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RELATIONSHIPS BETWEEN DWARFNESS (NORIN 10) AND AGRONOMIC TRAITS IN DURUM WHEAT USED IN BREEDING WORK

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SUMMARY

In the Experiment Institute for Cereal Research of Rome, semidwarf (Norin 10), high-yielding durum wheats, resistant to disease and possessing high spike fertility, have been obtained.

Simple phenotypic and genotypic correlation coefficients of F_2 *generations from crosses between three semidwarf "Gerardo" lines and medium-tall Italian varieties, show that plant height is not associated with heading date, ear length and percent of yellow-berry. On the contrary, dwarfness is correlated with low kernel weight; this unfavorable association is due to a genetic system of Norin 10. A certain correlation would exist between tall plants and ear characteristics (No. of kernels per ear, No. of fertile spikelets per ear, ear weight).*

Partial correlation and standard partial regression coefficients allow to ascertain that ear length possesses a greater influence than plant height on the expression of ear characteristics.

The necessity for increasing grain production of durum wheat in Italy has promoted the development of research for the genetic improvement of this species.

In the Experiment Institute for Cereal Research of Rome, high-yielding durum wheats ("Giorgio" and "Gerardo" lines) resistant to diseases (leaf and stem rusts, mildew) have been obtained with the collaboration of Dr. J. Vallega.

The "Giorgio" lines derive from the cross Cappelli x "Roman selections". The latter, in turn were selected at Rome (VALLEGA and ZITELLI, 1964) from F_2 populations of *T. durum* obtained in Mexico by Dr. N. Borlaug as a result of crossing the (Norin 10 x Brevor) lines, local bread and durum wheats, and durum varieties of various origin (BORLAUG, 1968).

The "Gerardo" lines derive from crosses of "Giorgio" lines with Italian traditional durum varieties, or with Italian varieties in which resistance factors had been incorporated, or with foreign material resistant to one or more diseases (VALLEGA and ZITELLI, 1968).

These lines appear of interest in possessing the following associated traits: short height (conferring resistance to lodging) and high spike fertility. Such traits differentiate these varieties from those usually grown in Italy (VALLEGA, 1972). During the last several years, studies have been carried out to analyze the genetic basis and the inheritance mechanisms responsible for the expression of such characters.

Semidwarfness was found to depend on a few independent "major genes" (possibly two), partially recessive with different expression, as well as likely cumulative in their effect. There was no association between the semidwarfness factors and those governing resistance to black rust (ZITELLI and VALLEGA, 1971). No significant association was found between plant height and ear length and ear fertility, but there was significant correlation between ear length and components of ear fertility such as number of kernels and number of fertile spikelets per ear (MARIANI and ZITELLI, 1973).

The independence between plant height and ear length allowed an easy selection of short plants with long and fertile spikes. Such an independence is found only in semi-dwarf wheats (both bread and durum groups) derived from Norin 10 (POWELL and SCHLEHUBER, 1967; REDDI *et al.*, 1969; ZITELLI and MARIANI, 1972).

During the breeding work, it was observed that, in general, shortness was combined with high fertility and high weight of spike, but also with unfavorable characters, such as lateness, low kernel weight, and susceptibility to yellow-berry. However, a severe selection made it possible to obtain semi-dwarf lines with high yielding capacity, sufficient earliness, and satisfactory grain characters.

MATERIAL AND METHODS

Three semidwarf lines - Gerardo 512 (= Valgerardo), Gerardo 515, Gerardo 523 - high yielding, with high number of kernels per ear, kernel weight per ear and 1000-kernel weight, were crossed with the medium-tall Capeiti 8, (Patrizio 6 x 368) and (368 x Capeiti 8). In heading time the lines ranged from the very early Capeiti 8 (121 days from January 1) to Gerardo 515 (132 days) (Table 1). Five crosses were studied.

Parental varieties and F_2 were grown in 1972 at Rome. The parental plots were represented by two rows replicated twice; the F_2 rows varied in number from 15 to 50. Row length was 2 m, rows were spaced 30 cm apart, and space between plants in each row was 10 cm. Because of the segregant nature, the F_2 material was not replicated (WEBER and MOORTHY, 1951).

