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Maize breeding for sustainable agricultural systems

Melhoramento do milho para sistemas agrícolas sustentáveis

Matheus Lima Oliveira[1], *Lucas Nunes da Luz*[2], *Ana Kelly de Sousa Julião*[1], *Antonio Fabio da Silva Lima*[1], *Francisco Aglauberto de Lima Gouveia*[1], *Maryssol Torres Gadelha*[1]

[1]Bacharel em Agronomia, Instituto de Desenvolvimento Rural, Universidade da Integração Internacional da Lusofonia Afro-brasileira, Redenção, Ceará, Brasil, mts.lima518@gmail.com; anakelly.juliao@gmail.com; antfabiosl@gmail.com; aglaubertogouveia@gmail.com; maryssoltorres@gmail.com [2]Professor Adjunto, Instituto de Desenvolvimento Rural, Universidade da Integração Internacional da Lusofonia Afro-brasileira, Redenção, Ceará, Brasil, lucasluz@unilab.edu.br.

A R T I C L E

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A B S T R A C T

In the present work, a recurrent selection program was initiated, between and within half-sib families in landrace maize, with the objective of obtaining, at the end of the process, a productive maize variety for agroecological cultivation systems adapted to the northeast region. A base population composed of 10 landrace varieties donated by farmers the region. In the base population, 60 half-sib families were selected. These were grown for selection among families, in Capistrano/CE, at Fazenda Repouso das Águas, in the agricultural year 2017/2018, in randomized blocks with three replications. It was used as a witness for a variety of BRS-Caatingueiro. The selection within the families was carried out in the agricultural year 2018/2019 at the Fazenda Experimental Piroás located in the municipality of Redenção/CE. 15 characteristics were evaluated in the selection among and 10 in the within families. In the selection between, the average production and productivity was 5.033,90 kg.ha^{-1} and 4.316,04 kg.ha^{-1}, respectively. The superiority in relation to the witness was 8.67%. In the selection within, the average production and productivity was 4.448,413 kg.ha^{-1} and 3.998,41 kg.ha^{-1}, respectively.

Palavras-chave:
Zea mays L.
Seleção recorrente
Semente crioula
Segurança alimentar
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R E S U M O

No presente trabalho iniciou-se um programa de seleção recorrente, entre e dentro de famílias de meios irmãos em milho crioulo, com objetivo de se obter ao final do processo, uma variedade de milho produtiva para sistemas de cultivo agroecológico adaptada à região nordeste. A população base foi composta de 10 variedades crioulas doadas por agricultores da região. Na população base foram selecionadas 60 famílias de meios-irmãos. Essas foram cultivadas para a seleção entre famílias, em Capistrano/CE, no ano agrícola 2017/2018, em blocos casualizados com três repetições. Utilizou-se como testemunha a variedade BRS-Caatingueiro. A seleção dentro das famílias, foi realizada no ano agrícola 2018/2019 no município de Redenção/CE. Foram avaliadas 15 características na seleção entre famílias e 10 na dentro de famílias. Na seleção entre a média de produção e produtividade foi de 5.033,90 kg.ha^{-1} e 4.316,04 kg.ha^{-1} respetivamente. A superioridade em relação a testemunha foi de 8,67%. Na seleção dentro a média de produção e produtividade foi de 4.448,413 kg.ha^{-1} e 3.998,41 kg.ha^{-1}, respetivamente..

INTRODUCTION

Maize is an extremely important nutritional and food security source for Brazilian families, mainly for small farmers, settled by agrarian reform and traditional communities (BECKER; ANJOS, 2010). In Brazil, maize stands out among other grains, ranked in the second position in production, only surpassed by soy (GALVÃO et al., 2014). Annual production is estimated in 97 million tons, which is the third position in the worldwide ranking (FAO, 2018).

The Northeastern Brazil, mainly characterized by severely irregular rainfall and physically poor soils, is the third producing region in the country (CONAB, 2018). However, its productivity is below the national average. According to the National Supply Company (CONAB), in 2017, the average maize productivity in the region was 3.194 kg.ha^{-1}, while the national average was 5.556 kg.ha^{-1}, while the productivity of small family businesses in the "Alto Sertão" region does not reach 800 kg.ha^{-1} (CONAB, 2017).

This huge difference in productivity between the Brazilian regions is due to not only the local climatic characteristics, but also the unsuitable use of technologies and / or the lack of appropriate agricultural inputs and machinery and the consequent use of technologies developed in the southeastern and midwestern Brazil. One of the most noticeable example of inadequate use of technology is the adoption of hybrid cultivars (transgenic or not) without due technological support.

