CONSIGLIO PER LA RICERCA E LA SPERIMENTAZIONE IN AGRICOLTURA, Unità di ricerca per la valorizzazione qualitativa dei cereali (CRA–QCE), Via Cassia, 176, 00191 Rome, Italy.

Indexed data for comparing the reaction to cereal soilborne mosaic virus of durum wheat cultivars assayed in different seasons.

V. Vallega and C. Rubies-Autonell, A.M. Pisi, and C. Ratti (University of Bologna, Dipartimento di Scienze e Tecnologie Agroambientali).

Cereal soilborne mosaic virus (CSBMV) is widespread in Italy, where it often causes yield reductions of ~50–70% on susceptible wheats. A total of 89 durum wheat cultivars were assayed in seven seasons (1995–96, 1996–97, 2000–01, 2001–02, 2002–03, 2003–04, and 2004–05) in a field near Bologna with natural inoculum sources of CSBMV. Each trial was comprised of 30–33 cultivars, grown in 10-m^2, solid-seeded plots and distributed according to a randomized block design with three replicates. Nineteen cultivars were tested for 4–7 seasons and 58 cultivars for 1–2 seasons. Symptom severity was scored on 2–4 dates in each season using a 0–4 scale. DAS-ELISA was performed on extracts from a bulk of the youngest or second youngest fully expanded leaf of 10 or 15 plants/plot collected on one (1996 and 2001) or two dates. Grain yield and other agronomic traits also were recorded. To minimize the confounding effects of disease pressure, differences between seasons, the symptom score, and ELISA data collected for each cultivar on different dates were averaged and subsequently indexed as a percent of the highest mean observed among all cultivars assayed in that season; grain yield data also were indexed.

The 89 cultivars demonstrated a wide and continuous range of reactions to CSBMV (Table 1, p. 100-101), both in terms of symptom severity (index range = 4.5–100.0%), ELISA value (index range = 3.4–100.0%), and grain yield (index range = 35.5–100.0%; data not shown). Various cultivars consistently presented mild symptoms and low ELISA values in various seasons, yet none proved completely resistant. It should be noted that, although symptom score and ELISA value indexes were closely correlated (r = 0.850***), they produced different and sometimes contrasting resistance cultivar rankings, particularly in the case of cultivars tested for only one or two seasons. A wide and continuous

Table 1. Symptom score and ELISA value indexes (%), and rankings for 89 durum wheat cultivars assayed for resistance to cereal soil-borne mosaic virus near Bologna, Italy, from 1995–96 to 2004–05.

Cultivar	No. of years tested	Symptom score		ELISA value		Cultivar	No. of years tested	Symptom score		ELISA value	
		Index	Rank	Index	Rank			Index	Rank	Index	Rank
Louxor	1	6.7	3	6.1	4	Norba	1	18.8	21	50.6	54
Neodur	7	12.1	12	3.4	1	Torrebianca	5	38.7	52	34.9	41
Ares (Ionio)	4	9.5	7	6.9	6	Vendetta	1	35.6	46	38.3	43
Campodoro	1	4.5	1	13.0	13	Tresor	2	35.4	45	38.9	44
Meridiano	5	11.4	11	6.4	5	Virgilio	2	50.8	58	26.6	33
Dylan	3	9.0	4	10.0	9	Quadrato	4	37.0	47	40.9	47
Nefer	1	4.6	2	15.2	17	Verdi	3	29.7	36	49.0	52
Giusto	1	17.4	17	10.5	11	Appio	2	37.9	50	42.8	48
Colorado	5	18.2	20	10.8	12	Exeldur	2	33.9	41	53.4	56
Valerio	1	24.7	29	4.7	3	Italo	2	37.6	49	52.3	55
Ceedur	1	10.1	8	19.4	24	Plinio	1	37.5	48	61.2	61
Pietrafitta	2	11.2	10	19.1	22	Colosseo	4	42.3	56	60.4	60
Provenzal	5	26.2	31	4.4	2	Sorrento	1	69.4	66	38.9	45
Solex	6	12.5	14	19.3	23	Ixos	3	40.2	54	68.2	63
Baio	1	10.1	9	25.2	31	Creso	6	55.3	60	58.0	58
Levante	2	28.6	35	7.3	7	Portobello	1	58.4	61	55.3	57

Table 1. Symptom score and ELISA value indexes (%), and rankings for 89 durum wheat cultivars assayed for resistance to cereal soil-borne mosaic virus near Bologna, Italy, from 1995–96 to 2004–05.