For the traits studied, means and standard deviations were calculated for parental lines and F_2 populations (Table 1). Moreover, for F_2 were computed:

Heritability, in broad sense: $h^2 = s^2_g / s^2_{ph} \times 100$.

Genetic advance: $Gs = h^2 \times ks_{ph}$; $k = 2.06$, assuming selection intensity of 5% (JOHNSON *et al.*, 1955). Gs is expressed as a percent of the mean.

In determining genotypic variance and covariance, the environmental variance and covariance were calculated as plant mean variance and covariance within parents (GRIFFING, 1953; WEBER and MOORTHY, 1951).

Multiple correlations, partial regression and correlation coefficients, and standard partial regression coefficients (STEEL and TORRIE, 1960) were calculated for the following combinations: plant height and ear length with number of kernels per ear, number of fertile spikelets per ear, ear weight, and 1000-kernel weight; number of kernels per ear and 1000-kernel weight with ear weight; and number of fertile spikelets per ear and 1000-kernel weight with ear weight.

Table 1. Means (m) and standard deviations (s) for 10 characters of parents and F_2 populations. G512, G515, G523 = Gerardo 512, 515, 523; C8 = Capeiti 8; P6x368 = (Patrizio 6 x 368); 368xC8 = (368 x Capeiti 8)

Parents and F_2	No. plts.	Heading date		Plant height cm		Peduncle length cm		Ear length cm		Fertile spikelets per ear no.		Ear weight g		Kernels per ear no.		Weight of 1000 kernels g		% of yellow-berry as arcsen$\sqrt{x}$		
		m	s	m	s	m	s	m	s	m	s	m	s	m	s	m	s	m	m	s
G512	56	127	0.96	77	2.86	37	6.29	7.9	0.69	22	1.57	3.9	0.50	64	10.54	61	6.38	36	0.64	0.35
C8	42	121	1.02	98	6.78	53	5.80	5.4	0.54	17	2.37	2.2	0.49	46	8.88	47	5.38	31	0.59	0.24
G512 x C8	648	124	3.89	90	15.68	44	8.89	6.5	0.76	19	3.10	2.8	0.88	51	13.36	54	13.70	27	0.55	0.42
P6 x 368	38	125	1.49	91	4.20	47	3.75	5.8	0.49	19	1.84	2.4	0.43	48	8.23	49	2.57	3	0.18	0.16
G512 x P6x368	216	126	3.91	90	19.22	43	10.83	7.5	1.04	20	3.24	2.9	1.06	48	15.31	60	9.70	13	0.37	0.24
368 x C8	45	125	1.60	103	7.95	49	4.14	6.4	0.59	19	2.25	2.7	0.66	53	10.94	52	3.59	4	0.19	0.09
G512 x 368xC8	374	126	3.57	91	17.21	42	8.61	7.5	0.93	20	3.53	3.2	1.13	54	17.10	58	9.00	71	1.01	0.48
G515	32	132	1.97	72	2.95	40	0.49	8.2	0.78	20	1.97	3.6	0.79	57	11.95	63	3.33	21	0.48	0.24
G515 x 368xC8	152	126	3.72	94	17.76	42	9.44	7.2	0.93	19	2.94	3.1	1.04	49	15.01	65	17.12	22	0.49	0.32
G523	44	130	1.29	74	5.63	31	1.80	7.8	0.76	21	2.31	3.6	1.05	58	13.68	61	5.77	7	0.27	0.16
G523 x P6x368	138	124	3.60	92	17.26	42	8.79	7.1	0.89	20	3.23	3.3	1.15	54	18.75	61	6.27	17	0.43	0.24

The standard partial regression coefficients have been expressed as per cent of their total and graphed in Figure 1.

RESULTS AND DISCUSSION

Heritability and Genetic Advance

The possibility of selecting individuals genetically different from the mean of a segregating population is obviously of great interest for the plant breeder. To evaluate such a possiblity, heritability is considered together with genetic advance. In fact, heritability alone provides insufficient information dealing with the range of variability of a given character within a population.