Regarding fertilization, there is a steady increase in the diffusion of alternative fertilization technologies, such as green fertilization, syrups and biofertilizers (CÉSAR et al., 2007) and organic fertilization (SCHERER; NESI, 2008). It is already proven that agroecological management maximizes the interactions that occur in the soil, which results in production systems that incorporate a more lasting character to fertility and reduce farmer's costs and risks (HANISCH et al., 2012). This type of management is fundamental for maintaining chemical, physical and biological conditions suitable for plant development to increase crop productivity.

The indiscriminate use of hybrid seeds has increased steadily, which reduces local seed banks and, consequently, food sovereignty and security. However, it must be clarified that it was exactly hybrid maize that led Brazil to the position of third world maize producer (GALVÃO et al., 2014). Nevertheless, in such a large and diverse country as Brazil, various strategies must be adopted to guarantee food sovereignty.

In this context, the use of landrace seeds is an important tool, due to their high potential for adaptation to specific environmental conditions (PATERNIANI et al., 2000). They are also important sources of genetic variability that can be exploited in the search for genes that are tolerant or resistant to biotic and abiotic factors. These seeds are already very well known among the population. It is important to point out that landrace populations are usually less productive than commercial cultivars.

Therefore, it is understood that, in order to improve the productivity levels of the Northeastern region, it is important to consider the use of cultivars adapted to climatic conditions, improved with the use of local populations and with wide capacity to respond to alternative management systems, mainly fertilization. Thus, this work evaluates the first cycle of a recurrent selection program, between and within half-sib families, starting from a population of landrace maize.

MATERIALS AND METHODS

The work started with the formation of the base population. It consisted of a mixture of seeds in equal proportions of 10 maize accessions cultivated in the Maciço de Baturité region / CE, a group of municipalities in the northern state of Ceará, considered creole maize. Students of the Agronomy program residing in rural areas donated maize accessions to the university. The accession mixture was planted at the Fazenda Experimental Piroás (Piroás Experimental Farm), under cultivation in an area fertilized only with leguminous green manure and tanned cattle manure. In this selection step, 60 plants were selected based on the morpho-agronomical traits size, height, number and size of ears and absence of pests and diseases.

The progeny evaluation phase, which includes selection between families, was installed in the 2017/2018 harvest, in an experimental field at the farm called Fazenda Repouso das Águas, located in the municipality of Capistrano/CE, Latitude: 4 ° 28 '20' 'S , Longitude: 38 ° 54 '14' 'O, with climate characterized as Hot and Humid Tropical (CEARÁ, 2007) and local average rainfall of 1087mm per year, according to the Fundação Cearense de Meteorologia e Recuros Hídricos (Meteorology and Water Resources Foundation of Ceará) (FUNCEME, 2019).

The experiment was carried out in a randomized block design, with three replications. Manual sowing was carried out on March 25, 2017. The experimental unit consisted of a five-meter line, spaced 0.70 *m* between rows and 0.20 *m* between plants. Three seeds were used per hole, at a depth of 0.04 *m*. At 21 days after emergence, thinning was carried out, and one plant was placed in each hole. In conjunction with the 60 half-sib progenies, the commercial variety BRS-Caatingueiro was used as control, planted on March 8, 2017, in order to avoid contamination via pollen of the progenies under analysis. Cultural treatments were performed whenever necessary, according to the recommendations for the crop (FANCELLI et al., 2000).

Fifteen traits were evaluated in the selection between families: PH (Plant Height), HIFE (Height of insertion of the first ear), NEP (Number of ears per plant), NEPP (Number of ears per plot), TNE (Total number of ears), EL (ear length), DE (Diameter of the ear), FEW (Full ear weight), CW (cob weight), TWS (Total weight of seeds), WSE (Weight of stuffed ear), NGL (Number of grain lines), NGPL (Number of grains per line), EY (ear yield in $kg.ha^{-1}$) and GY (grain yield in $kg.ha^{-1}$) yields were calculated according to the estimation method of the University of Illinois (REETZ, 1987).

The data were subjected to analysis of variance and the F test at 1 and 5% probability of error. The phenotypic and genotypic covariance matrices were also determined. The selection indexes of Smith & Hazel, Williams, Pešek & Baker and Mulamba & Mock (CRUZ et al., 2012) were tested, based on these matrices and the means of the variables, aiming at selecting the 20 best progenies.

The third stage of the first cycle of recurrent selection, recombination of progenies and selection within families, was carried out in the 2018/2019 agricultural year on the farm called Fazenda Experimental Piroás (FEP), owned by UNILAB, located in the municipality of Redenção / CE, Latitude: 04º 13 '33 "South, Longitude: 38º 43' 50" West, with climate characterized as Hot and Sub-humid Tropical (IPECE, 2007), and average rainfall is 1.062 *mm* per year, according to the Fundação Cearense de Meteorologia e Recuros Hídricos (Meteorology and Water Resources Foundation of Ceará) (FUNCEME, 2019).