Cultivar	No. of years tested	Symptom score		ELISA value		Cultivar	No. of years tested	Symptom score		ELISA value	
		Index	Rank	Index	Rank			Index	Rank	Index	Rank
Tiziana	3	23.0	25	13.1	14	Giove	1	67.2	64	64.3	62
Lloyd	3	17.4	18	20.4	25	Ofanto	2	55.1	59	79.5	66
Parsifal	2	17.9	19	23.5	28	Claudio	5	78.8	73	75.7	65
Cosmodur	2	20.8	23	21.9	26	Portorico	5	67.3	65	89.9	76
Duilio	7	24.2	27	19.1	21	Prometeo	2	98.2	87	59.4	59
Avispa	3	30.5	37	13.2	15	Anco Marzio	1	86.5	78	72.4	64
Fiore	2	39.3	53	7.5	8	Giemme	2	64.3	63	95.5	85
Flavio	2	23.3	26	24.4	29	Ciccio	2	61.0	62	99.0	86
Svevo	1	33.5	40	15.6	18	Marco	2	78.4	72	83.3	69
Gianni	5	24.6	28	24.7	30	Balsamo	2	75.3	70	90.4	77
San Carlo	5	26.8	32	22.7	27	Derrick	2	79.7	74	87.1	71
Rusticano	1	33.3	39	17.5	20	Platani	2	75.0	69	93.2	79
Grecale	2	40.6	55	10.3	10	Vettore	2	86.1	77	82.5	67
Peleo	1	9.4	6	43.0	49	Simeto	7	74.4	68	94.5	80
Vitron	2	12.3	13	40.8	46	Sorriso	1	76.5	71	94.6	81
Canyon	1	38.0	51	15.2	16	Vinci	1	71.2	67	100.0	89
Brindur	1	9.4	5	44.7	51	Orobel	5	82.2	75	89.4	74
Portofino	2	21.9	24	32.3	38	Vesuvio	3	88.7	80	87.2	72
Iride	6	26.0	30	29.3	35	Cannizzo	3	87.8	79	88.3	73
Valsalso	1	20.5	22	34.8	40	Grazia	5	93.0	84	86.0	70
Preco	1	12.5	15	43.6	50	Bronte	1	83.0	76	99.4	87
Vitomax	3	27.3	33	29.2	34	Carioca	1	100.0	88	82.5	68
Normanno	2	27.4	34	29.3	36	Cirillo	3	93.9	85	89.5	75

range of reactions to CSBMV in terms of symptom severity and ELISA value, as well as a higher similarity between symptom and ELISA index rankings, was observed for the 19 cultivars assayed four or more seasons (Table 2). The grain yield index also became more closely related to the other two indexes when analysis' were restricted to the 19 cultivars assayed four or more seasons. These 19 rather closely related cultivars, representing only 22% of those examined, showed no less than six distinct levels of resistance to CSBMV, suggesting that they differed for at least three major CSBMV resistance genes.

Table 2. Symptom score, ELISA value, and grain yield indexes (%) and rankings for 19 durum wheat cultivars assayed for CSBMV resistance in four or more seasons (Bologna, 1995–96 – 2004–05).

Cultivar	No. of years tested	Symptom score		ELISA value		Grain yield	
		Index	Rank	Index	Rank	Index	Rank
Neodur	7	12.1	3	3.4	1	85.3	4
Ares (Ionio)	4	9.5	1	6.9	4	86.7	2
Meridiano	5	11.4	2	6.4	3	86.1	3
Colorado	5	18.2	5	10.8	5	83.0	5
Provenzal	5	26.2	9	4.4	2	89.8	1
Solex	6	12.5	4	19.3	7	78.6	10
Duilio	7	24.2	6	19.1	6	80.1	7
Gianni	5	24.6	7	24.7	9	78.8	9
San Carlo	5	26.8	10	22.7	8	80.7	6
Iride	6	26.0	8	29.3	10	79.3	8
Torrebianca	5	38.7	12	34.9	11	76.1	11
Quadrato	4	37.0	11	40.9	12	74.7	12
Colosseo	4	42.3	13	60.4	14	65.5	15
Creso	6	55.3	14	58.0	13	70.7	13
Claudio	5	78.8	17	75.7	15	35.5	19
Portorico	5	67.3	15	89.9	18	55.6	16
Simeto	7	74.4	16	94.5	19	52.8	17
Orobel	5	82.2	18	89.4	17	66.5	14
Grazia	5	93.0	**19**	86.0	**16**	48.2	**18**

Predicting agronomic performance of durum wheat cultivars on the basis of CSBMV concentration and symptom severity evaluations made on different dates.

