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Combining Ability Analysis of Some Quantitative Characters in Hexaploid *Triticale*

L. V. Reddy, Department of Plant Breeding, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (India)

Summary. Seven parental lines of hexaploid *Triticale* were selected to study the nature of inheritance of various agronomic characters. Combining ability analysis was carried out for eleven characters following Method 4, Model I of diallel cross analysis given by Griffing (1956).

Both the general and specific combining ability variances were highly significant or significant for all the characters studied. However, the former were greater than the latter for each of the characters, except for spike length and number of days to maturity, indicating the predominance of additive gene action in the material studied.

The corresponding general combining ability effects for grain yield and one or two of its components suggest the importance of the component method of selection in *Triticale* breeding. The important yield contributing characters were found to be productive tillers per plant, 1000 kernel weight, kernels per spike and kernels per spikelet.

The possibility of capitalising both the additive and non-additive portions of genetic variability by practising selections successively on the basis of general and specific combining abilities is discussed.

Introduction

Significant achievements have been made in breeding hexaploid Triticales, mostly in the second half of the present century (Kiss and Tréfás 1970, Larter et al. 1970). Three distinct approaches to the development of these Triticales are the following:

1) octoploid × hexaploid forms (Pissarev 1963, Kiss 1966);
2) hexaploid *Triticale* × hexaploid wheat (Nakajima and Zennyozi 1966);
3) hexaploid × hexaploid *Triticale* (Jenkins 1966)

The improvements in *Triticale* have been made without much knowledge of the mode of inheritance of yield and its components. As this information is scanty in this crop, the present investigation was undertaken with the objective of studying the nature of inheritance of some quantitative characters of economic importance.

Materials and Methods

The seven parental lines of hexaploid *Triticale* used in this study were selected, on the basis of good agronomic characters, from breeding nurseries and initial evaluation trials during 1971-72. All these strains, namely, PC 202-52, Arm PPV 13, PC 222-46, T16A-1, T15-2, PC 191-2 and 16610-1, were obtained from CIMMYT, Mexico, in the International Triticale Yield Nurseries and/or other breeding material. Except for PC 191-2 and 16610-1, they are Armadillo strains. Crosses were made in all possible combinations, excluding reciprocals, during 1972-73. All the 21 F_1's and 7 parents were grown in a Randomised Block Design with three replications during 1973-74. Each plot consisted of a single row 3 metres long, with 30 × 10 cm row to row and plant to plant spacing. Because of the poor germination of parental lines, reliable data could not be obtained on their performance. The data on the performance of F_1 populations were recorded from five randomly selected, competitive plants and averages were obtained for each of the characters except for test weight and grain yield, the data of which were taken on a whole plot basis. The analysis of general and specific combining ability effects and variances obtained from the 7 × 7 diallel set was carried out according to Method 4, Model 1, of Griffing (1956).

Results

Among the twenty-one hybrids, Arm PPV 13 × PC 191-2 was the highest grain yielding and it had the highest tiller producing capacity (Table 1). There were highly significant ($P \le 0.01$) genotypic differences among hybrids for all the characters studied. Both the general combining ability (g.c.a.) and specific combining ability (s.c.a.) were highly significant ($P \le 0.01$) or significant ($P \le 0.05$) for each of the characters (Table 2). However, the magnitude of g.c.a. variances was greater than of s.c.a. variances for all the char-

