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Cytological microevolutive changes in hexaploid triticale (X *Triticosecale* Wittmack)

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Abstract — The objectives of this study were to evaluate a) the success in meiosis of disruptively selected triticale progenies used as recurrent selection parents, and b) the changes that took place in their meiotic behavior after three cycles of recurrent selection in hexaploid triticale. From samples of five immature spikes per experimental unit, the meiotic index (MI) and the percentage of tetrads containing micronuclei in 1, 2, 3 or 4 microspores were estimated. The families used as recurrent selection parents showed a significantly higher MI than those with the lower agronomical performance. A positive and significant linear relation between the MI and cycles of recurrent selection was observed. The analysis of the tetrads with micronuclei showed a non-significant positive tendency to increase the percentage of tetrads with micronuclei in 1 microspore in the more evolved cycle, while negative linear relations between tetrads with micronuclei in 2, 3 and 4 microspores and cycles were observed. These results suggest that in triticale those individuals with superior reproductive performance tend to reduce their meiotic irregularities.

Key words: genetic progress, hexaploid triticale, meiotic behavior

INTRODUCTION

Evolutive changes are commonly observed between and within species (Hossaert-McKey *et al.* 1996; Kondraskov & Kondraskov 1999). Within a species, the morpho-physiological modifications are leading to generate ecological adaptations (Arcioni *et al.* 1985; Sharma & Sen 1989; Montalvo *et al.* 1991). These modifications reflect the fixation of specific genetic determinants (Greenberg *et al.* 2003; McKey *et al.* 2003).

Recurrent selection, a cyclical process of selection and gene recombination, has been proposed as a plant breeding method directed to change artificially the gene frequencies (Hallauer 1987). Genetic progress is measured for the selected trait(s) by periodically sampling successively developed genotypes from the different populations. In general, the original population is named as C_0, and the populations derived from it as C_1 to Cn.

Grain yield, its components and other characters are considered as selection criteria with the objective to harmonize in one genotype the superior genetic aspects dispersed in several ones. In this context, a selection index constitutes the best way to improve integrally a species.

In spite of its synthetic origin, triticale (X *Triticosecale* Wittmack) is not as diverse as naturally evolved crops. The specific genome combination of this allopolyploid, at the moment to cross wheat and rye species, must be successful enough to allow its survival in nature.

The cytological stability of this new genome has been reported by several authors (Manero de Zumelzú *et al.* 1995; Manero de Zumelzú *et al.* 1998; Maich *et al.* 1999; Torres *et al.* 2002; Maich & Ordóñez 2003); however, it is very important to evaluate if the microevolutive changes with respect to the agronomical success (Cooper & Jessop 2002; Green 2002), were accompanied by improved meiotic performance. Even when they do not remain neutral with respect to the triticale reproductive behavior (Falcao *et al.* 1991), the cytological traits are rarely constituents of the selection indexes.

The objectives of this study were: a) to evaluate the success in meiosis of disruptively selected triticale progenies used as recurrent selection parents, and b) to evaluate the changes occurred in

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their meiotic behavior after three cycles of recurrent selection in hexaploid triticale.

MATERIALS AND METHODS

In order to evaluate the meiotic performance of the recurrent selection parents, ten agronomically superior S_0 progenies of triticale were selected from a sample of 142, pertaining to the third cycle of a recurrent selection program, with the intention of obtain, by hand crossing, the fourth cycle. Details of the population origin were presented by TORRES *et al.* (2002). The agronomical selection criteria used was a selection index constituted by eleven traits measured at plot level. In accordance with the regular procedure to test the efficiency of a selection criterion, ten S_0 progenies with the lowest agronomical performance were also selected. The 20 S_1 triticale families (ten per group) were evaluated during 2003 at the Experimental Farm of the School of Agriculture (Cordoba National University), Córdoba, Argentina (31° 29' S; 64° 00' W). A completely randomized block design with two replications was used. Samples of five spikes each from every experimental plot were collected and treated according to OCHOA DE SUAREZ *et al.* (1986). One hundred tetrads per spike were analyzed in order to determine the meiotic index.

