

# Selection responses for some agronomic traits in hexaploid triticale

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## SUMMARY

The aims of this study were to estimate the direct response to selection for grain number per spikelet and meiotic index and to evaluate the correlated responses for several agronomic traits. The selection and evaluation processes were performed at Campo Escuela de la Facultad de Ciencias Agropecuarias (Universidad Nacional de Córdoba) Córdoba, Argentina. The  $F_{2:3}$ ,  $F_{2:4}$  and  $F_{2:5}$  families were evaluated respectively during 1997, 1998 and 1999. The triennial analysis showed significant differences between the mean values of the families corresponding to the divergent groups derived from plants selected and evaluated according to high and low number of grains per spikelet and high and low percentage of normal tetrads criteria. With respect to other traits, significant statistical differences between group mean values of the selected material for high and low grain number per spikelet were observed for grain yield per plot and per spike, some physical grain yield components such as grain number per spike, grain number per square metre and one physiological component such as harvest index. In conclusion, the grain number per spikelet has two essential requirements from a plant breeder's point of view viz. it has genetic variability and presents correlated responses in relation to the grain yield. We consider the inclusion of this character in the inner part of a selection index directed to improve hexaploid triticale integrally through a recurrent selection scheme.

**Key words:** triticale, number of grains per spikelet, meiotic index, direct and correlated responses

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## RESUMEN

Los objetivos de este estudio fueron estimar las respuestas directas a la selección para número de granos por espiguilla e índice meiótico y evaluar las respuestas correlacionadas a la selección evidenciadas por estas características

reproductivas. Los procesos de selección y de evaluación fueron llevados a cabo en el Campo Escuela de la Facultad de Ciencias Agropecuarias (Universidad Nacional de Córdoba) en Córdoba, Argentina. Las familias F<sub>2:3</sub>, F<sub>2:4</sub> y F<sub>2:5</sub> fueron evaluadas respectivamente durante 1997, 1998 y 1999. El análisis trienal mostró diferencias significativas entre los valores medios de las familias correspondientes a los grupos divergentes de las plantas seleccionadas y evaluadas de acuerdo a los criterios alto y bajo número de granos por espiguilla y alto y bajo porcentaje de tétrades normales. Con respecto a otros caracteres se observaron diferencias significativas entre los valores medios de los grupos del material seleccionado por alto y bajo número de granos por espiguilla para rendimiento en grano por parcela y por espiga, para algunos componentes físicos del rendimiento como número de granos por espiga, número de granos por metro cuadrado y para el componente fisiológico índice de cosecha. En conclusión, el número de granos por espiguilla reúne dos requerimientos esenciales desde el punto de vista de un fitomejorador, posee variabilidad genética y presenta respuestas correlacionadas en relación al rendimiento en grano. Consideramos de importancia incluir este carácter como parte de un índice de selección dirigido a mejorar integralmente al triticale hexaploide a través de un esquema de selección recurrente.

**Palabras clave:** triticale, número de granos por espiguilla, índice meiótico, respuestas directas y correlacionadas.

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## INTRODUCTION

Hexaploid triticale (*X Triticosecale* Wittmack), an intergeneric synthetic species originally obtained crossing self-pollinating wheat (*Triticum turgidum* var. *durum* L.) and cross-pollinating rye (*Secale cereale* L.), is considered very important to investigate inheritance factors in such new conditions. After one century it has been transformed from a botanical curiosity into a commercial crop and, thanks to breeding efforts, it is a new alternative which is biologically competitive with other winter cereals in many agroecological niches and well adapted to difficult environments (Varughese, 1996). Concerning its feed uses, triticale is superior to barley and wheat since it has higher protein levels and a good amino acid balance (Fischer, 1993); however, it is necessary to improve milling and bread making quality aspects in order to increase its potential for human nutrition (Gryka, 1998). In this context, as a new hybrid species in evolution, the relationship between wheat and rye genomes produces meiotic irregularities; during the production of primary triticale numerous cases of genome incompatibility and instability have been described (Müntzing, 1979; Lelley, 1996). Two alternative ways to study and to improve triticale reproductive performance are the improvement of the number of grains per spikelet

and of the meiotic behaviour. The number of seeds per spikelet has a low heritability value, and it presents a positive correlated response for grain yield per spike (Maich & Manero de Zumelzú, 1998). With respect to the meiotic approach, the number of normal tetrads (meiotic index) is important as it is the final outcome of all the meiosis stages (Dubovets *et al.*, 2002); this character also possesses a low heritability estimate (Maich & Manero de Zumelzú, 1998). Antagonistic associations have been determined between the meiotic index and the grain number per spikelet or spike (Hsam & Larter, 1973; Szpiniak de Ferreira, 1983; Maich *et al.*, 1999).

