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RESEARCH ARTICLE

CYCLE SEGREGATION IN CROSSINGS OF LANDRACE CORN POPULATIONS

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ABSTRACT

Studies aimed at elucidating the gene actions that control traits little investigated in the plant breeding area are important for the choice of the parents to be crossed. The present study aimed to evaluate the segregation and reciprocal effects, relating to genetic effects prevalent in demanding thermal sum of land racescorn populations contrasting for this trait. Thus, we used three contrasting populations for thermal sum, (1 - super-early, 2 early and 3 Late), totaling a set of six crossovers, with the following combinations of population: 1x2, 1x3, 2x1, 2x3, 3x1 and 3x2. The crosses were performed in complete diallel scheme. In the first year, artificial crosses were made and in the second year, sowing of hybrid populations together with its genitor populations was carried out to assess the requirement of thermal sum of the crosses. The findings showed that: selection of populations for thermal demand should be considered the reciprocal effects. Additive and nonadditive gene actions reveal importance to the thermal sum trait. To reduce the cycle, it is necessary that the population used as female progenitor presents late cycle and male progenitor early cycle. Crosses between early-cycle females and super-early cycle males, or super-early cycle females and early-cycle males, generate populations with higher thermal requirement.

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INTRODUCTION

Populations' genetics provides subsidies for plant breeding. All populations have a gene pool that they are private and which characterize it. These are transmitted generation by generation. Within a given population, breeding works in the identification of individuals who present desirable characteristics of agricultural viewpoint and indicate the frequencies of these alleles, which will be transmitted to the following generations. The probability of obtaining anagronomically desirable line will depend of the frequency of favorable alleles in this population (Duvick, 2005; Wellin Troyer, 2009). The elevation of these frequencies can be given through different selection methods, such as mass selection and / or intra- or interpopulationrecurrent selection (Vencovsky, 1987). One of the main ways of knowing the additive and nonadditive genetic components in the genetic control of traits is the diallel cross method, which occupy a prominent place in corn genetic breeding (Jesus *et al*., 2008; Souza *et al*., 2008; Bueno *et al*., 2009; Faria *et al*., 2015; Paini *et al*., 2015). Cycle time of a crop is a quite-worked trait by breeders and demand great attention during the stages of selection in populations. In order to understand the genetic control of flowering in corn, Koester *et al*., (1993) found that the number of days to reach the flowering is controlled by quantitative loci located on chromosome 1, near to centromere region. Corn crop has three

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separations as cycle time, which can be classified basically super-early, early and late (Sangoi *et al*., 2002). Fancelli and Dourado-Neto (2004) classify the super early cycle constitutions as those that need between 780-830 Growing Degree Units (GDU), early between 831-890 GDU and individuals classified as late cycle have caloric demand between 891-1200 GDU up to flowering. Most economic interest traits have continuous segregation, such as grain yield, plant height and vegetative cycle duration, where in a population may have large variation (Hallauer *et al*., 2010). Multiple factors hypothesis explains that the control of a quantitative trait is influenced by a large number of genes, each one contributing with a little effect on phenotype; thus, variations for quantitative traits are much larger, which undergo marked effect of the environment, a fact that demands attention of geneticists and breeders, because the decomposition of the total variation into genetic and environmental effects, it is necessary (Ramalho *et al*., 2012).
Studies by Lima *et al*., (2008) reported the genetic control of flowering in corn inbred lines, but there is little information in the literature around the gene actions that control the cycle in landraces of corn. In this context, this study aimed to evaluate the segregation and reciprocal effects, relating to genetic effects prevalent on demanding thermal sum in crossing of contrasting populations for this trait.