C. Rubies-Autonell, C. Ratti (University of Bologna, Dipartimento di Scienze e Tecnologie Agroambientali), and V. Vallega.

Different sets of cultivars of durum wheat were tested over seven seasons in a field near Bologna, Italy, with natural inoculum sources of CSBMV. Each trial was comprised of 30–33 cultivars. Symptom severity, DAS-ELISA absorbance, and various agronomic characters were investigated. In each season, symptom severity was scored on 2–4 dates using a 0–4 scale, whereas DAS-ELISA was performed on extracts from a bulk of the youngest or second youngest fully expanded leaf of 10 or 15 plants/plot collected on one (1995–96 and 2000–01) or two dates. The cultivars were grown in 10-m^2, solid-seeded plots distributed according to a randomized block design with three replicates. The effects of CSBMV on the agronomic performance of cultivars manifesting diverse symptom severity were estimated by regression analysis. The data collected were used to estimate the damage caused by CSBMV and to identify the most informative dates for rating symptom severity and assessing virus concentration.

Symptom scores above 3.0 were associated with mean grain yield and mean plant height reductions of 48% and 25%, respectively, as well as with notable decreases in kernel weight and test weight (Table 3). Even mild symptoms caused appreciable negative effects on grain yield (-9%) and plant height (-5%). Mean ELISA absorbance (Table 4) was significantly (P = 0.05) correlated with mean symptom severity, grain yield, and plant height in all seven seasons, with kernel weight and test weight in four seasons, and with heading date in two seasons. Mean symptom severity also was more closely correlated with grain yield and plant height than with the other three agro-

Table 3. Mean actual performance and estimated effects of cereal soilborne mosaic virus (CSBMV) for durum wheat cultivars with different symptom severity grown in a field with CSBMV near Bologna, Italy, over seven seasons.

Symptom score (0–4)	Actual grain yield	Reduction (%)	Actual plant height	Reduction (%)	Actual kernel weight	Actual test weight	Actual heading date
0.0–1.0	4.66	8.7	81.4	4.6	42.4	78.4	40
1.0–2.0	3.97	22.2	78.2	8.4	41.6	77.6	41
2.0–3.0	2.97	41.8	70.4	17.5	38.5	76.7	41
3.0–4.0	2.64	48.2	64.1	24.9	36.1	77.1	43

Table 4. Correlations between ELISA absorbance values on different dates and agronomic characters and mean symptom score for 89 durum wheat cultivars grown in a field with cereal soilborne mosaic virus near Bologna, Italy, in trials comprised of 30–33 cultivars.

Year	No. of cultivars	Date	Grain yield		Plant height		Kernel weight		Test weight		Heading date		Mean symptom Score	
1996	33	26 March	-0.710	**	-0.721	**	-0.516	**	-0.383	*	0.523	**	0.855	**
1997	33	4 April	-0.736	**	-0.436	**	-0.351	*	-0.409	*	0.170	ns		
		7 May	-0.720	**	-0.462	**	-0.428	*	-0.583	**	0.282	ns		
Mean ELISA			-0.752	**	-0.468	**	-0.412	*	-0.533	**	0.246	ns	0.826	**
2001	30	21 March	-0.570	**	-0.404	*	-0.079	ns	-0.371	*	—		0.808	**
2002	30	13 March	-0.709	**	-0.790	**	-0.231	ns	-0.472	**	0.099	ns		
		3 April	-0.467	**	-0.511	**	-0,074	ns	-0.152	n.s.	0.173	ns		
Mean ELISA			-0.703	**	-0.781	**	-0.206	ns	-0.422	*	0.130	ns	0.862	**
2003	31	13 March	-0.853	**	-0.667	**	-0.547	**	-0.635	**	0.332	ns		
		2 April	-0.897	**	-0.773	**	-0.401	*	-0.536	**	0.391	*		
Mean ELISA			-0.920	**	-0.758	**	-0.494	**	-0.612	**	0.413	*	0.942	**
2004	31	30 March	-0.816	**	-0.746	**	-0.431	*	-0.313	n.s.	0.244	ns		
		22 April	-0.861	**	-0.784	**	-0.524	**	-0,310	n.s.	0.267	ns		
Mean ELISA			-0.874	**	-0.797	**	-0.497	**	-0.325	n.s.	0.266	ns	0.928	**
2005	32	6 April	-0.501	**	-0.744	**	-0.179	ns	0.240	n.s.	0.119	ns		
		20 April	-0.507	**	-0.669	**	-0.204	ns	0.139	n.s.	0.087	ns		
Mean ELISA			-0.519	**	-0.732	**	-0.197	ns	0.200	n.s.	0.108	ns	0.819	**