The soil of the area was prepared under the agroecological system, three months before the planting of maize, using a combination of leguminous green manure (black Mucuná, gray mucuná, labe-labe, crotalaria and feijão de porco (pig bean). During the vegetative phase of the legumes, before flowering, the plant material was cut and subsequently incorporated into the soil. Forty days after the incorporation of legumes into the soil, the 20 superior progenies selected by the selection index were sown.

The experimental design in set was used, with three replications, spacing of 0.70 *m* between rows and 0.30 *m* between plants and 9-meter plots, with three seeds sown in each hole. After 15 days, thinning was carried out, and two plants were placed in each hole. Genetic recombination was performed in the 2:1 Irish system, with two mother lines and one father line, respectively. The tassels of the female plants were removed at the beginning of their reproductive phases, before the maturity of the pollen grains. Cultural treatments were performed when necessary, according to the Fancelli et al. (2000) recommendations for the crop.

In the selection within the families, 10 traits were evaluated: EL (ear length), DE (Diameter of the ear), FEW (Full ear weight), CW (cob weight), TWS (Total weight of seeds), WSE (Weight of stuffed ear), NGL (Number of grain lines), NGPL (Number of grains per line), EY (ear yield in kg.ha^{-1}) and GY (grain yield in kg.ha^{-1}) . The yields were calculated according to the estimation method of the University of Illinois (REETZ, 1987).

Data from 200 half-sib progenies were collected, visually selected within the half-sib families. They were subjected to analysis of variance and the F test at 1 and 5% probability of error. The phenotypic and genotypic covariance matrices were also determined. Based on these matrices and the averages of the variables, the test was performed, using the Mulamba & Mock selection index, which was chosen in the progeny evaluation phase, aiming at the selection of the 60 top progenies that will be used to start the cycle 2 of the recurrent selection program.

In the computational analyses, both in the selection between families and within families, economic weights were attributed, by attempts (Table 01), for each trait analyzed. The analysis of variance and the selection of superior progenies based on selection indexes were performed using the Genes software system, version 2013.5.1 (CRUZ, 2013).

Table 01. Economic weights used to estimate the genetic gain of the variables of the steps for the assessment and recombination of progenies.

Trait	Economic weight
PH	1.80
HIFE	0.70
NEP	02
NEPP	10
TNE	40
EL	18
DE	50
FEW	150
WSE	135
CW	20
TWS	115
NGL	25
NGPL	45
EY	5000
GY	6000

PH (Plant Height), HIFE (Height of insertion of the first ear), NEP (Number of ears per plant), NEPP (Number of ears per plot), TNE (Total number of ears), EL (ear length), DE (Diameter of the ear), FEW (Full ear weight), CW (cob weight), TWS (Total weight of seeds), WSE (Weight of stuffed ear), NGL (Number of grain lines), NGPL (Number of grains per line), EY (ear yield in kg.ha^{-1}) and GY (grain yield in kg.ha^{-1}).

RESULTS AND DISCUSSION

Based on the analysis of variance of the selection between families (Tables 02 and 03), submitted to the F test at 1 and 5% probability of error, significant differences were found between the families for all variables. This result indicates genetic variability between genotypes, which is essential for obtaining genetic gains from breeding programs (KRAUSE et al., 2012). The values found for the coefficients of variation are classified as good, which demonstrates high experimental accuracy, Fritsche-Neto et al. (2012).

The high heritability values for all evaluated traits is another fundamental aspect, according to Bespalhok et al., (2010), in a recurrent selection program, in which the phenotypic traits are the main parameters for the selection of superior progenies.

The grain yield of the progenies is the first datum to be highlighted. The overall average of treatments was 4.316 kg.ha^{-1}, a productivity rate much higher than the average for the northeastern region in recent harvests. Progeny 31 stood out for its grain yield (PROG) of 5.927,42 kg.ha^{-1}, which surpassed the control BRS Caatingueiro (4.778,19 kg.ha^{-1}) and the national average productivity of 5.556 kg.ha^{-1}.

Table 02. Synthesis of the analysis of variance of the selection between families, in Capistrano/Ceara, for the variables PH, HIPE, NEP, NEPP, TNE, FEW, EL, DE and TWS.

