AGRISCIENTIA, 2002, VOL. XIX : 51-54

Spike reproductive performance in hexaploid triticale *(X Triticosecale* Wittmack). Selective direct and correlated responses.

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ABSTRACT

The main objective of this study was to measure the effect of disruptive selection of number of seeds per spikelet on primordial and fertile florets in hexaploid triticale. A divergent selection scheme was used choosing 15 F_2plants with the highest and lowest spikelet fertility. During 1999 the thirty $F_{2:5}$ families were sowed using one row plots 5 m long and 0.2 m apart and with 250 seed/m^2. A significant direct response to selection was observed. The spike analysis by thirds showed significant changes only in the lower and middle thirds. The observed correlated responses with respect to the number of primordia and fertile florets per spikelet confirm that the plasticity of two or more characters is inversely proportional to their ontogenic proximity. From the definition of the terminal spikelet to the number of seeds determination, the number of seeds per spikelet plays an essential role as regards its positive effects on the preceding and succeeding determined traits.

Keywords: triticale, spikelet fertility, correlated responses, disruptive selection.

Guidobaldi, H.A. and R.H. Maich, 2002. Comportamiento reproductivo de las espigas en triticale hexaploide (X *Triticosecale* Wittmack). Respuestas selectivas directas e indirectas. Agriscientia XIX: 51-54

RESUMEN

El objetivo de este trabajo fue evaluar el efecto de la selección disruptiva en cuanto al número de semillas por espiguilla sobre el número de primordios florales y flores fértiles por espiguilla en triticale hexapioide. Se utilizó un esquema de selección disruptiva dentro del cual se seleccionaron 15 plantas F_2 con alta fertilidad de espiguilla y 15 plantas F_2 con baja fertilidad de espiguilla. Durante 1999 se sembraron las 30 familias $F_{2:5}$ en parcelas de un surco de 5 m de longitud separadas a 0.20 m, con una densidad de siembra de 250 semillas m^{-2}. Se observó una respuesta directa significativa a la selección, aunque sólo a nivel de los tercios inferior y medio. Las respuestas correlacionadas observadas con respecto al número de primordios florales y flores fértiles por espiguilla confirman que la plasticidad de dos o más caracteres es inversamente proporcional a su proximidad

Fecha de recepción: 10/06/02; fecha de aceptación: 12/12/02

ontogénica. Desde la definición de la espiguilla terminal hasta la determinación del número de granos, el número de semillas por espiguilla juega un papel esencial en relación a sus efectos positivos sobre caracteres determinados anterior y posteriormente a éste.

Palabras clave: triticale, fertilidad de espiguilla, respuestas correlacionadas, selección disruptiva.

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INTRODUCTION

Grain yield is located at the end of a sequence of stages, where those physiological aspects more closely related to it are phytomass and harvest index. Retrospective studies have demonstrated associated changes in the harvest index, which are simultaneous to an improved grain yield as primary selected trait (Slafer *et al.,* 1994). Within the grain yield physical components, the number of seeds plays an essential role, in its turn supported by the number of seeds per spikelet and spike number per m^2 (Cantrell & Haro-Arias, 1986). These studies are directed to analyze how yield is determined, in order to recognise the secondary yield advancing characters to be used as indirect selection criteria. However, sometimes the effectiveness of indirect responses to selection is lower than the direct ones (Gallais, 1984).

On the other hand, unlike other allopoliploids such as wheat (*Triticum aestivum* L), oat (*Avena sativa* L.) or cotton (*Gossypium* spp.), the genomes of triticale (X *Triticosecale* Wittmack) have not been subjected to an evolutionary co-adaptation. Triticales are still characterized by cytogenetic instabilities, which seems to be a problem (Oettler, 1998). Therefore, improving reproductive behavior of triticale is a way to assist it to meet its own identity as a grain producer crop. In this sense, Maich & Manero de Zumelzú (1998), when selecting for spikelet fertility (number of seeds per spikelet), proved significant direct and correlated responses on the subsequent ontogenically determined characters such as the number and weight of seeds per spike. With respect to the effect of the artificial selection, spikelet traits determined beforehand, Siddique *et al.* (1989) showed that the higher number of seeds per spikelet (and per spike) of modern bread wheat cultivars, compared with older ones, was due to both the initiation of more florets and the survival of a higher proportion of florets per spikelet. However, the results of Cerana *et al.* (2002) showed that the survival of fertile florets measured as the relationship between fertile and primordia florets did not show a significant increase in the more evolved cycle of a recurrent selection program performed in bread wheat.

The main objective of this study was to measure the effect of disruptive selection of number of seeds per spikelet on primordia and fertile florets per spikelet in hexaploid triticale.