Table 2. Heritability (h^2) and genetic advance (Gs) for 10 characters of F_2 populations (values in %). Abbreviations of names of parents as in Table 1.

Characters	G512 x C8		G512 x (P6x368)		G512 x (368xC8)		G515 x (368xC8)		G523 x (P6x368)	
	h^2	Gs	h^2	Gs	h^2	Gs	h^2	Gs	h^2	Gs
Heading date	89.5	5.8	89.6	5.7	87.5	5.1	88.5	5.4	87.7	5.2
Plant height	88.0	31.6	92.1	40.6	88.5	34.5	89.2	34.7	88.5	34.2
Pedun. lgth.	71.3	29.6	80.9	42.0	67.8	28.8	73.2	33.5	69.1	29.8
Ear length	34.8	7.7	65.6	18.7	56.5	14.7	56.3	15.3	52.3	14.1
F. splts/ear	53.9	17.8	57.6	19.4	64.3	23.9	48.5	15.2	57.6	18.6
Ear weight	59.2	39.3	69.7	51.7	68.2	50.0	62.4	41.9	69.2	48.5
Kernels/ear	39.5	21.4	53.9	37.3	63.1	41.1	52.1	32.9	69.3	49.6
1000-kern. wt.	78.7	41.0	75.0	25.1	68.6	21.9	91.3	49.9	35.5	7.6
% yellow-berry	71.3	109.0	9.6	13.5	77.7	79.2	48.4	61.2	8.5	9.3

With the exception of yellow-berry, heritability is rather high for all the characters considered (Table 2). Plant height is highly heritable and characterized by a remarkable genetic advance; the same applies to the peduncle length. Obviously this derives from the fact that the material studied possesses Norin 10 genotype, in which few (possibly only 2) genetic factors control the height; and that the same few factors condition the peduncle length (MARIANI and ZITELLI, 1973).

Among the ear characters high values in heritability and good chances for genetic gain are found in ear weight, and, decreasingly, in the number of kernels per ear, in 1000-kernel weight (in the different crosses different responses), and in the number of fertile spikelets per ear. The ear length shows a reduced value for genetic advance. Highly variable are the indexes for yellow-berry in various crosses, both for heritability and genetic advance. Finally the heading date is highly heritable, but shows a poor genetic-advance value.

RELATIONSHIP BETWEEN DWARFNESS AND AGRONOMIC TRAITS

Simple Correlations

The simple phenotypic and genotypic correlation coefficients (not included because of space limitations but available from the authors on request), the multiple and partial correlations, and the standard partial regression coefficients (Fig. 1) allow a better knowledge of the nature and degree of association of the traits considered.

The simple correlation coefficients suggest that in all crosses there is independence between plant height and ear length.

Plant height is positively correlated with the number of kernels per ear in the crosses Gerardo 512 x Capeiti 8, Gerardo 512 x (Patrizio 6 x 368), and Gerardo 515 x (368 x Capeiti 8), although the values of the coefficient are low. This repeats the behavior of Gerardo 512 crossed with Sincape 9, a variety of intermediate height but rather fertile.

The "Gerardo" lines possess a genetic behavior different from that of the "Giorgio" lines studied in the previous work. In fact, in the "Giorgio" lines there was absolute independence between plant height and ear length, as well as between plant height and the characters that are responsible for ear fertility (MARIANI and ZITELLI, 1973).

Generally ear weight and 1000-kernel weight were positively correlated with plant height.

Considering plant height and yellow-berry, only for the cross Gerardo 523 x (Patrizio 6 x 368) was there a correlation (highly negative).

As rather expected, the correlations between peduncle length and the other traits were similar to those occurring for plant height.

Ear length was positively and significantly correlated with number of fertile spikelets per ear, with ear weight, and with number of kernels per ear; but not with yellow-berry.

Of course there was a strong association between number of fertile spikelets and ear weight, as well as between the former trait and number of kernels per ear.

Ear weight was highly correlated with number of kernels per ear and with 1000-kernel weight, except in Gerardo 323 x (Patrizio 6 x 368). The values of the correlation coefficients between ear weight and yellow-berry were significantly positive for the crosses with Gerardo 512, but negative for the other two cross combinations.