In order to obtain harmonious genotypes with respect to its cytological, physiological and sanitary aspects, progress for grain yield and other agronomic traits in future breeding builds on existing genetic variability and associations with other traits. Such traits, like grain yield, integrate several physiological processes (i. e., they are poligenic), and their remoteness from single-gene control results in low heritability (Loomis, 1993). Therefore, the fact that each individual yield component is not only powerful in itself (direct response) but also sufficient for yield advancement (correlated responses) are also important issues. However, progress with quantitative traits depends more on understanding the mech-

organisms and on the clarity of goals than on the simultaneous success with all criteria.

Based on the preceding commentaries, the objectives of this study were to estimate the direct response to selection for spikelet fertility and meiotic index and to evaluate the correlated responses for several agronomic traits.

## MATERIALS AND METHODS

During 1996 a  $F_2$  population originated by crossing Don Frank (forage producer) and Tatú (grain producer) hexaploid triticale varieties was cultivated under low plant densities (25 grains per square metre) in order to select plants with high and low spikelet fertility (grain number per spikelet) and with high and low meiotic index (percentage of normal tetrads). In order to carry out a manageable experiment, a random sample of 250  $F_2$  plants was analysed and a disruptive selection intensity of 6 % was applied in each sense and for each character. The 60  $F_2$  derived families (15 per group) were evaluated during 1997 ( $F_{2:3}$ ), 1998 ( $F_{2:4}$ ) and 1999 ( $F_{2:5}$ ) respectively using a completely randomized design considering families of each group as replications. One-row plots 5 m long spaced 20 cm apart at a seeding rate of 50 grains per square metre (1997) and of 200 grains per square metre (1998-1999) were used. The lower seeding rate used during 1997 was due to the seed availability. The selection and evaluation processes were performed at Campo Escuela de la Facultad de Ciencias Agropecuarias (Universidad Nacional de Córdoba) Córdoba, Argentina (31° 29' S; 64° 00' W); in all occasion the materials were grown under rainfed conditions. Systematic controls were distributed every twelve plots alternating both parents. A random sample of five principal fertile culms per family was taken in order to analyse five characters potentially associated with grain yield (including physical, morphological and cytological ones): spikelet number per spike; grain number per spike and spikelet; grain yield per spike in g; and meiotic index in %. Other six traits, including grain yield per square metre in g, two physiological components such as biomass yield per square metre in g and harvest index in %; and three physical components such as grain number and spike number per square metre and 1000 grain weight in g, were analysed at plot level. All traits were measured at maturity except the meiotic index; in this case five immature spikes per family were taken, and one hundred tetrads per spike were observed. Aerial phytomass at harvest was considered as biomass yield; harvest index was determined as grain to

biomass yield ratio; the number of grains per square metre was estimated through grain yield to 1000 grain weight ratio.

The results were worked out statistically by the analysis of variance considering groups within each selection criterion, year and groups x years interaction as variation sources.

## RESULTS AND DISCUSSION

Significant differences were observed between the mean values of the  $F_2$  derived families corresponding to the divergent groups constituted from plants selected and evaluated according to high and low number of grains per spikelet and high and low percentage of normal tetrads criteria (Table 1). Moreover, no significant interactions groups x years were observed. With respect to the former selection criterion, the mean value of the high group was 24.4% superior to the lower one (Table 2). In relation to the meiotic index, the two divergent groups differed in 23.5 % (Table 3).

With respect to the other traits, significant statistical differences between group mean values of the selected material for high and low grain number per spikelet were observed for grain yield per plot and per spike, some physical grain yield components such as grain number per spike, grain number per square metre and physiological ones such as harvest index (Table 2). For grain yield per plot the high group families showed a mean value of 30.1 % superior to the lower one; differences of 37.9% and 16.9% were observed for grain number per square metre and harvest index, respectively. The families originated from the plant group with high meiotic index value differed significantly from the lower one for plant height (5.1%) and biomass yield (12.8%) (Table 3).