With respect to the second objective, both S_1 seed samples originated from the base population (C_0) and the following three cycles of recurrent selection (C_1, C_2 and C_3) were sown. A total of ten S_1 plants per population were selected according to their individual seed production and evaluated as $S_{1:2}$ derived families during 2004. The material was sown in one-row plots and a completely randomized design with two replications was used. Samples of five immature spikes per experimental unit were collected and treated according to Ochoa de Suarez *et al.* (1986). Additionally, the percentage of tetrads containing micronuclei in 1, 2, 3 or 4 microspores was estimated.

Statistical Analysis - The meiotic index cytological data referred to the former objective were subjected to the ANOVA, considering groups and blocks as the only source of variation. The LSD test was utilized for contrasting means. In order to evaluate the meiotic behavior along the cycles of recurrent selection, linear regressions of the percentage of tetrads without and with micronuclei on cycles of recurrent selection were calculated.

The statistical analyses were carried out using the software INFOSTAT (2004).

RESULTS AND DISCUSSION

It was observed by analyzing the meiotic index of disruptively selected triticale progenies, that there existed significant differences between the means group values concerning the agronomically superior families (recurrent selection parents) and those with the lowest agronomical performance (inferior group). This agrees with the results obtained by MAICH & ORDÓÑEZ (2003). The superior group showed a 53.61 % of normal tetrads with respect to the 44.04 % corresponding to the inferior group. It is well known that most of the allopolyploids are not cytologically stable (ELLNESKOG-STAAM & MERKER 2002); however, in this case, the improved meiotic index of the selected triticale progenies suggests that, in a newly created allopolyploid, those individuals with superior reproductive performance tend to reduce their meiotic irregularities. These results are coincident with those found by other authors, who observed that the meiotic disturbances in triticale can be overcome by selecting and crossing those phenotypes with a satisfactory grain production (ELLNESKOG-STAAM & MERKER 2002; TORRES *et al.*, 2002; MAICH & ORDÓÑEZ 2003).

With respect to the meiotic behavior after three cycles of recurrent selection for higher agro-

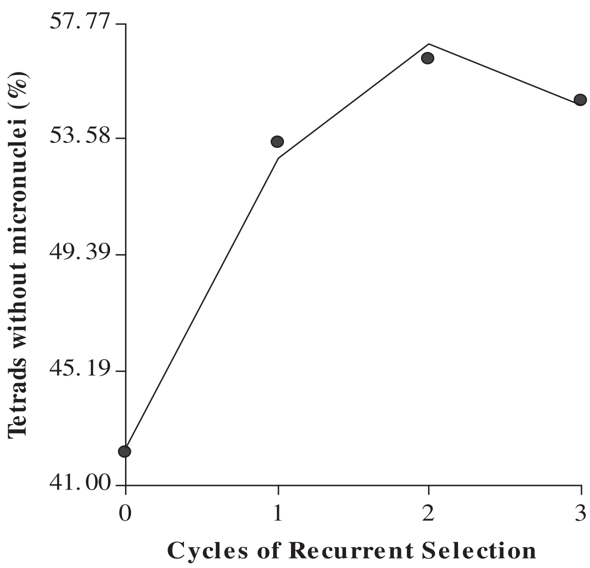

Fig. 1 —The relation tetween the percentage of tetrads without micronuclei and cycles of recurrent selection. Each point represents the tetrads mean value (%) per cycle.