FV	GL	QM								
		PH	HIFE	NEP	NEPP	TNE	FEW	EL	DE	TWS
Blocks	2	0.15	0.07	0.0021	0.01	21.80	47174.38	134.41	316.74	40325.43
Treatments	60	0.34 **	0.20 **	0.01 **	0.49 **	31.65 **	1905.19 **	9.09 **	36.51**	1315.90**
Residue	120	0.07	0.04	0.0069	0.2108	12.57	531.57	2.07	6.52	413.72
Average		2.48	1.12	1.03	5.18	18.40	134.38	14.69	38.95	116.87
CVg (%)		11.95	20.85	6.05	5.94	13.71	15.92	10.41	8.12	14.84
CVg/CVe		1.05	1.16	0.75	0.67	0.71	0.93	1.06	1.24	0.85
Genetic S²		0.08	0.05	0.0039	0.09	6.35	457.87	2.34	10.00	300.73
Environmental S²		0.07	0.004	0.0069	0.21	12.57	531.57	2.08	6.53	413.73
Heritability		76.77	80.26	62.98	57.43	60.27	72.10	77.16	82.14	68.56
CV%		11.38	17.91	8.04	8.86	19.27	17.16	9.81	6.56	17.40

**Significant at 1% by the F test. QM – Average square, FV – Source of variation, GL- Degrees of freedom, CVg – Coefficient of genetic variation, CVe – Coefficient of environmental variation, S² – Variance, CV- Coefficient of Variation. PH (Plant Height), HIFE (Height of insertion of the first ear), NEP (Number of ears per plant), NEPP (Number of ears per plot), TNE (Total number of ears), FEW (Full ear weight), WSE (Weight of stuffed ear), TWS (Total weight of seeds), EL (ear length), DE (Diameter of the ear).

Table 03. Synthesis of the analysis of variance of the selection between families, in Capistrano/Ceara, for the variables CW, NGL, NGPL, WSE, EY and GY.

FV	GL	QM					
		CW	NGL	NGPL	WSE	EY	GY
Blocks	2	755.38	16.80	403.30	24374.59	9860079.7	10286035.76
Treataments	60	39.44 **	5.41 **	65.98 **	945.50 **	2200805.79 **	1578786.11 **
Residue	120	11.52	1.09	19.86	283.56	242830.88	233695.60
Average		18.52	13.13	29.76	100.42	5033.90	4316.04
CVg (%)		16.47	9.14	13.17	14.79	16.05	15.51
CVg/CVe		0.90	1.15	0.88	0.88	1.64	1.39
Genetic S²		9.31	1.44	15.37	220.65	652658.30	448363.50
Environmental S²		11.52	1.09	19.86	283.56	242830.88	233695.60
Heritability		70.79	79.73	69.89	70.01	88.97	85.20
CV%		18.33	7.99	14.98	16.77	9.79	11.20

**Significant at 1% by the F test. QM – Average square, FV – Source of variation, GL- Degrees of freedom, CVg – Coefficient of genetic variation, CVe – Coefficient of environmental variation, S² – Variance, CV- Coefficient of Variation. CW (cob weight), WSE (Weight of stuffed ear), NGL (Number of grain lines), NGPL (Number of grains per line), EY (ear yield in $kg.ha^{-1}$) and GY (grain yield in $kg.ha^{-1}$).

Falcão et al. (2017) obtained similar results in a research work conducted in the Northeastern region, with the creole varieties Branca and Viçosense. The authors report grain yields of 5.296,66 $kg.ha^{-1}$ and 4.249,90 $kg.ha^{-1}$, respectively. Coimbra et al. (2010) compared creole and commercial varieties, and reported that the creole varieties sometimes presented yield potential close to those of the hybrids evaluated. Carpentieri-Pípolo (2010), on the other hand, conducted an experiment with creole populations and commercial varieties in a low technology system and concluded that creole varieties P-13, P-15 and P-05 presented very high productive potential. The results of the evaluation of these progenies, combined with the literature already mentioned, lead us to disagree with the current and dominant thought that creole varieties are always inferior with respect to grain yield.

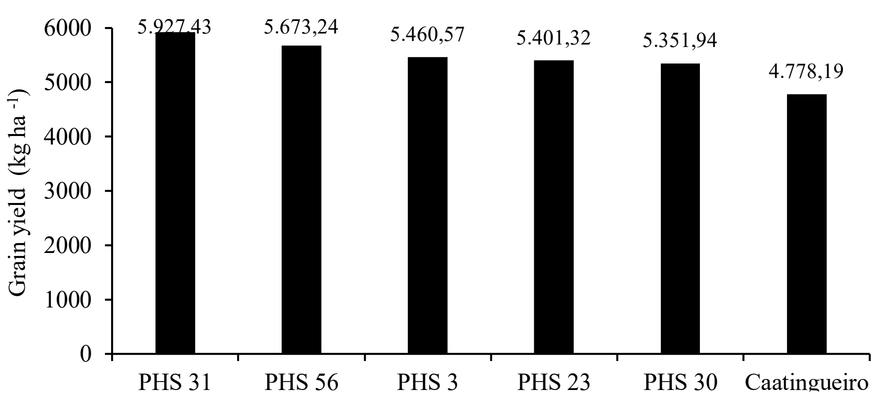
To draw the right conclusions, it is necessary to consider the materials used, the places where the experiments are carried out and the level of technology used. In this work, it was observed that, under the same biotic and abiotic conditions, the control showed lower yield than the progenies, which is fundamental to understand the yield obtained in the northeastern Brazil. Figure 01 shows grain yield in kilograms per hectare, among the five best progenies and the commercial variety BRS-Caatingueiro.