MATERIALS AND METHODS

Thirty F_2 derived families ($F_{2:5}$) from a crossing between Tatú and Don Frank hexaploid triticale varieties were evaluated. From a population of 254 F_2 plants, the spikelet fertility was measured as the number of seeds/spike divided by number of spikelets/spike (Cantrell & Haro-Arias, 1986). A divergent selection scheme was used and two F_2 plant groups were constituted. The high fertility group was created by selecting the 15 individuals with the highest spikelet fertility. The low fertility group involved the 15 individuals with the lowest spikelet fertility.

During 1999 the thirty $F_{2:5}$ families were sowed at random at the Campo Escuela, Facultad de Ciencias Agropecuarias, Córdoba, Argentina (31º 29' S; 64º 00' W). One row plots 5 m long and 0.2 m apart and with 250 seed/m^2 were used to evaluate them. The material was recollected during the heading (before anthesis) and at physiological maturity, in both cases 5 spikes per family were sampled. Each spike was split into lower, middle and upper thirds corresponding to the spikelets 4-5, spikelets 14-15 and the subterminal ones, respectively. The following traits were measured on the first recollected sample: *Number of primordia,* total number of florets including the terminal one and *Number of fertile florets,* the number of florets which present recognizable anthers. From the second sample the following characters were measured: *Number of seeds per spikelet,* total number of seeds from a mechanically threshed sample of 10 spikelets (2 spikelets for each split third of 5 spikes) divided by 10 and *1000 grain weight,* the weight of the seeds of the 10 spikelet sample divided by the number of seeds multiplied by 1000.

A two way ANOVA with interaction was performed, considering the divergent groups and the thirds in which the spike was split as the source of variation. The 15 families pertaining to the same group were considered as replications and the Duncan's Multiple Range test was used for comparing treatment means. Among the measured traits phenotypic correlation coefficients were computed for each group.

RESULTS

With respect to the number of primordia, fertile florets and seeds per spikelet, the mean values at the lower and middle third in the high fertility group were significantly superior to the ones in the lower group (Table 1). The upper third showed a similar, although not significant, tendency between groups. With respect to the 1000 grain weight, the higher mean values corresponded to the lower fertility group, being significant ¡n the middle and upper thirds.

When thirds were compared, all traits evidenced the same distribution along the spike: the higher values corresponded to the middle third of the spike, followed by the lower third and, finally, by the upper one. The number of seeds per spikelet in the low fertility group did not show significant differences among the upper and lower thirds (Table 1).

With respect to the phenotypic correlation coefficients (Table 2), the number of fertile florets exhibited a highly significant and positive correlation with the number of primordia, in all thirds and in the high and low fertility groups. The number of seeds per spikelet showed a significant positive correlation with the number of primordia and fertile florets only in the middle third of the high fertility selected group. The 1000 grain weight did not present significant correlation coefficients with any of the other analyzed traits.

Table 1: Spike divided into thirds mean values and ranges (in brackets) in four traits measured in two family groups (low and high) selected according to spikelet fertility in hexaploid triticale.

Character	Third	Spikelet fertility	
		Low	High
Number of primordia (n°)	Lower	3.42 b (2.6 - 4.4)	3.91 c (3.0 - 5.2)
	Middle	4.07 c (3.0 - 4.9)	4.45 d (3.8-5.1)
	Upper	2.91 a (2.3 - 3.4)	3.11 ab (2.8 - 3.6)
Number of fertile floret (n°)	Lower	2.45 b (1.3-4.2)	2.83 c (1.8-4.2)
	Middle	3.01 c (2.0 - 3.8)	3.38 d (2.8 - 3.9)
	Upper	1.98 a (1.4 - 2.4)	2.11 ab (1.8 - 2.6)
Grain number per spikelet (n°)	Lower	1.15a (0.6 -1.6)	1.43 b (0.6 - 2.0)
	Middle	1.61 b (1.0-2.2)	2.00 c (1.5-2.7)
	Upper	1.07 a (0.5 - 1.5)	1.15a (0.4 - 1.6)
1000 grain weight (g)	Lower	37.41 cd (28.33 - 43.45)	34.41 bc (25.33 - 44.38)
	Middle	43.77 e (38.13-50.21)	39.13 d (32.37 - 49.68)
	Upper	33.28 b (25.64 - 40.33)	29.01 a (20.71 - 42.00)

Means with different letters are significant at p<0.05

Table 2: Phenotypic correlation coefficients between four traits by spike divided into thirds in hexaploid triticale.