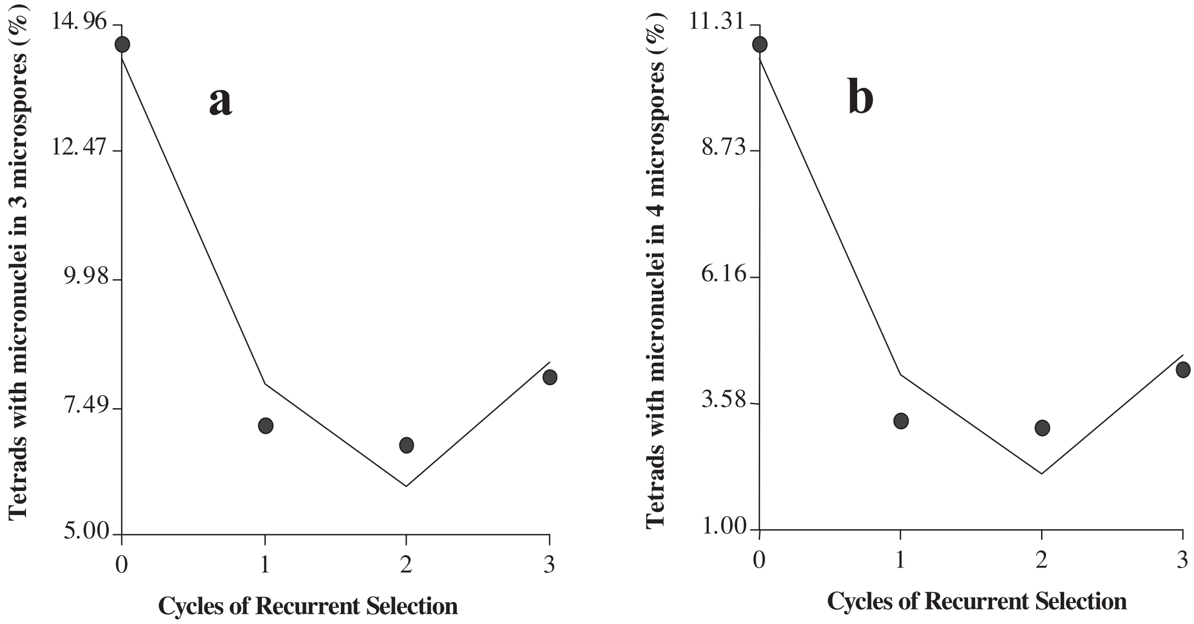

Fig. 2 — Relationschip between the percentage of tetrads with micronuclei in 3 (a) and 4 (b) microspores and cycles of recurrent selection. Each point represents the tetrads mean value (%) per cycle.

nomical performance in hexaploid triticale, significant differences between cycles were observed for the meiotic index. A positive and significant linear relation between the percentage of normal tetrads or meiotic index (MI) and cycles of recurrent selection (CRS) was observed. This relation was defined by the following quadratic equation: $Y= 42.35 + 13.73\ CRS - 3.19\ CRS^2$ ($r^2 = 0.16$).

From this regression analysis an increase of 12.48 % for the percentage of normal tetrads at the end of the third cycle was estimated. Taking into account that each cycle includes a two year period, the frequency of normal tetrads was improved by 2.08 % per year (Figure 1). However, it must be taken into account that, although a greater rate of genetic progress for the meiotic index was observed at the beginning of the plant breeding program, probably with the course of the microevolutive process the rate of genetic progress will have lower values due to the progressive exhaustion of the specific genetic variability (Falconer & Mackay 2001).

The statistical analysis of the tetrads with micronuclei in 1, 2, 3, or 4 microspores, showed that all of them tended to adjust to a linear regression model. Although there was a positive tendency to increase the percentage of tetrads with micronuclei in 1 microspore at the more evolved cycle, the regression analysis was not significant. The microevolutive strategy of this species consists in increasing its agronomical performance, the percentage of healthy tetrads and the percentage of tetrads with micronuclei in only one microspore, simultaneously. In this respect, Weimarck (1973) concluded that the selection for agronomical traits may also imply a positive effect on meiotic stability.

On the other hand, negative linear relations between tetrads containing micronuclei in 2, 3 and 4 microspores and cycles were observed; but they were only significant for tetrads with 3 and 4 affected microspores (Figure 2) and were described by the following quadratic equations:

$Y_{III\ MICROSPORES} = 14.30 - 8.54\ CRS + 2.19\ CRS^2$ ($r^2 = 0.34$)

$Y_{IV\ MICROSPORES} = 10.61 - 8.64\ CRS + 2.21\ CRS^2$ ($r^2 = 0.45$)

These results confirm the progressive diminution of the frequency of microspores with micronuclei observed by Maich & Ordóñez (2003).

In conclusion, the meiotic behavior of this new allopolyploid tends to the normality when those genotypes with higher agronomical performance are intercrossed in order to constitute the next cycle of selection, and also confirm the tendency observed by Torres *et al.* (2002) who demonstrated that the meiotic index can be progressively improved throughout a cyclical process of selection and recombination.

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