Another aspect is that the profitability obtained in the culture of maize with the use of creole varieties is higher than that achieved under the conventional systems used in Brazilian agriculture, mainly because it does not require high investments in inputs to achieve high productivity, differently from the conventional agriculture. Therefore, it is a viable alternative for family farming, which lacks resources to invest in crops (SANDRI; TOFANELLI, 2008). As for the gains obtained with the selection, table 05 presents the contributions of each index per evaluated trait.

The Pesek & Baker index resulted in undesirable gains for FH and HIPE, 0.87 and 2.66%, respectively (Table 04). Therefore, this index is not indicated, as bigger plants, with higher ears, are difficult to be harvested and more susceptible to breakage and lodging. As mentioned by Miranda et al. (2003), plant height and the high proportion between plant height and ear height can make the cultivar more susceptible to lodging and, consequently not recommended for cultivation in places with high winds and fertile soils, which cause the plant to grow more than the usual.

Based on the region where the breeding program is installed, the Mulamba & Mock (CRUZ et al., 2012) index best fits the traits PH and HIPE, due to the negative values presented, -1.08 and -0.85%, respectively. This corroborates the results presented by Freitas et al. (2013), who worked with recurrent intrapopulation selection, with pop maize full-sibs, and defined Mulamba & Mock as the index that best suited the needs of regions with plant lodging risks.

Figure 01. Comparison of grain yield in $kg.ha^{-1}$, for the five best progenies evaluated and the control. PHS- (half-sib progenies).



The Smith & Hazel, Mulamba & Mock (CRUZ et al., 2012) and Williams (CRUZ et al., 2012) indices showed positive selection gains for the traits related to grain development, which is the case of TWS, whose indexes showed genetic gain of 10.52, 11.67 and 10.79%, respectively. Another very significant character in these indices was the gain in EY, with the respective results 15.73, 14.93 and 16.09%, whereas for the other GY productivity variable, the average estimates of genetic gain were 13.89, 13, 15 and 15.08%.

Table 04. Estimates of percentage gains based on the selection differential, by simultaneous selection in fifteen traits, in the first recurrent intrapopulation selection cycle, in half-sib progenies of creole maize.

Trait (*)	Selection Indices			
	Pesek & Baker	Smith & Hazel	Mulamba & Mock	Williams
PH	0.87	- 0.58	- 1.08	-0.01
HIPE	2.66	0.37	- 0.85	2.21
NEP	2.67	1.87	1.87	1.66
NEPP	2.62	1.87	1.87	1.70
TNE	- 0.98	2.75	4.41	2.57
EL	0.28	4.79	6.04	4.95
DE	1.35	3.14	4.41	3.65
FEW	1.91	12.12	12.81	11.60
TWS	1.82	10.65	12.89	10.47
CW	1.98	9.90	12.51	13.26
WSE	3.03	10.52	11.67	10.79
NGL	- 0.11	3.06	2.43	3.56
NGPL	2.71	7.15	8.50	7.77
EY	1.67	15.73	14.93	16.09
GY	3.72	13.89	13.15	15.08
Total Gain (%)	26.2	97.23	105.56	105.35

(*) PH (Plant Height), HIFE (Height of insertion of the first ear), NEP (Number of ears per plant), NEPP (Number of ears per plot), TNE (Total number of ears), EL (ear length), DE (Diameter of the ear), FEW (Full ear weight), CW (cob weight), TWS (Total weight of seeds), WSE (Weight of stuffed ear), NGL (Number of grain lines), NGPL (Number of grains per line), EY (ear yield in $kg.ha^{-1}$) and GY (grain yield in $kg.ha^{-1}$).

Berilli et al., (2011) used the Smith & Hazel index in his study on maize, in a recurrent selection program with full sib progenies, and obtained a gain of 14.26% for grain yield per hectare. Working with recurrent intrapopulation selection with full-sibs of pop maize, Freitas et al. (2013) obtained 16.02% of genetic gain in grain yield per hectare, with the Williams index, which agrees with the results of the present work.

Based on the objectives of the breeding program, the region where the recurrent selection is installed and the results achieved by the indexes, it was determined that the top 20 progenies would be selected using Mulamba & Mock (CRUZ et al., 2012), as this showed satisfactory genetic gains for most variables, mainly for plant height and the insertion of the first ear (negative gains), for the ear traits, such as length and diameter, and the main factor for a successful selection, which is grain yield.

The following 20 top progenies were selected in the selection phase between progenies: 31, 47, 56, 60, 24, 33, 44, 18, 30, 37, 34, 59, 28, 55, 49, 29, 23, 26, 45 and 3, which were used in the progeny recombination stage and selection within the families.

