown in fields with this virus.

A number of cultivars were resistant to SBWMV with ELISA. Among these, 'Colorado', 'Ionio' and 'Neodur' may be safely recommended since they also exhibited very high levels of resistance to this virus in several other trials.

Cultivar reactions to SBWMV in Rome were consistent with those previously recorded near Bologna (northern Italy), in terms of ELISA rankings (Vallega *et al.*, 1999a, 1999b; 2002). This suggested that the SBWMV strains at each of these two sites were pathogenically identical, or at least very similar. Whether or not this applies to all the SBWMV strains in Italy and elsewhere in the world remains to be determined.

Cultivars which had previously shown low ELISA values for SBWMV in fields with only this virus also manifested low ELISA values in fields with both SBWMV and WSSMV. This demonstrates that

Table 2. Simple correlation coefficients between disease severity, ELISA values and various agronomic characters for 43 cultivars of durum wheat grown in a field infected with both SBWMV and WSSMV near Rome, Italy, in 1998–99.

	Disease severity (0–4 scale)	ELISA value	
		SBWMV	WSSSMV
Grain yield (t ha^{-1})	-0.499 **	-0.316*	-0.264
Test weight (kg hl^{-1})	-0.01	-0.189	0.126
Days to head	0.344*	-0.238	0.287
Thousand-kernel weight (g)	-0.323*	-0.187	-0.076
Disease severity (0–4 scale)	-	0.253	0.537**
ELISA value (SBWMV)		-	0.388*

* Significant at P=0.05; ** significant at P=0.01.

the concomitant presence of WSSMV does not necessarily cause a breakdown in resistance to SBWMV, as suggested by other authors (Brakke *et al.*, 1982; Lommel *et al.*, 1986; Kendall and Lommel, 1988).

Grain yield losses caused by the mixed infection in the most susceptible cultivars, estimated on the basis of the disease symptoms induced by both viruses, approached 60%. However, as might be expected, the effects of each of the two viruses on grain yield loss could not be distinguished since the ELISA values separately recorded for each virus were only loosely correlated with grain yield loss and with symptom severity.

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