Table 1. Average performance of all the crosses for various characters

Sl. No.	Crosses		Grain yield per plant	Test weight in kg.	1000 kernel weight in gm.	Kernels per spike	Kernels per spikelet	Spikelets per spike	Productive tillers per plant	Spike length in cm.	Plant height in cm.	Days to flowering	Days to maturity
1.	PC202-52	xArmPPV13	33.5	61.7	50.3	71.8	3.0	23.6	13.0	11.7	128.5	95.3	143.3
2.	"	xPC222-46	32.3	68.7	43.3	83.4	3.3	25.6	11.3	10.9	115.5	100.0	143.0
3.	"	xT16A-1	26.6	64.8	46.9	62.0	2.2	27.6	10.7	12.8	129.0	100.7	144.7
4.	"	xPC191-2	23.4	65.2	39.9	84.3	3.1	27.2	8.3	11.3	122.7	100.3	147.0
5.	"	xT15-2	31.2	67.7	47.6	73.5	3.1	23.6	11.3	10.9	118.0	98.3	143.0
6.	"	x16610-1	40.4	65.2	57.5	74.9	2.9	25.9	13.0	13.0	139.3	99.7	144.3
7.	ArmPPV-13	xPC222-46	44.8	68.3	40.5	65.8	2.4	27.6	16.0	10.7	122.1	110.0	149.0
8.	"	xT16A-1	33.8	61.7	52.9	75.9	2.8	27.4	11.0	13.5	136.4	99.3	142.0
9.	"	xPC191-2	51.4	65.3	41.4	76.2	2.8	27.5	17.0	11.5	130.4	107.3	149.3
10.	"	xT15-2	31.5	61.7	42.5	65.1	2.6	25.2	11.7	11.3	120.3	98.0	144.3
11.	"	x16610-1	38.4	65.5	54.5	83.7	3.3	25.6	11.0	13.4	130.7	96.7	139.7
12.	PC222-47	xT16A-1	24.8	65.3	45.9	64.7	2.3	27.5	11.0	12.5	128.8	103.3	145.3
13.	"	xPC191-2	27.3	66.5	38.7	83.6	3.0	27.3	9.7	11.9	120.6	103.3	142.0
14.	"	xT15-2	24.6	65.7	47.5	78.4	3.1	24.8	10.7	11.3	131.8	96.0	143.7
15.	"	x16610-1	23.4	67.3	46.7	62.3	2.4	25.2	10.3	12.7	151.1	110.3	149.3
16.	T16A-1	xPC191-2	13.0	63.0	41.1	65.7	2.4	27.0	7.0	12.4	123.3	106.7	147.0
17.	"	xT15-2	16.6	63.2	50.2	68.3	2.5	26.6	8.3	12.9	144.1	100.0	144.7
18.	"	x16610-1	14.7	65.2	52.6	67.7	2.6	26.3	9.0	10.2	155.3	99.3	143.7
19.	PC191-2	xT15-2	35.2	68.2	40.9	80.1	2.9	27.4	12.3	11.7	127.5	106.0	144.0
20.	"	x16610-1	38.9	64.3	46.2	80.6	3.0	27.5	12.7	12.9	134.1	102.3	142.0
21.	T15-2	x16610-1	37.0	64.5	56.7	68.1	2.5	27.1	14.3	13.2	135.9	100.3	144.3
	S.Em ±		8.64	2.84	3.09	4.72	0.27	2.11	1.80	0.97	14.48	2.91	2.71

Table 2. Estimates of combining ability effects and variances in a 7 x 7 diallel of hexaploid *Triticale*

Parents	Grain yield per plant in gm.	Test weight in kg.	1000 kernel weight in gm.	Kernels per spike	Kernels per spikelet	Spikelets per spike	Productive tillers per plant	Spike length in cm.	Plant height in cm.	Days to flowering	Days to maturity
General combining ability effects											
Pc 202-52	0.75	0.43	0.87	2.23	0.19	-0.94	-0.20	-0.34	-6.28	-2.60	-0.40
Arm PPV-13	9.95	-1.39	0.18	-0.04	0.02	-0.24	2.25	-0.02	-3.20	-0.74	0.06
PC 222-46	-1.29	2.13	-2.84	-0.12	-0.01	-0.04	0.11	-0.44	-2.90	2.52	0.99
T 16A-1	-10.83	-1.59	1.71	-6.89	-0.36	0.87	-2.29	0.42	6.50	-0.20	0.02
PC 191-2	1.11	0.27	-6.56	6.35	0.12	1.15	-0.29	-0.10	-5.16	3.72	0.80
T 15-2	-1.51	-0.03	0.89	-1.03	0.03	-0.70	-0.03	-0.18	-1.36	-2.34	0.66
16610-1	1.83	0.17	6.61	-0.29	-0.003	0.10	0.37	0.64	12.40	-0.34	-0.80
S.e./g_i-g_j/	1.45	0.63	0.69	1.05	0.06	0.47	0.39	0.22	3.20	0.65	0.60
Variances											
G.c.a.6	187.82^{xx}	7.74^{xx}	87.50^{xx}	78.16^{xx}	0.15^{xx}	2.94^{xx}	8.35^{xx}	0.30^{x}	235.48^{xx}	27.61^{xx}	2.56^{x}
S.c.a.14	55.48^{xx}	3.16^{xx}	8.81^{xx}	50.02^{xx}	0.09^{xx}	1.13^{x}	4.88^{x}	1.23^{xx}	53.65^{x}	14.86^{xx}	8.11^{xx}
Error 40	5.29	1.00	1.19	2.77	0.01	0.55	0.39	0.12	25.85	1.06	0.91
G.c.a./S.c.a.	3.38	2.45	9.93	1.56	1.67	2.60	1.71	0.24	4.39	1.86	0.31