From the analysis of variance of the selection within the families (Table 05), subjected to the F test at 1 and 5% probability of error, significant differences were found within the families for all variables. This indicated the presence of genetic variability between genotypes, which is fundamental for obtaining genetic gains in breeding programs (KRAUSE et al., 2012).

Table 05. Synthesis of analysis of variance of selection within families, in Redenção/Ceara, for the variables EL, DE, FEW, CW, NGL, NGPL, WSE, TWS, EY and GY.

FV	GL	QM									
		EL	DE	FEW	CW	NGL	NGPL	WSE	TWS	EY	GY
Blocks	2	234.41	416,74	46325.43	955.38	29.35	508.26	58264	38554	10624068	17366315
Treatments	199	6.62**	32.79**	1290.05**	42.52**	4.40**	99.59**	1455.45**	915.56**	1950457**	1343681**
Residue	398	5.09	10.65	621.54	19.68	5.29	25.53	784.65	572.44	424720	413475
Average		12.03	38.71	74.51	11.01	11.06	21.31	83.23	65.06	4448.41	3998.41
CVg (%)		20.05	6.29	38.91	41.66	9.71	26.21	37.20	38.45	38.91	38.45
CVg/CVe		2.24	1.27	3.83	1.59	1.11	2.29	3.42	4.08	3.83	4.0821
Genetic S²		5.82	5.94	840.95	21.06	1.15	31.22	957.97	625.99	1906918	1419498
Environmental S²		0.38	1.21	19.06	2.77	0.31	1.97	27.17	12.52	43234	28395
Heritability		93.77	83.01	97.78	88.36	78.76	94.06	97.24	98.03	97.78	98.03
CV%		8.94	4.93	10.14	16.18	8.74	11.40	10.85	9.41	10.15	9.42

**Significant at 1% by the F test. QM – Average square, FV – Source of variation, GL- Degrees of freedom, CVg – Coefficient of genetic variation, CVe – Coefficient of environmental variation, S^2 – Variance, CV- Coefficient of Variation. EL (ear length), DE (Diameter of the ear), FEW (Full ear weight), CW (cob weight), WSE (Weight of stuffed ear), TWS (Total weight of seeds), NGL (Number of grain lines), NGPL (Number of grains per line), EY (ear yield in $kg.ha^{-1}$) and GY (grain yield in $kg.ha^{-1}$).

Genetic recombination generated 200 half-sib progenies. Among the characteristics evaluated, it is worth highlighting, as well as in the selection between progenies, the traits related to grain production that presented results above the average obtained by producers in the Northeastern Brazil, with an average productivity between treatments of 3.998,41 $kg.ha^{-1}$. Progeny 54 showed the best result, 5.768,43 $kg.ha^{-1}$. One of the factors of this recombination phase was cultivation in an agroecological system, which reveals the scenario found by Northeastern producers, who have low capacity to invest in technologies for increasing productivity, with the use of hybrid cultivars that require a conventional cultivation system.

As mentioned by Hanisch et al., (2012), the agroecological production system, with the cultivation of creole varieties, initial correction of nutrients, maintenance of soil cover and biomass input, is capable of reaching grain productivity of around 6.500 $kg.ha^{-1}$, in agreement with the results of this work. Araujo et al., (2013), also used this system in the conductance of the participatory breeding of local varieties of maize. Their results demonstrated a greater economic viability of productive systems with agroecological focus, using the maize creole seeds, in addition to undeniable socio-environmental advantages.

This type of cultivation does not require high levels of investment in inputs to achieve interesting yields, which demonstrates that creole maize, in conjunction with agroecological systems, is a viable alternative for the development of agriculture in Northeastern Brazil, which gives food security to farmers.

The Mulamba & Mock (CRUZ et al., 2012) selection index was used again to select the 60 progenies (Table 06) that will continue in the breeding program. The selection gains for the traits TWS, EY and GY, which are fundamental for grain production, showed satisfactory average results for genetic gains, 10.63, 13.98 and 14.58%, respectively. The good results achieved in selection gain within families demonstrate good adaptability of the progenies to the agroecological cultivation system, considering that no marked reduction was observed for the selection between families (Figure 02) carried out under a different cultivation model.

Table 06. Estimates of percentage gains based on the selection differential, by simultaneous selection in ten traits, in the first intra-population recurrent selection cycle, in half-sib progenies of creole maize.