nomic traits (Table 5). In four out of five seasons, ELISA correlations with grain yield and plant height were practically identical for the two sampling dates considered; only in 2002 was the earlier date (13 March) distinctly more informative; correlations with kernel weight and test weight also were similar on different dates. The correlation of symptom score with grain yield and plant height were essentially identical for the various sampling dates considered, except for the first scoring date in 2005 (18 March), which proved markedly less informative than the three subsequent dates. Correlations with kernel weight, test weight, and heading date also proved similar on different dates. The results indicated that multiple symptom and ELISA observations allow more meaningful CSBMV-damage estimates only with respect to the more loosely associated agronomic traits (kernel weight, test weight, and heading date), whereas a single scoring and sampling date suffices to produce reliable grain yield and plant height reduction estimates. However, symptom score and ELISA value rankings among cultivars change, sometimes substantially, during the season, thus rendering multiple observations mandatory for adequately classifying the response of single cultivars to CSBMV.

Table 5. Correlations between CSBMV-symptom severity on different dates and agronomic characters and mean ELISA absorbance for 89 durum wheat cultivars grown in a field with CSBMV near Bologna, Italy, in trials comprised of 30–33 cultivars.

Year	No. of cultivars	Date	Grain yield		Plant height		Kernel weight		Test weight		Heading date		Mean ELISA	
1996	33	26 March	-0.760	**	-0.776	**	-0.647	**	-0.458	**	0.609	**		
		17 May	-0.757	**	-0.786	**	-0.601	**	-0.382	*	0.735	**		
Mean symp.			-0.773	**	-0.800	**	-0.638	**	-0.425	*	0.693	**	0.855	**
1997	33	26 March	-0.657	**	-0.558	**	-0.364	*	-0.288	ns	0.515	**		
		4 April	-0.761	**	-0.484	**	-0.180	ns	-0.298	ns	0.352	*		
		16 April	-0.825	**	-0.494	**	-0.439	**	-0.461	**	0.348	*		
		24 April	-0.777	**	-0.541	**	-0.365	*	-0.444	**	0.363	*		
Mean symp.			-0.812	**	-0.556	**	-0.368	*	-0.408	*	0.418	*	0.826	**
2001	30	19 February	-0.635	**	-0.655	**	-0.224	ns	-0.344	ns	-			
		5 March	-0.604	**	-0.675	**	-0.306	ns	-0.342	ns	-			
		21 March	-0.615	**	-0.595	**	-0.261	ns	-0.279	ns	-			
Mean symp.			-0.630	**	-0.653	**	-0.273	ns	-0.325	ns	-		**0.808**	**
2002	30	28 February	-0.514	**	-0.711	**	-0.087	ns	-0.223	ns	0.110	ns		
		13 March	-0.606	**	-0.771	**	-0.077	ns	-0.225	ns	0.247	ns		
		3 April	-0.653	**	-0.784	**	-0.132	ns	-0.286	ns	0.319	ns		
		22 April	-0.698	**	-0.789	**	-0.137	ns	-0.442	*	0.189	ns		
Mean symp.			-0.651	**	-0.803	**	-0.114	ns	-0.307	ns	0.233	ns	0.862	**
2003	31	13 March	-0.914	**	-0.835	**	-0.549	**	-0.515	**	0.332	ns		
		2 April	-0.859	**	-0.767	**	-0.563	**	-0.499	**	0.469	**		
		16 April	-0.912	**	-0.850	**	-0.545	**	-0.531	**	0.367	*		
Mean symp.			-0.913	**	-0.834	**	-0.564	**	-0.526	**	0.396	*	0.942	**
2004	31	18March	-0.790	**	-0.730	**	-0.456	**	-0.327	ns	0.335	ns		
		30 March	-0.823	**	-0.754	**	-0.589	**	-0.317	ns	0.318	ns		
		15 April	-0.891	**	-0.766	**	-0.521	**	-0.363	*	0.319	ns		
		22 April	-0.775	**	-0.665	**	-0.481	**	-0.286	ns	0.283	ns		
Mean symp.			-0.859	**	-0.765	**	-0.537	**	-0.340	ns	0.330	ns	0.928	**
2005	32	18 March	-0.395	*	-0.569	**	-0.155	ns	0.213	ns	0.036	ns		
		1 April	-0.552	**	-0.712	**	-0.417	*	0.246	ns	0.105	ns		
		6 April	-0.635	**	-0.796	**	-0.435	*	0.257	ns	0.105	ns		
		18 April	-0.687	**	-0.777	**	-0.391	*	0.282	ns	0.151	ns		
Mean symp.			-0.633	**	-0.782	**	-0.400	*	0.272	ns	0.116	ns	0.819	**