MATERIAL E MÉTODOS

Corn landraces populations were collected in the municipality of Seberi - RS (27º28'20 "S and 53º24'10"W) in February 2010, they are: population 1, population 2 and population 3. Experimental work was carried out in 2011/2012 and 2012/2013 growing seasons. In the 2011/2012 growing season, landraces populations were sown to obtain the seeds of hybrid populations. In the 2012/2013 growing season was carried out sowing of the three genitor populations along with the hybrid seed coming from the crossings. Climate classification in experimental area is subtropical Cfa, with an average annual temperature of 18.8 ° C, the average temperature of the coldest month of 13.3 ° C and the temperature of the hottest period between 18-26 ºC. Soil preparation was done conventionally with disking, the sowings were made in ferric aluminum red Latosol (Streck *et al*., 2008).A randomized complete block design was used, consisting of six 8-m cultivar rows, spaced by 0.3 m between plants and 1.0 m between rows. In order to avoid edge effects, only four central lines were considered for evaluation. In both experiments, the fertilizer used at sowing was equivalent to 300 kg ha^{-1} of 05-20-20 formulae and 135 kg ha^{-1} of nitrogen in coverage in urea's form at V6 stage, in the two growing season. To determine populations cycle was considered the average thermal sum for progenitor populations and their subsequent hybrids when 50% of individual had male flowering, considering the period between sowing and flowering. Cycle of populations and their subsequent hybrid populations were classified according to the methodology proposed by Fancelli and Dourado-Neto (2004). According this methodology, cycles of the populations were classified as: population 1 with 824.86 GDU, classified as super-early, population 2 with 874.89 GDU, classified as early and population 3 with 1032.39 GDU, classified as a late cycle. Based on the characterization of populations with contrasting cycles, there was the assembly of cross blocks with staggered sowing of individuals of each population, in order to reach maximum number of crosses. Crosses between populations were carried out in a complete diallel scheme, forming six combinations of populations:1x2, 1x3, 2x1, 2x3, 3x1 and 3x2, each crossing consists of five female plants x five male plants. The crosses were artificially carried out by protection of female inflorescence in the period before the issue of style-stigmas of plants used as female. Collection of pollen from plants used as male was carried out for the protection of male inflorescence with a paper bag about 24 hours before fertilization. After completion of the artificial crosses and seed harvest in the 2010/2011 season, the sowing of the original populations and hybrid populations was carried out in the following harvest in 2011/2012. Evaluations and data collection as the thermal time were obtained based on the period between emergence and flowering.

The base temperature of the corn used was 10° C for the entire crop cycle as proposed by Berlato and Matzenauer (1986). In order to determine the diary thermal sum, we used following equation (Arnold, 1960).

$$GDD = \sum_{i=0}^{n} \rightarrow \left(\frac{T\max + T\min}{2} - Bt \right)$$

Were GDD growing degree-day from emergence to flowering; Tmax is the maximum daily air temperature (° C); Tmin is the minimum daily air temperature (° C); Bt is the base temperature (ºC); n is the number of days from sowing period the female flowering. Accumulated thermal sum (Ats ºC day), from sowing to female flowering was calculated by Ats = ΣGDD.

Temperature data were collected from the meteorological station of INMET, located in the area of Agroclimatology Laboratory of UFSM- Campus Frederick, RS, about 200 meters from the experimental area. Data were collected from the sowing of the crossings the population up to 50% of individuals in the population and/or hybrids showed full flowering (50% of anthers' tassel releasing pollen grains). Calculations were performed, and by the thermal sum accumulation, classification of hybrid populations and their respective progenitors were assessed. Data collected after passing through issue were submitted to univariate analysis to identify the position and dispersion measurements; procedures were carried out by PROC UNIVARIATE in SAS 9.3 (2012).

RESULTS AND DISCUSSION

In the frequency distribution analysis for the diallel all, crossings assumed average, median and mode with different values; thus skewed distributions were observed for thermal sum (Table 1).Regarding to the magnitude of skewness, crosses 2 (3x1), 3 (1x2); and 6 (2x3) had positive skewness, individuals were located to the right of the distribution curve. For crosses 1 (2x1), 4 (3x2) and 5 (1x3) skewness was negative, so the individuals were concentrated left of the distribution curve. Averages distant from mode contribute to greater extension of tail; averages of the crosses 1 (2x1) and 2(3x1) were more distant, then the tail of the distribution assumes a greater extent in the distribution and higher contribution to the skewness in these crosses' individuals.

Table 1. Results for the six corn crosses contrasting to cycle, average and dispersion measurements and for thermal sum, 2012/2013 growing season, CGF-UFPel. 2015

Crossing	♀	X	♂	Average	Median	Mode	Variance
1	E	X	SE	900.54	909.01	922.53	592.01
2	L	X	SE	928.35	922.53	909.01	605.06
3	SE	X	E	915.30	909.01	909.01	677.00
4	L	X	E	863.05	867.61	867.61	197.74
5	SE	X	L	935.64	937.13	937.13	215.86
6	E	X	L	913.11	909.01	909.01	178.90

*SE: super-early; E: early; L: late.