		Fertile floret		Grain number		1000 Grain weight	
		LFG	HFG	LFG	HFG	LFG	HFG
Primordia	Lower	0.864 *	0.991*	0.413	0.208	0.168	-0.015
	Middle	0.975*	0.977*	0.414	0.693*	0.075	0.174
	Upper	0.954*	0.966*	0.292	0.422	-0.096	0.196
Fertile floret	Lower			0.400	0.182	0.076	-0.020
	Middle			0.403	0.697*	0.146	0.174
	Upper			0.220	0.510	-0.133	0.262
Grain number	Lower					0.127	0.146
	Middle					0.314	-0.249
	Upper					-0.299	0.346

* Significant at the 0.01 probability levels

LFG: Low Fertility Group; HFG: High Fertility Group

DISCUSSION

Coincidently with previously published results (Maich & Manero de Zumelzú, 1998) a significant direct response to selection was achieved for the number of seeds per spikelet. However, the spike analysis by thirds showed significant changes only in the lower and middle thirds. A plausible explanation of this differentiated genetic progress along the spike could be the intrinsic morpho-physiological spike characteristics. With respect to the organ size, Bonnett (1983) makes a description of the development of the inflorescence of wheat and rye, the triticale parents. The longest spikelet primordia are in the middle of the spike. From it to the base and to the top of the spike they are successively shorter, and the top spikelets are not as long as the basal ones. Taking this into account, it is possible to establish a direct relationship between size of the spikelet and the magnitude of the genetic gain. Considering a higher reproductive potential, principally in the middle third, the genetic parameters could achieve significant higher values. Similarly, the absence of significant correlations between number of seeds per spikelet and number of primordia and fertile florets, other than that of the middle third, may be related with the physiology of the development of the fruits along the spike.

The correlated responses observed in both primordia and fertile florets with respect to the selected trait, i.e., number of seeds per spikelet, confirm that the plasticity of two or more characters is inversely proportional to their ontogenic proximity (Grafius, 1978). In other words, those preceding and succeeding steps with respect to the number of seeds per spikelet determination were closely associated to it, and showed significant correlated responses. In the case of 1000 grain weight, due to the higher number of seeds in the high fertility group, a counterbalance in the seed weight was observed. This effect is widespread among the major crop plants originated by a developmental rather than by a genetic source (Adams, 1967). In this sense, comparing modern wheat cultivars with older ones, Slafer *et al.* (1994) have noted that the increase of number of seeds generated a decrease in the individual grain weight due to a lower quantity of photoassimilates available for each grain.

The changes of the number of seeds per spikelet generate indirect changes in the previously determined number of primordia and fertile florets per spikelet characters. From the definition of the terminal spikelet to the number of seeds determination, the number of seeds per spikelet plays an essential role in relation to its positive effects on the preceding and succeeding determined traits.

ACKNOWLEDGEMENT

The authors wish to acknowledge the valuable comments on this manuscript made by Prof. A. Pérez de Pereyra.

REFERENCES

Adams, M.W., 1967. Basis of yield component compensation in crop plants with special reference to the Field Bean, *Phaseolus vulgaris. Crop Sci.* 7:505-510.

Bonnett, O.T., 1983. Las inflorescencias de maíz, trigo, centeno, cebada y avena: su iniciación y desarrollo. Ed. Hemisferio Sur S.A. Argentina.

Cantrell, R.G. and E.S. Haro-Arias, 1986. Selection for spikelet fertility in semidwarf durum wheat population. *Crop Sci.* 26:691-693.

Cerana, M.M., S.P. Gil and R.H. Maich, 2002. Plant breeding scheme effects on the flower number and grain yield components in bread wheat. *Cereal Res. Commun.* 30(3-4):307-313

Gallais, A., 1984. Use of indirect selection in plant breeding. In: Lange, W., Zeven, A.C. & N.G. Hogenboon (eds), Efficiency in plant breeding, Proc. 10th Congress Eucarpia, Pudoc, Wageningen, pp 45-60

Grafius, J.E., 1978. Multiple characters and correlated response. *Crop Sci.* 18:931-933

Maich, R.H. and D. Manero de Zumelzú, 1998. Spikelet fertility and meiotic index in hexaploid triticale. Realized heritabilities and correlated responses for agronomical traits. *Cereal Res. Commun.* 26(4):433-437.

Oettler, G., 1998. Creating genetic variability in triticale and its potential for breeding: 1. Agronomic traits. In: Juskiw, P. (Ed.), Proceedings of the 4th International triticale symposium, vol 1, pp 1-12. Alberta, Canada, July 26-31, 1998. International Triticale Association, Canada.

Siddique, K.H.M., E.J.M. Kirby and M.W. Perry, 1989. Ear-to-stem ratio in old and modern wheat; relationship with improvement in number of seeds per ear and yield. *Field CropsRes.* 21:59-74.

Slafer, G.A., E.H. Satorre and F.H. Andrade, 1994. Increases in grain yield in bread wheat from breeding and associated physiological changes. In: Slafer, G.A. (Ed.) Genetic improvement of field crops, M. Dekker, Inc., New York, pp 1-68.