

Diallel Analysis and Heterosis for Yield and Associated Characters in Durum Wheat under Upland Conditions¹

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ABSTRACT

The combining ability studies were made in ten F₁ progenies involving five diverse parents in durum wheat. The analysis of variance for 15 populations and variances of general combining ability (GCA) showed highly significant differences for grain yield, spikes per plant, 1000 kernel weight, plant height and days to heading. The estimated specific combining ability (SCA) variances were slightly higher to GCA variances for grain yield, indicating considerable non-additive gene action in the inheritance of this complex trait. The two parents 'DT367' and 'Wascana' were superior general combiners for grain yield and spikes per plant, while the variety Pelissier was the best combiner for 1000 kernel weight, flag leaf area and plant height. The cross combinations 'Pelissier' x '7561-EZ2E', 'DT367' x '7461-Q4A' and 'DT367' x 'Pelissier' recorded higher values for SCA effects for yield and related characters. Heterosis over superior parent ranged from -27.6% to 22.1% for grain yield and five out of 10 F₁ progenies excelled their better parent.

INTRODUCTION

The objective of many plant breeding programs in the self- and cross-pollinated crops is to develop high yielding varieties, superior hybrids and potential populations like synthetics and composites through hybridization programs. Success in crossing programs depends upon the choice of suitable parental material which will combine well to generate superior progeny. Several guidelines for parental choice have been used with some success in developing outstanding cultivars like high mean yield, diversity in pedigree between parents (12, 14) and studying combining abilities (5, 6, 11, 14). However, if the trait to be improved is not highly heritable, methods of selecting superior parents will be moderately successful (14).

COMPENDIO

Se estudió la aptitud combinatoria en diez progenies F₁, descendientes de cinco progenitores diversos en trigo duro. El análisis de variancia para 15 poblaciones y de variancias de la aptitud combinatoria general (GCA) mostraron diferencias altamente significativas en el rendimiento de granos, espigas por planta, peso de mil granos, altura de planta y días a floración. Las variancias estimadas de aptitud combinatoria específica (SCA) fueron ligeramente más altas que las de GCA en rendimiento de granos, lo que indica una considerable acción no aditiva de genes en la herencia de esta característica compleja. Los progenitores 'DT 367' y 'Wascana' fueron los mejores combinadores para rendimiento de granos y espigas por planta, mientras que la variedad Pelissier fue el mejor combinador para peso de mil granos, área de hoja-bandera y altura de planta. Los cruces entre 'Pelissier' y '7561-EZ2E', entre 'DT367' y '7461-Q4A', y entre 'DT367' y 'Pelissier' registraron altos valores de SCA en rendimiento y características relacionadas con éste. La heterosis sobre el progenitor superior varió entre -27.6% y 22.1% para rendimiento de granos y cinco de las diez progenies F₁ superaron a sus mejores progenitores.

A knowledge of general and specific combining abilities (GCA, SCA) influencing yield and its components has become increasingly important to plant breeders in the choice of suitable parents for developing potential hybrids in many crop plants (2, 13, 15). Several studies (2, 3, 7, 8, 16) have attempted to determine the GCA and SCA for yield and related characteristics in wheat crosses under irrigated conditions, but such information is scant under dryland conditions. The objective of this research was thus to identify superior parents based on higher GCA values and better crosses with higher SCA values, and to study hybrid vigor for yield and associated characters in the F₁ generation of a five parent diallel cross in durum wheat (*Triticum turgidum* L. var. Durum) in a dryland environment.

MATERIALS AND METHODS

The five cultivars (DT367, Wascana, Pelissier, 7461-Q4A and 7561-EZ2E) of spring durum assumed to be homogeneous and homozygous were selected as parents. The four parents 'DT367', 'Wascana', 'Pelissier' and '7561-EZ2E' were selected because of their excellent rooting abilities, tall stature, drought

¹ Received for publication 23 May 1989.

* The author is most grateful to the authorities of the International Development Center, Ottawa, Canada for financial help and to the authorities of the Agricultural Research Station, Swift Current, Canada, for providing facilities to carry out this investigation.

resistance and high yield under dryland conditions in different yield trials and greenhouse experiments. The cultivar 7461-Q4A was chosen for its short-statured and early maturity qualities. These cultivars differed in yield and their components, plant height, days to heading, grain size and drought resistance. These lines were crossed in all possible combinations excluding reciprocals to obtain ten hybrids in the greenhouse. A diallel set involving these parents and their ten F₁ hybrids were seeded in a randomized block design at the Agricultural Experiment Station, Swift Current, Saskatchewan, Canada. Each treatment was seeded in a single row of 2 m length and the plants in each row were spaced 10 cm apart, keeping a row to row distance of 23 cm. The seeding was effected with the conserved moisture in the soil and afterwards the crop was grown strictly under drought conditions. A random sample of five plants was chosen for each entry for recording data on six traits, grain yield per plant, spikes per plant, 1000 kernel weight, plant height, days to heading and flag leaf area.