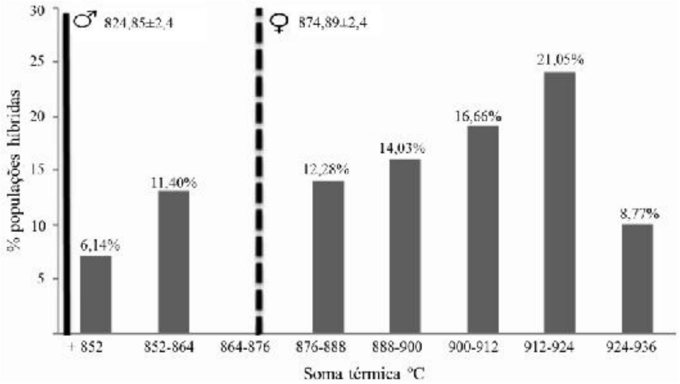

Figure 1. Frequency distribution of the progeny resulting from crossing 1 between early corn parental (female receiver) and super-early (male donor) in relation to the thermal sum, CGF-UFPel. 2015

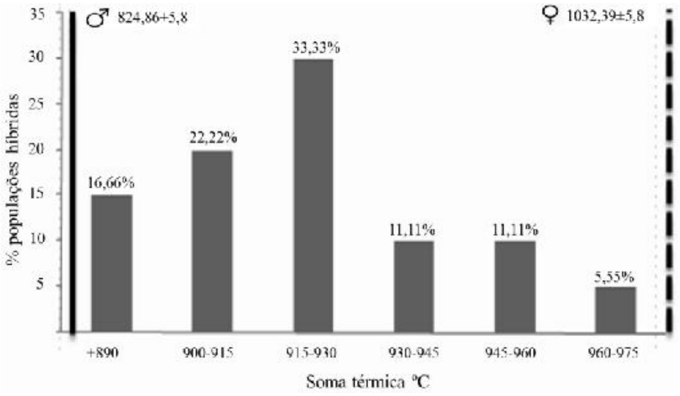

Figure 2. Frequency distribution of progenies from cross 2 between late cycle corn (female receiver) and super-early (male donor) in relation to the thermal sum, CGF-UFPel. 2015

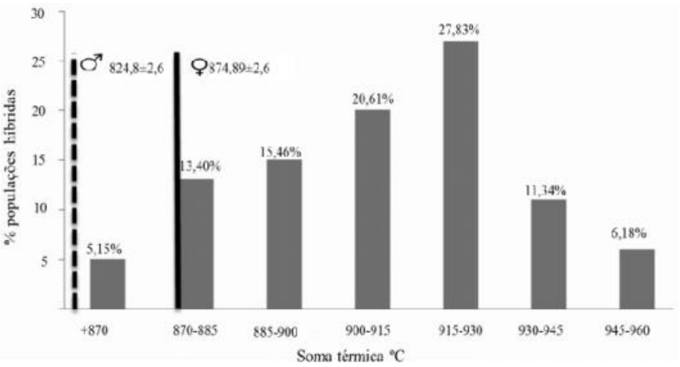

Figure 3. Frequency distribution of the progeny resulting from the crossing 3, between super-early cycle (female receiver) and early (male donor) in relation to the thermal sum, CGF-UFPel. 2015

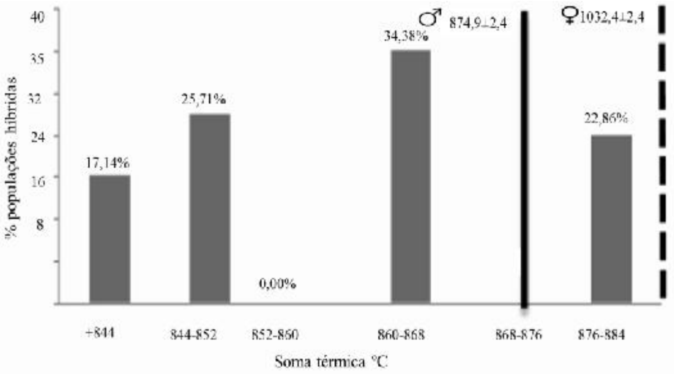

Figure 4. Frequency distribution of progeny resulting from cross 4 between corn parents of late cycle (female receiver) and early cycle (male donor) in relation to the thermal sum, CGF-UFPel. 2015