Trait (*)	Mulamba & Mock
EL	4.38
DE	4.31
FEW	13.32
WSE	11.57
CW	10.17
TWS	10.63
NGL	3.44
NGLP	8.34
EY	13.98
GY	14.58
Total Gain (%)	94.72

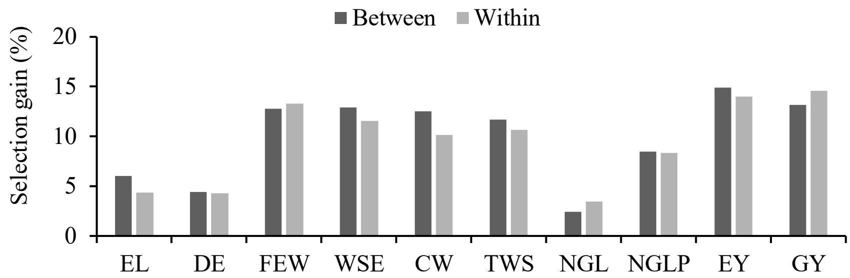
EL (ear length), DE (Diameter of the ear), FEW (Full ear weight), CW (cob weight), TWS (Total weight of seeds), WSE (Weight of stuffed ear), NGL (Number of grain lines), NGPL (Number of grains per line), EY (ear yield in kg.ha^{-1}) and GY (grain yield in kg.ha^{-1})

The following 60 progenies were selected, respectively, 54, 117, 103, 160, 106, 63, 116, 51,170, 165, 126, 48, 141, 26, 96, 7, 87, 166, 68, 75, 58, 145, 112, 78, 56, 197, 155, 29, 7, 57, 17, 101, 66, 183, 186, 181, 147, 117, 157, 91, 148, 26, 32, 101, 132, 88, 7, 186, 110, 51, 67, 113, 103, 132, 19, 168, 191, 117, 67 and 180, which were used in the following recurrent selection cycle between and within half-sib families.

CONCLUSION

The first cycle of recurrent selection between and within half-sibling families generated gains for later stages of selection. And that there is genetic variability in the population for new cycles of selection and a prospect of medium-long-term increase. The data presented here lead us to conclude that the cultivation of improved varieties based on landraces is fundamental for the improvement of the corn crop in Northeastern Brazil.

Figure 02. Table with comparison of the average percentage genetic gain for the traits EL, DE, FEW, CW, TWS, WSE, NGL, NGPL, EY and GY, from selections between families and within families. EL (ear length), DE (Diameter of the ear), FEW (Full ear weight), CW (cob weight), TWS (Total weight of seeds), WSE (Weight of stuffed ear), NGL (Number of grain lines), NGPL (Number of grains per line), EY (ear yield in kg.ha^{-1}) and GY (grain yield in kg.ha^{-1})



REFERENCES

ARAUJO, A. V. DE; BRANDÃO JUNIOR, D. DA S.; FERREIRA, I. C. P. V.; COSTA, C. A. DA; PORTO, B. B. A. Desempenho agronômico de variedades crioulas e híbridos de milho cultivados em diferentes sistemas de manejo. Revista Ciência Agronômica, v. 44, n. 4, p. 885-892, 2013. 10.1590/s1806-66902013000400027.

BECKER, C.; ANJOS, F. S. Segurança alimentar e desenvolvimento rural: limites e possibilidades do programa de aquisição de alimentos da agricultura familiar, em municípios do sul gaúcho. Segurança Alimentar e Nutricional, Campinas, v. 17, n. 1, p. 61-72, 2010.

BERILLI, A. P. C. G.; PEREIRA, M. G.; GONCALVES, L. S. A.; CUNHA, K. S. DA; RAMOS, H. C. C.; SOUZA FILHO, G.A.; AMARAL JÚNIOR, A. T. do. Use of molecular markers in reciprocal recurrent selection of maize increases heterosis effects. Genetics and Molecular Research, v.10, p. 2589-2596, 2011. 10.4238/2011.October.25.6.

BESPALHOK F., J. C.; GUERRA, E. P.; OLIVEIRA, R. Introdução ao Melhoramento de Plantas. In: BESPALHOK F., J. C.; GUERRA, E. P.; OLIVEIRA, R. Melhoramento de Plantas. Available in: http://www.bespa.agrarias.ufpr.br. 2010, p.11-15.

CEARÁ, Instituto de Pesquisa e Estratégia Econômica do Ceará (IPECE) (org.). Ceará em Mapas. Fortaleza: IPECE, 2007. Available in: http://www2.ipece.ce.gov.br/atlas/capitulo1/12/126x.htm. Access in: 24 nov. 2019.

CESAR, M. N. Z; PAULA, P. D.; POLIDORO, J. C.; RIBEIRO, R. L. D.; PADOVAN, M. P. Efeito estimulante da urina de vaca sobre o crescimento de mudas de pepino, cultivadas sobre manejo orgânico. Ensaios e Ciência, v.11, n.1, p. 67-71, 2007.