In the crosses with Gerardo 512 there was a clear association between number of kernels per ear and 1000-kernel weight, whereas in the other two crosses the correlation was negative.

The values of the correlation coefficients between earliness of heading and plant height indicated that no association exists between these traits, except possibly in the crosses Gerardo 512 x (Patrizio 6 x 368) and Gerardo 512 x (368 x Capeiti 8). Also, there was no association between earliness of heading and ear length, except for the cross Gerardo 512 x (368 x Capeiti 8). The earliness of heading seems to be correlated with the ear characters (fertile spikelets per ear, ear weight, kernels per ear, 1000-kernel weight) for the crosses with Gerardo 512; in the other two crosses no correlation is detectable.

Consequently, it should be possible to obtain plants early and short, and possibly with long and fertile ear.

Moreover, it seems likely that earliness of heading is positively correlated with per cent of yellow-berry. However, yellow-berry is known to be greatly influenced by environmental conditions; moreover, since the rate is variable from cross to cross, it is impossible to formulate any conclusion, especially if it is considered that the experiments have been conducted only in one year at a unique locality.

Multiple Correlations

The simple correlations indicate that plant height is not associated with ear length, but is associated with the characters that affect fertility, which in turn are correlated with ear length. These results appear somewhat contradictory. To clarify this, calculation of the multiple correlations among plant height, ear length and ear characters turned out to be of great use. The partial correlation coefficients, together with the standard partial regression coefficients, have allowed evaluation of how plant height and ear length affect number of kernels per ear, number of fertile spikelets per ear, ear weight, and 1000-kernel weight.

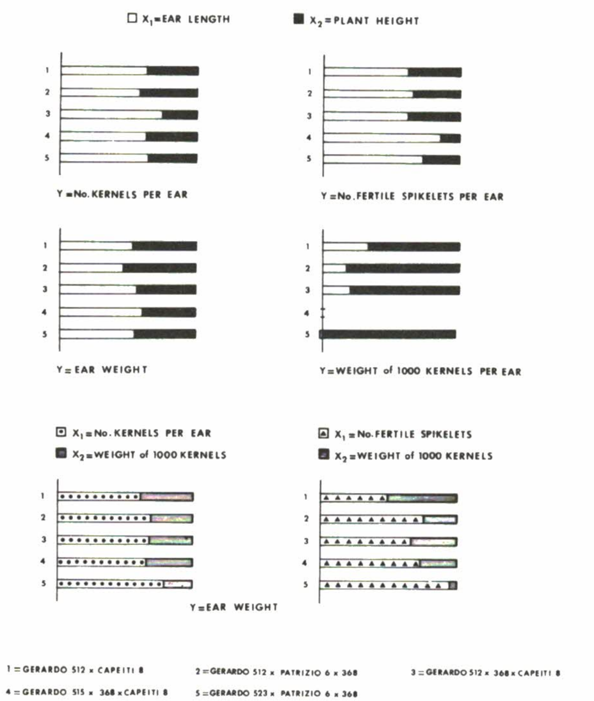

Figure 1. Standard partial regression coefficients expressed as per cent of their total.

Figure 1 shows that ear length has a greater influence than plant height in determining number of kernels per ear (58-74%), number of fertile spikelets per ear (62-86%), and, to a lower degree, ear weight (46-61%). On the other side, the influence of plant height is predominant on 1000-kernel weight (67-98%), except for the Gerardo 515 x (368 x Capeiti 8) cross.

Finally, number of kernels per ear (61-78%) and number of fertile spikelets per ear (58-95%) are more important than 1000-kernel weight in determining ear weight.

In conclusion, the results of these studies on the genetic behavior of the "Gerardo" lines indicate that, at least for some of the lines examined, it will be possible to select plants that are fairly short and early, with long, fertile and heavy ears; but it will be difficult to recover all these characters together with a satisfactory 1000-kernel weight, in spite of the fact that the "Gerardo" lines already possess high 1000-kernel weight, are short, and have long, heavy and fertile ears.

The unfavorable association between shortness and low 1000-kernel weight is one of the limiting factors in successful use of Norin 10 as source of dwarfness.

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