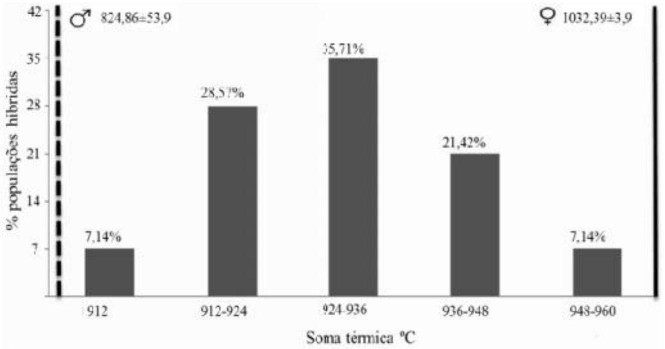

Figure 5. Frequency distribution of progenies from cross 5, between the corn progenitors of super-early cycle (female receiver) and late cycle (male donor) in relation to the thermal sum, CGF-UFPel. 2015

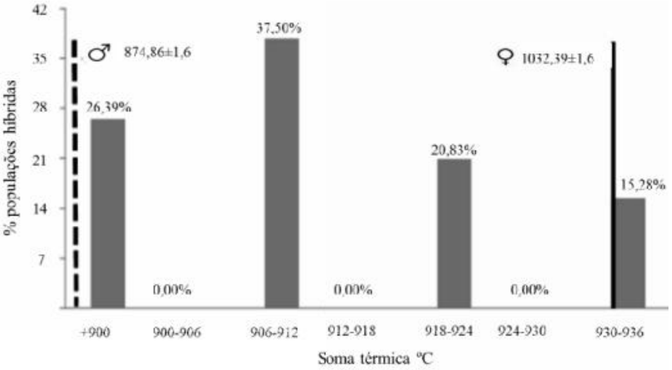

Figure 6. Frequency distribution of the resulting progeny from cross 6, between early corn cycle (female receiver) and late cycle (male donor) in relation to the thermal sum, CGF-UFPEL. 2015

Crosses 1, 2 and 3 showed higher variance within the cross, crosses 4, 5 and 6 revealed lower magnitudes of variation, then the individuals presented thermal sum values with smallest variance. The cross 2x1 (super early male x early mother) showed the resulting populations showed increasing trend of thermal demand from their progenitors, and 80.58% of the plants had higher thermal demand compared to their progenitors; largest frequency of individuals for thermal summation is 912-924 ° C with 23.30% of subjects (Figure 1). The populations resulting from crosses between populations of super-early cycle (father) and early (mother) increase the vegetative cycle due to the higher thermal demand, indicating that the gene actions for most of the group are over dominance. According to Hallauer *et al*. (2010), the increase of the thermal sum of progenies points to the existence of heterosis Regarding to cross 2 (3x1), conducted among populations of super-early cycle (male donor) and late cycle (female receiver) hybrid population had the value of the thermal sum between its parent's values. Largest frequency of subjects was located between 915-930ºC (Figure 2), with a general average of 938.35 ° C (Table 1). In this cross there is strong evidence that the genetic control was the only additive component. Câmara *et al*., (2007) worked with two populations of tropical corn and evaluated the genetic parameters involved in agronomically important traits and found high heritability estimates (94.12%) for male flowering. Such estimates facilitate the breeding of hybrid populations for male flowering.