^{xx} and ^{x} - significance at $p \leq 0.01$ and $p \leq 0.05$ respectively

G.c.a./S.c.a. - estimate of the ratio of additive to non-additive gene effects.

acters except spike length and number of days to maturity. The ratios of g.c.a. to s.c.a., which are estimates of the ratio of additive to non-additive gene effects, were: considerably greater than unity for 1000-kernel weight, plant height and grain yield; greater than unity for number of spikelets per spike and test weight; near unity for number of days to flowering, number of productive tillers per plant, number of kernels per spikelet, and number of kernels per spike; less than unity for number of days to maturity and spike length (Table 2).

Discussion

The results of the present study agree with those found by Kaltsikes and Lee (1973) for *Triticale* and Widner and Lebsock (1973) for durum wheat, where the major part of the total variability for each trait was associated with highly significant g.c.a. variances. However, Kaltsikes and Lee reported nonsignificant s.c.a. variances for kernels per spike, kernels per spikelet, and 1000-kernel weight, in contrast to the present results. These discrepancies can be attributed to differences in their experimental material, which consisted of five lines of hexaploid *Triticale* derived from the same cross involving four primary hexaploid Triticales. In the present study, two lines differ in origin from the rest, and the secondary hexaploid Triticales differ from primary ones in that hexaploid wheat is involved as a parent in their pedigree during the process of improvement (Zillinsky and Borlaug 1971).

As indicated by Sprague and Tatum (1942), variance due to g.c.a. includes additive genetic variance and additive × additive interaction variance, whereas, s.c.a. variance is assumed to include non-additive genetic variance arising from dominance and epistatic deviations and genotypic × environment interactions. The results of the present study reveal the significant role of both additive and non-additive gene action in the total genetic variability and the preponderance of additive gene action for all the characters studied, except for spike length and number of days to maturity. The significant role of non-additive genes in the inheritance of agronomic characters in hexaploid *Triticale* may be due to the diverse gene pool formed by the addition of the extra genome of the out-breeding rye to that of the self-fertilising tetraploid wheat (Kaltsikes and Lee 1973).

Breeding Implications

In *Triticale*, a self-pollinated crop, only the genetic variability resulting from additive gene action can be effectively utilised because of its retainment in subsequent self-fertilisation. If male sterility and fertility-restoring gene sources are available for commercial hybrid production, it should also be possible to capitalize on non-additive gene action. The preponderance of additive over non-additive genetic variance in the present study suggests that lines should be selected on the basis of high g.c.a. effects for grain yield and one of the yield components. A second selection could be practised based on s.c.a. for grain yield.

So far, no correlation studies between different agronomic traits have been reported in hexaploid *Triticale*. However, it is apparent from the present findings that the number of productive tillers per plant, number of kernels per spike, 1000-kernel weight and number of kernels per spikelet are the major yield contributing characters. Selection to increase these components should increase the total yield if there is no negative correlation among them.

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L.V. Reddy
P.O. Saidapuram
via Yadgarpalli 508115
Tq. Bhongir
Dist. Nalgonda, A.P. (India)