COIMBRA, R. R.; MIRANDA, G. V.; CRUZ, C. D.; MELO, A. V.; ECKERT, F. R. Caracterização e divergência genética de populações de milho resgatadas do Sudeste de Minas

Gerais. Revista Ciência Agronômica, Fortaleza, v. 41, n. 1, p.159-166, 2010.

CONAB. Acompanhamento de safra brasileiro – grãos: Décimo levantamento, julho 2018 – safra 2017/2018, Brasília: Companhia Nacional de Abastecimento. 2018.

CRUZ, C. D. GENES. A software package for analysis in experimental statistics and quantitative genetics. Acta Scientiarum, 35: p. 271-276, 2013.

CRUZ, C. D.; REGAZZI, A. J.; CARNEIRO, P. C. S. Modelos biométricos aplicados ao melhoramento genético. 3.ed. Viçosa: Ed. da UFV, 2012. 480p.

FALCÃO, R. F. Avaliação de populações de polinização livre, variedades comerciais e crioulas de milho em dois municípios de alagoas. Cultura Agronômica, Ilha Solteira, v. 26, n. 4, p.611-624, 2017.

FANCELLI, A.L.; DOURADO NETO, D. Produção de milho. Guaíba: Agropecuária, 2000. 360p.

FAO. Top 10 Country Production of Maize. 2018. Available in: <http://www.fao.org/faostat/en/#rankings/countries_by_commodity>. Access in: 07 nov. 2019.

FREITAS, I. L. J. Ganho genético avaliado com índices de seleção e com REML/Blup em milho-pipoca. Pesquisa agropecuária Brasileira. Brasília, v. 48, n. 11, p. 1464-1471, 2013. 10.1590/S0100-204X2013001100007.

FRITSCHE-NETO, R.; VIEIRA, R. A.; SCAPIM, C. A.; MIRANDA, G. V.; REZENDE, L. M. Updating the ranking of the coefficients of variation from maize experiments. Acta Scientiarum, 34: p. 99-101, 2012.

FUNCEME. Calendário das Chuvas no Estado do Ceará. 2019. Available in: <http://www.funceme.br/app/calendario/produto/municipios/media/anual>. Access em: 28 nov. 2019.

GALVÃO, J. C. C.; MIRANDA, G. V.; TROGELLO, E.; FRITSCHE-NETO, R. Sete décadas de evolução do sistema produtivo da cultura do milho. Revista Ceres. v. 61, p. 819-828, 2014. 10.1590/0034-737x201461000007.

HANISCH, A. L.; FONSECA, J. A; VOGT, G. A. Adubação do milho em um sistema de produção de base agroecológica: desempenho da cultura e fertilidade do solo. Revista Brasileira de Agroecologia, Dois Vizinhos, v. 7, n. 1, p.176-186, 2012.

KRAUSE, W.; SOUZA, R. S. de; NEVES, L. G.; CARVALHO, M. L. da S.; VIANA, A. P.; FALEIRO, F. G. Ganho de seleção no melhoramento genético intrapopulacional do maracujazeiro-amarelo. Pesquisa Agropecuária Brasileira, [S.L.], v. 47, n. 1, p. 51-57, 2012. 10.1590/s0100-204x2012000100008.

MIRANDA, G. V.; COIMBRA, R. R.; GODOY, C. L.; SOUZA, L. V.; GUIMARÃES, L. J. M.; MELO, A. V. de. Potencial de melhoramento e divergência genética de cultivares de milho-pipoca. Pesquisa Agropecuária Brasileira, [S.L.], v. 38, n. 6, p. 681-688, 2003. 10.1590/s0100-204x2003000600003.

PATERNIANI, E.; NASS, L. L.; SANTOS, M. X. O valor dos recursos genéticos de milho para o Brasil: uma abordagem histórica da utilização do germoplasma. In: UDRY, C. W.; DUARTE, W. (Ed.). Uma história brasileira do milho: o valor dos recursos genéticos. Brasília, DF: Ed. Paralelo, p. 11-41, 2000.

PIPOLO, V. C. Avaliação de cultivares de milho crioulo em sistema de baixo nível tecnológico. Acta Scientiarum. Agronomy, Maringá, v. 32, n. 2, p.229-233, 2010. 10.4025/actasciagron.v32i2.430.

REETZ, H. Here’s how to estimate yields for corn and soybeans before harvest. Better Crops With Plant Food, Atlanta, v. 71, p. 18-19, 1987.

SANDRI, C. A.; TOFANELLI, M. B. D. Milho crioulo: uma alternativa para rentabilidade no campo. Pesquisa Agropecuária Tropical, Goiânia, v.38, n. 1, p.59-61, 2008.

SCHERER, E. E.; NESI, C. N. Avaliação de fontes e doses de nitrogênio na produtividade de forragem de gramíneas anuais de estação fria e quente, em sucessão. Agropecuária Catarinense, v. 21, p. 68-73, 2008.