In the cross 3 (1x2) super-early cycle (female receiver) and early (male donor) , the hybrid population showed a tendency to increased demand for thermal unit (Figure 3). Only 5.15% of the individuals were located between its parents' averages, though 13.40% of the individuals have the same requirement for thermal sum of the father. In this case the overdominance effects were more pronounced, resulting in a population with most individuals greater than the highest parent (early), in other words, the overdominance resulted in a late hybrid population. The use of earlier varieties allows the evacuation of the area in advance, increasing exploitation, but this is not always synonymous of higher grain yields, since early varieties have less time to recover from environmental constraints such as water stress (Araujo *et al*., 2013).At the cross 4 (3x2), between the parents of late cycle (female receiver) and early (male donor),hybrids showed lower thermal requirement than parents, 22,85% of the subjects were between its parents' average (Figure 4). For breeding these results are of great importance because it indicated that the cross between an early variety with demand of 874.9 ± 2.4 with a variety of late cycle 1032.4 ± 2.4 resulted in a hybrid population with lower demand for thermal sum that the populations used as parents. According Ramalho *et al*., (2012), it is important to note that the dominance interactions and or / overdominance not always act to increase the phenotypic value; interactions can occur reducing trait's expression, this was evidenced by the results obtained in this cross. Araujo *et al*. (2013) evaluated the agronomic performance of landraces and corn hybrids grown in different management systems, observed that there is a abando of landraces to rise the technological level, the varieties favor the autonomy in production, and according to their results found that the landraces were able to respond to technological advances in the field. Thus, the development of super-early/early hybrid populations, as obtained in this study, associated with satisfactory yields, must be sought because of many agricultural systems still depends on these landraces.

Regarding to the cross 5 (1x3), characterized as super-early female population (824.86 ± 3.9) and late male population (1032.4 ± 3.9), the resulting hybrid population showed the separation between the two parents (Figure 5). According to Ramalho *et al*., (2012) such effects are explained by additive gene interaction in which each allele contributes little cumulative effect on the phenotype, where the average of the F_1 generation is equal to the average of the parents.Regarding the cross 6 (2x3), which is used as female early-cycle population (874.89 ± 1.6) and a late cycle male (1032.39 ± 1.6), the hybrid population showed segregation between its parents' average, and 15.27% of the subjects showed average thermal demand equal to the male parent who needs more thermal sum, showing that in this case the effects of additivity are more pronounced. Unlike when used in cross early male population and late female population (Figure 4) where the hybrid population showed a tendency toward lower heat requirement. In the early female x late male crossing, hybrid population resulted in values between the two parents, but the results of this cross are similar to crosses 2 and 5. Landraces breeding, particularly for smaller cycle, it is important for your guidance the regions of low technologies of cultivation, since there is already numerous benefits associated with resistance to diseases, pests and climate fluctuations, and due to its seeds can be stored for subsequent years, reducing the production cost (Carpentieri-Pipolo *et al*., 2010; Ferreira *et al*., 2009; Araujo *et al*., 2013).The results shown with crosses between contrasting populations for the trait vegetative cycle revealed the effects on hybrid populations are different when the original populations are used as a male or female at the cross, so it was deduced that there was maternal effect. In this sense, the reciprocal crosses allowed to elucidate the effects of population when used as male or as female, indicating that its inheritance is controlled by nuclear genes. Most traits of higher plants are controlled by genes present in the nucleus, but other group of traits that is inherited from the genes present into cytoplasm. Thus, the trait is controlled by cytoplasmic genes, mother holds and responsible for the expression in descending progenies. If the results of the cross and its reciprocal are different, trait expression may be due to the effects of cytoplasmic genes, that persists in successive generations and / or phenotypic effect of maternal origin and cross product only will manifest in following generation (Ramalho *et al*., 2012).

According to results of this work, both additive and nonadditive gene actions are important in explaining the variation of hybrid populations in relation to thermal sum, results that corroborate Ajala (1992) that proved where both genic actions were important to explain flowering in corn. In studies with four lines in dialelic crosses scheme, Lopes *et al*., (1995) concluded the trait cycle is controlled by a few genes and their control is by additive gene actions and also dominant, data also corroborate this work about landraces cycle segregation coming from diallel cross. Lima *et al*. (2008) used two lines and rated the F1, F2, BC1 and BC2, concluded the genetic control of flowering in corn has the importance of additive and dominance components.

Conclusion

The findings indicate that:

In selecting populations to thermal demand should be considered the reciprocal effects.

Additive and nonadditive gene actions reveal importance to the trait thermal sum when crossed population contrasting for this trait.

To reduce the cycle, it is necessary that the population used as a female presents late cycle and that used as male presents early cycle.

Crosses between early-cycle females and super-early cycle males, or super-early cycle females and early-cycle males, generate populations with higher thermal requirement.

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