The plot means of the characters were utilized to calculate the statistical analysis of variance and combining ability effects following Griffing (6) Method II and Model I.

RESULTS AND DISCUSSION

The analysis of variance for genotypes and GCA variance (Table 1) indicated highly significant differences for grain yield, spikes per plant, 1000 kernel weight, plant height and days to heading, and SCA for the last three characters listed revealed a considerable variability in these traits among the genotypes included in the study. However, close examination revealed that

the estimates of SCA variance were slightly higher than GCA variance for grain yield, indicating considerable non-additive gene action involved in the inheritance of this character. Bhatia *et al.* (2) and Kuruvadi (9) have reported that the SCA component of variance was higher than that of GCA variance for grain yield in durum wheat, revealing the predominant role of non-additive gene effects in the genetic control of grain yield. Several researchers (7, 8, 12) detected significant SCA effects for grain yield in the space planted in experiments in wheat. Cregan and Busch (5) indicated that the absence of SCA effects in competitive growth conditions in the field suggests that non-additive genetic variance may not be well-expressed in wheat under such circumstances. The variances due to GCA effects were greater than those due to SCA effects for the characters spike number and plant height, indicating the predominant role of additive gene effects for these traits. The estimates of SCA variance were greater than GCA variance for 1000 kernel weight and days to heading, revealing the greater magnitude of non-additive gene effects on these two characters (Table 1).

The grain yield per plant varied from 8.2 g to 13.5 g and 9.6 g to 14.8 g in the parents and hybrids respectively (Table 2) and the hybrids recorded 11.9% more grain yield over parents. 'Wascana' produced maximum grain yield of 13.5 g per plant followed by 'DT367' (12.3 g) in the parents. Among the crosses 'DT367' x 'Wascana' topped in yield with 14.8 g per plant followed by 'DT367' x 'Pelissier' with 14 g, and 'Pelissier' x '7561-EZ2E' also with 14 g.

The estimates of GCA effects (Table 3) revealed that the parent 'DT 367' and 'Wascana' were excellent general combiners for grain yield and spikes per plant.

Table 1. Analysis of variance for combining ability in durum wheat.

Source of variation	Degrees of freedom	Mean sum of squares					
		Grain yield per plant	Spikes per plant	1000 kernel weight	Plant height	Days to heading	Flag leaf area
Replication	1	0.00	0.66	3.22	0.96	41.36	33.36
Genotypes	14	3.49**	2.13**	12.19**	118.58**	52.06**	1.20NS
GCA	4	7.57**	4.57**	4.51**	395.88**	117.02**	2.08NS
SCA	9	1.86NS	1.15NS	15.26**	7.66**	26.08**	0.85NS
σ_g^2	-	0.94	0.10	-2.88	74.83	1.24	0.17
σ_g^2	-	0.99	0.03	26.72	8.99	2.40	-0.14

** Significant at 1 percent level.

NS Non significant

Table 2. Mean values of parents and their hybrids for different characters in durum wheat.

Parents and hybrids	Grain yield per plant (g)	Spikes per plant	1000 kernel weight (g)	Plant height (cm)	Days to heading	Flag leaf area (cm ²)
DT367	12.3	5.3	57.6	88.3	61.9	21.1
Wascana	13.5	6.4	57.9	98.3	60.8	22.0
Pelissier	9.4	4.3	60.1	97.5	64.5	23.8
7461-Q4A	8.2	4.3	53.2	56.4	60.7	21.4
7561-EZ2E	11.4	5.0	58.5	86.9	60.6	23.2
1 x 2	14.8	5.7	63.2	93.7	62.5	23.2
1 x 3	14.0	5.8	68.2	100.0	65.3	22.2
1 x 4	13.0	4.9	68.4	75.2	59.5	22.4
1 x 5	11.8	5.2	60.3	88.0	62.3	23.9
2 x 3	11.8	5.2	65.7	103.6	64.2	23.0
2 x 4	9.8	4.3	66.9	84.3	60.8	20.5
2 x 5	13.1	5.8	60.0	98.1	63.8	21.0
3 x 4	9.7	5.0	67.5	81.7	64.9	22.1
3 x 5	14.0	5.5	67.7	98.2	65.9	32.9
4 x 5	9.6	4.3	64.9	73.8	68.7	22.0
Mean for parents	11.0	5.1	57.5	85.5	61.7	22.3
Mean for hybrids	12.2	5.2	65.3	98.2	70.0	27.5
General mean	11.8	5.1	62.7	88.3	62.4	22.4