Inheritance of resistance to CSBMV in lines derived from a cross between durum wheat cultivars Neodur and Cirillo.

V. Vallega, C. Ratti and C. Rubies-Autonell (University of Bologna, Dipartimento di Scienze e Tecnologie Agroambientali), and P. De Vita and A.M. Mastrangelo (CRA–CER, Foggia).

Most of the durum wheat cultivars marketed in Italy are quite susceptible to CSBMV and none was found completely resistant. The same observation was made for a large number of durum wheat cultivars from other countries. A high proportion of the few, highly CSBMV-resistant cultivars identified are derived from Edmore wheat and, therefore, a reasonable assumption is that Edmore and its CSBMV-resistant derivatives carry a major CSBMV-resistance gene or gene-block. To test this hypothesis, 160 F_8 RILs obtained by single-seed-descent from a cross between cultivars Neodur (a resistant derivative of Edmore) and Cirillo (highly susceptible) were grown during 2007–08 in a field with natural inoculum sources of CSBMV near Bologna. The lines and parental cultivars were grown in 2.4-m^2, solid-seeded plots distributed according to a randomized block design with three replicates and evaluated for symptom severity (on 11 March, 27 March, and 15 April) and ELISA absorbance (on 11 March and 15 April). Symptom severity was scored on a 0–4 scale. DAS-ELISA was determined on extracts from a bulk of the youngest fully expanded leaf of 15 plants/plot. Grain yield, test weight, kernel weight, and plant height also were recorded.

Symptom scores and ELISA values were significantly correlated, and both parameters showed significant negative associations with each of the four agronomic traits examined, particularly with grain yield and plant height. Symptom-severity score frequency distributions showed a markedly greater proportion of resistant lines (about 96 vs. 64) on all three observation dates and eight major peaks (Fig. 1, p. 105). Grain yield, plant height, and ELISA-absorbance means for the lines contributing to each of the eight major symptom frequency-peaks were highly differentiated and closely matched the values expected for the corresponding symptom score peaks. The ELISA value distributions also revealed a greater proportion of resistant lines (about 89 vs. 71) and seven distinct, major peaks. Most of the major frequency peaks obtained for each of the two resistance parameters were bi-modal. Segregation distortions analogous to that causing a preponderance of CSBMV-resistant types have often been reported for RILs and may be attributed to various factors; particularly to genetic interactions and, in the case of materials obtained by SSD, which cumulate the effects of multiple generations, to selective advantages of the corresponding genes or gene-blocks. The number of genes (2.8, 3.4, and 3.1 for 11 March, 27 March, and 15 April, respectively) estimated by the formula of Wright approximately corresponds to that envisaged by the major peaks in the frequency distributions. Nonwithstanding segregation distortion, we concluded that the cultivar Neodur contributed at least three, possibly linked, major genes that account for the 7–8 major frequency peaks and their seemingly bi-modal form. The study gave evidence of the presence of a sizeable temporal change in the relative degree of resistance of the lines in terms of both symptom severity and ELISA absorbance causing substantial changes in resistance ranking order among lines. This temporal change may be attributed to the diverse duration of the efficacy of the resistance genes identified or to genes controlling morphological or phenological plant traits affecting the onstart and/or progress of CSBMV infection. We have observed previously and reported resistance rankings changes between cultivars during the course of a same season; the present experiment offered the opportunity to validate the phenomenon in a common genetic background. Presently, the 'Neodur/Cirillo' population is being profiled to identify the QTL associated with its specific CSBMV-resistance genes and to elucidate the nature of the genes causing a temporal change in resistance and of that originating the inheritance pattern distortion.