Based on the direct responses to selection along the triennial analysis, it is possible to assert that both characters used as selection criteria, namely grain number per spikelet and meiotic index, possess

**Table 1.** Mean squares from the analysis of variance for grain number per spikelet and meiotic index of four groups of hexaploid triticale genotypes evaluated during three years

Source	df	Grain number per spikelet	Meiotic index
Groups (G)	3	0.86**	977.57**
Years (Y)	2	0.22	4685.55**
G.Y	6	0.06	274.99
Error	168	0.09	196.73

\*\* significance at  $P < 0.01$

**Table 2.** Three years (1997-98-99) mean values and ranges (in bracket) of eleven traits in F2 derived hexaploid triticales progenies evaluated, classified disruptively (low and high group) respect to the grain number per spikelet selection criterion

			Parental varieties		
	Low group		High group	Tatú	Don Frank
Grain yield (g m <sup>-2</sup> )	165.3	**	215.0	250.0	98.5
	(97.0-258.0)		(131.0-289.0)		
Spikelet number per spike	29.8	n.s.	30.3	25.7	30.5
	(26.7-32.8)		(28.1-34.2)		
Grain number per spike	39.2	**	49.5	48.8	29.0
	(26.6-48.6)		(36.1-56.9)		
Grain number per spikelet	1.31	**	1.63	1.90	0.95
	(0.90-1.70)		(1.30-1.90)		
Grain yield per spike (g)	1.63	**	1.99	2.04	0.86
	(1.10-2.00)		(1.60-2.80)		
Meiotic index (%)	45.0	n.s.	49.4	32.7	58.1
	(24.8-68.4)		(36.7-65.3)		
Biomass yield (g m <sup>-2</sup> )	775.4	n.s.	861.5	796.5	1024.0
	(491.3-1205.3)		(669.0-1081.0)		
Harvest index (%)	20.7	**	24.2	31.4	9.6
	(13.8-24.8)		(18.1-30.5)		
Grain number m <sup>-2</sup>	4331.3	**	5974.9	6493.5	3634.7
	(2663.8-6145.0)		(4208.1-8519.5)		
Spike number m <sup>-2</sup>	165.9	n.s.	177.6	178.5	141.0
	(108.3-223.7)		(136.3-235.0)		
1000-grain weight (g)	37.7	n.s.	36.3	38.5	27.1
	(31.6-43.0)		(30.2-42.7)		

\* significance at P< 0.05

\*\* significance at P< 0.01

n.s. is not significant

genetic variability necessary to improve them.

In order to discuss the correlated responses with respect to the improved mean value of grain number per spike, reference to those not co-responsive traits is relevant. Due to the fact that the spike number per spike, mean value did not present significant differences between groups, the increase of the grain number per spike mean value generated a direct effect on the grain number per spike. Taking into account the absence of significant differences between group mean values with respect to spike number per square metre, the grain number per square metre was also directly related to the grain number per spike. The superior grain number per square metre of the high group resulted in superior

grain yield and harvest index taking into account that no significant differences in kernel weight and biological yield were evidenced between groups.

On the other hand, the meiotic index trait does not constitute an appropriated trait to be used as selection criterion.

In conclusion, the grain number per spikelet has two essential requirements from a plant breeder's point of view: it has genetic variability and presents correlated responses in relation to the grain yield. We consider the inclusion of this character in the inner part of a selection index directed to improve hexaploid triticales integrally through a recurrent selection scheme.

**Table 3.** Three years (1997-98-99) mean values and ranges (in bracket) of eleven traits in F2 derived hexaploid triticale progenies evaluated, classified disruptively (low and high group) respect to the meiotic index selection criterion

			Parental varieties	
	Low group		Tatú	Don Frank
Grain yield (g m <sup>-2</sup> )	171.8 (45.0-285.3)	n.s.	182.5 (136.3-250.0)	250.0 98.5
Spikelet number per spike	29.7 (26.9-32.5)	n.s.	29.6 (26.4-33.3)	25.7 30.5
Grain number per spike	42.8 (26.1-53.0)	n.s.	41.3 (26.9-60.2)	48.8 29.0
Grain number per spikelet	1.44 (0.90-1.80)	n.s.	1.38 (0.90-1.80)	1.90 0.95
Grain yield per spike (g)	1.73 (0.80-2.40)	n.s.	1.50 (1.20-2.30)	2.04 0.86
Meiotic index (%)	43.8 (29.9-56.7)	**	54.1 (41.1-70.4)	32.7 58.1
Biomass yield (g m <sup>-2</sup> )	736.7 (366.7-1122.3)	*	830.9 (589.7-1066.0)	796.5 1024
Harvest index (%)	22.5 (11.2-28.4)	n.s.	21.7 (16.8-28.2)	31.4 9.6
Grain number m <sup>-2</sup>	4676.5 (1534.6-7336.6)	n.s.	4798.9 (3705.0-6130.0)	6493.5 3634.0
Spike number m <sup>-2</sup>	158.2 (93.3-216.0)	n.s.	182.2 (149.3-228.3)	178.5 141.0
1000-grain weight (g)	36.2 (28.0-43.0)	n.s.	37.9 (28.7-42.5)	38.5 27.1

\* significance at P&lt; 0.05

\*\* significance at P&lt; 0.01

n.s. is not significant

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