The variety Pelissier was the best combiner for the three characters, 1000 kernel weight, tall stature and flag leaf area. Kuruvadi and Smith (10) studied the root models of 14 varieties in durum wheat and mentioned that the variety Pelissier produced a remarkably good root model, increasing the quantity of root mass in the soil profile from 60 cm to 120 cm depth in the rhizotron. The same authors (11) studied the combining abilities for root potential in F₁ and F₂ generations in durum wheat and identified 'Pelissier' as a good general com-

biner for root mass and recommended it as the best donor for breeding improved varieties under drought conditions based on root potential. In addition, Clark and Smith (4) demonstrated that the tetraploid variety Pelissier retains high water content in the excised-leaf experiments which contributes to drought resistance in the field condition. The advance generation line 7461-Q4A was a superior combiner for dwarfness and earliness.

Table 3. General combining ability effects for parents and specific combining ability effects for crosses in durum wheat.

Parents and crosses	Grain yield per plant	Spikes per plant	1000 kernel weight	Plant height	Days to heading	Flag leaf area
DT367	1.90	0.20	-0.10	0.56	-0.16	-0.06
Wascana	0.84	0.43	-0.63	6.67	-0.23	-0.37
Pelissier	-0.32	-0.10	1.89	6.99	2.10	0.65
7461-Q4A	-1.72	-0.53	-0.28	-14.54	-1.33	-0.65
7561-EZ2E	0.11	0.10	-0.88	0.33	-0.37	0.43
1 x 2	1.06	-1.62	1.28	-1.80	0.47	1.19
1 x 3	1.46	0.57	3.71	4.19	0.94	-0.80
1 x 4	1.86	0.10	6.06	0.92	-1.43	0.76
1 x 5	-1.16	-0.13	-1.38	-1.15	0.41	1.11
2 x 3	-0.46	-0.26	1.80	1.68	-0.09	0.33
2 x 4	-0.10	0.73	5.17	3.91	-0.06	-0.87
2 x 5	0.37	0.24	-1.13	2.83	1.99	-1.34
3 x 4	-0.28	0.50	3.22	0.99	1.61	-0.29
3 x 5	2.40	0.47	4.01	2.26	1.76	0.45
4 x 5	-0.10	-0.30	-8.93	-0.25	-2.01	0.27

Generally the parents with higher mean performance of a character were mostly involved with superior values of GCA effects and vice versa. Bailey *et al.* (1) studied the heterosis and gene action for yield in wheat and mentioned that the ranking of the parents based on parental means was the same as ranking based on additive effects. However, Bhatia *et al.* (2) concluded that the mean performance of parents and their GCA effects were generally inconsistent, indicating that breeding values of the parents may not be precisely predicted for their performance in durum wheat. Considering the mean and direction and magnitude of the general combining ability, the overall best combiners identified were 'DT367', 'Wascana' and 'Pelissier' for yield and other related traits, and these varieties could be exploited for higher grain productivity under dryland conditions as these lines contain considerable frequency of desirable additive genes for grain yield and other associated characters. The general combining ability is attributable to additive gene action and additive x additive epistasis, and conventional pedigree breeding methods would therefore be more fruitful in the improvement of this crop.

Considering magnitude and direction of SCA effects, the crosses 'Pelissier' x '7561-EZ2E', 'DT367' x '7461-Q4A' and 'DT367' x 'Pelissier' have manifested positive and higher values of SCA effects for grain yield, spikes per plant and 1000 kernel weight, and offers greatest promise for further exploitation. The parents 'DT367', 'Pelissier' and 'Wascana' were mostly involved in many productive crosses.

Heterosis over midparental value for grain yield ranged from -10% to 33.7% and 7 out of 10 F₁ progenies produced higher yields than midparental values. Heterosis above the better parent ranged from -27.6% to 22.1% and five out of 10 F₁ progenies surpassed their better parent. Winder and Lebsack (16) and Kuruvadi (9) have demonstrated significant hybrid vigor for grain yield of F₁ population in durum wheat. The crosses 'Pelissier' x '7561-EZ2E' for grain yield (22.1%); 'Pelissier' x '7461-Q4A' for spikes per plant (16.3%); 'Wascana' x '7461-Q4A' for 1000 kernel weight (15.7%); 'Pelissier' x '7461-Q4A' for dwarfism (-16.2%); 'DT367' x '7461-Q4A' for earliness (-3.9%) and 'DT367' x 'Wascana' for flag leaf area (5.2%), expressed highest heterotic effect over superior parent. The high heterotic effect for these characters may be attributed to high GCA of one or both parents, desirable and higher SCA effect of the cross, or a combination of high GCA and SCA effect of the parents and the crosses respectively. These high yielding crosses could be directly exploited for practical breeding under rainfed conditions.

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