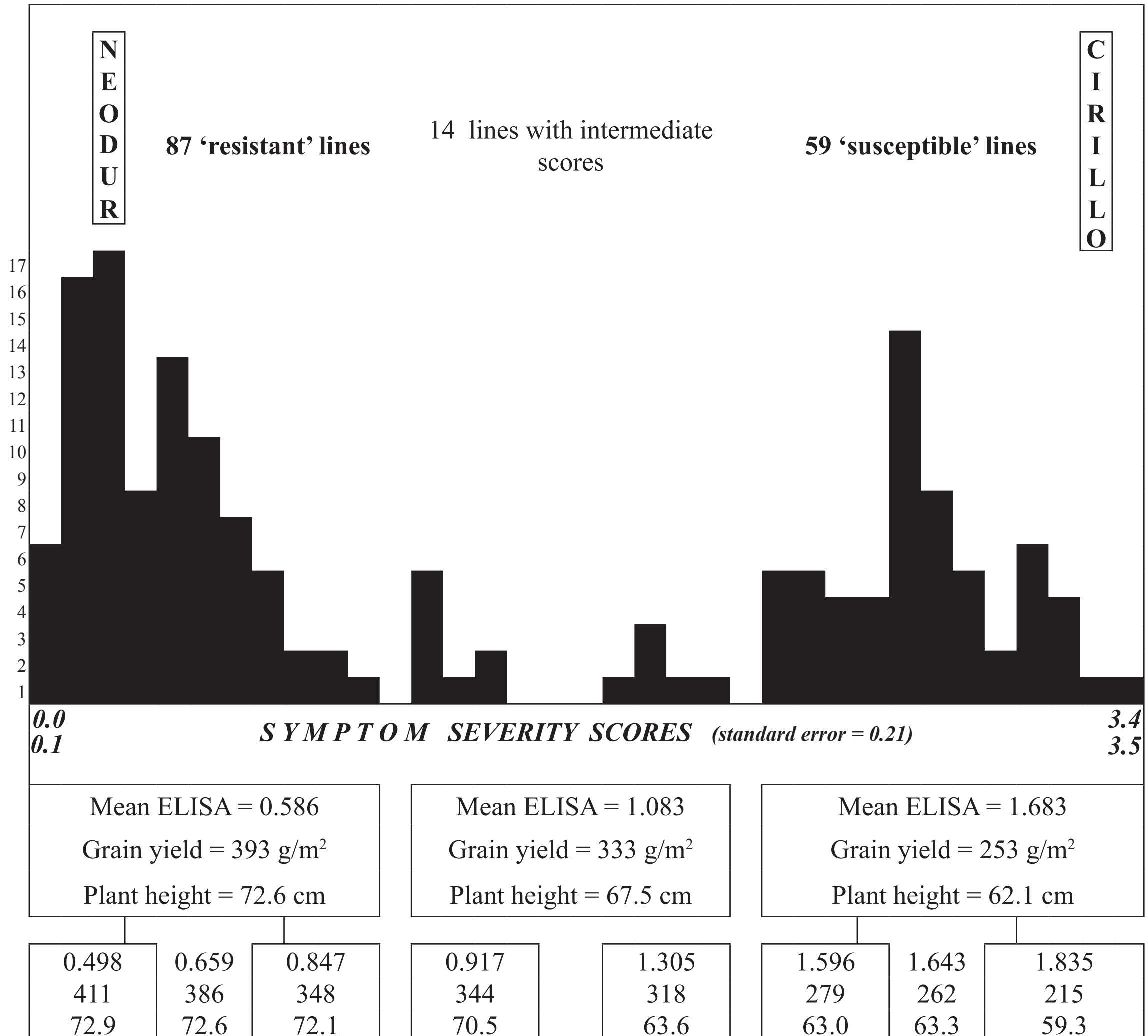

Fig. 1. Number of lines derived from the durum wheat cross ‘Neodur/Cirillo’ with different CSBMV symptom severity scores (0–4 scale; means of 27 March and 15 April, 2008) and mean ELISA value, grain yield (g/m^2), and plant height (cm) of the lines corresponding to the eight major frequency peaks.