NOTE

Genetic gain of 'Valenciana' onion populations developed in the Brazilian Semi-Arid region

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Antonio Esmael Silva de Oliveira[1*], Carlos Antônio Fernandes Santos[2], Lucas Nunes da Luz[3], Valter Rodrigues Oliveira[4], Jonas Araújo Candeia[5] and José Luiz Sandes de Carvalho Filho[1]

Abstract: *The aim of the present study was to estimate the genetic improvement in the last recurrent selection cycles applied in two 'Valenciana' onion populations in Petrolina, PE. The experiments were carried out between October 2014 and January 2015, in Petrolina and Juazeiro, BA. The experiment consisted of a randomized block design, with 12 treatments and three replications. Analyses of variances were carried out separately for each population. The control population CNPH6400 was the comparison basis. Heritability and genetic gain were estimated for total (Prototal) and commercial (Procom) bulb yields. Significant differences were observed for Prototal and Procom in both populations and in both environments, except for the 25CA10 population, in Juazeiro. The highest Procom genetic gains were observed in Petrolina for 25CA10 and T811CR13 populations (510.5% and 522.1%, respectively), proving the efficiency of recurrent selection cycles. Genetic gains were nonlinear, and fluctuations may have occurred due to genetic drift.*

Key words: *Allium cepa, genetic progress, recurrent selection.*

INTRODUCTION

Onion (*Allium cepa* L.) is the second most relevant vegetable in the world (Abdelmageed et al. 2013). It is among the three most important vegetables in Brazil (IBGE 2016). Onions are of great economic importance in the northeast of Brazil, mainly due to the soil and climatic conditions that offers great comparative advantages to other producing regions, since it allows planting throughout the year. The states of Pernambuco and Bahia are the largest northeastern producers (Souza et al. 2008). Currently, this region contributes with 22.9% of the national production. The major-producer counties in the states of Bahia and Pernambuco are located in the sub-medium of São Francisco river (IBGE 2016).

The onion grown in the aforementioned region is yellow and has thin cataphylls. It differs from the 'Valenciana' type, which presents dark yellow color, greater cataphylls thickness, better post-harvest quality and higher price in the Brazilian market. 'Valenciana' is largely imported from Argentina in order to supply the Brazilian market, especially from April to June, when the best prices for the product are practiced (Santos et al. 2010).

The periodic estimate of genetic gain in recurrent selection method is crucial since it guides breeders on the selective strategies applied by them and on alternatives they may adopt to improve efficiency (Menezes Júnior et al. 2008).

***Corresponding author:**
E-mail: antonioesmael@hotmail.com

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[1] Universidade Federal Rural do Pernambuco, Av. Dom Manuel de Medeiros, s/n, 52.171-900, Dois Irmãos, Recife, PE, Brazil
[2] Embrapa Semiárido, Rod. BR-428, km 152, s/n, 56.302-970, Zona Rural, Petrolina, PE, Brazil
[3] Universidade da Integração Internacional da Lusofonia Afro-Brasileira, Av. da Abolição, nº 9, 62.790-000, Centro, Redenção, CE, Brazil
[4] Embrapa Hortaliças, Rod. BR060, km 09, s/n, Fazenda Tamanduá, 70.275-970, Brasília, DF, Brazil
[5] Instituto Agronomico de Pernambuco (IPA), Ilha do Estreito, 56.440-400, Belém do São Francisco, PE, Brazil,

Genetic gain refers to the changes observed in the characteristics of interest during the selection cycle by means of recombination and multiplication of selected units. Such changes happen in different magnitude and directions, depending on the strategies adopted and on the selection criteria. Thus, one of the most important tasks faced by plant breeders is the identification of selection criteria capable of promoting changes in the desired direction and in the characteristics of interest of a breeding program (Borges et al. 2009). Genetic gain estimate is easily obtained when recurrent selection is applied to assess the population in different cycles, since remaining seeds are available for evaluation.

The present study aimed to estimate the genetic improvement at the least five cycles of recurrent selection and was carried out at Embrapa Semiarido, having the CNPH6400 as the base population, to release a new cultivar for the Brazilian semi-arid region. These populations are from the 'Valenciana' type, and are the result of the cross between 'Baia Periforme' and 'Valcatorce INTA'.

MATERIAL AND METHODS

Experiment sites and plant material

The experiments were carried out in Petrolina, PE (lat. 09º09'S, long. 40º22'W, at 365.5 m asl), and in Juazeiro, BA (lat 09° 24' S, long 40° 26' W, alt 350 m asl), in the experimental areas of Embrapa Semiárido, from October 2014 to January 2015, which coincides with the highest temperatures of the year in the region. The experiment consisted of a randomized block design, with 12 treatments and 3 replications. The experimental plots set in Petrolina and Juazeiro measured 3.5 m^2, with estimated populations of 440,000 plants ha^{-1}.

Treatments (Table 1) consisted of recurrent selection cycles applied to two more distinct and promising 'Valenciana' populations (25CA10 and T811CR13), and to the control population CNPH6400. The initial selection cycles were not used due to seed-germination power losses, although the seeds were stored in cold chamber. These two populations were selected from the control population CNPH6400 after ten recurrent selection cycles in order to select productive populations presenting 'Valenciana' characteristics and which were adapted to Petrolina conditions. After recombination of each cycle, seeds were obtained by bulb vernalization in cold chamber at 8ºC, and with relative humidity of approximately 70%, during 120-150 days. CNPH6400 population was obtained at Brasilia, DF, after four recurrent selection cycles applied to the population resulted from the cross between Baia periforme population and Valcatorce INTA cultivar (Galmarini 2000). 'Valcatorce INTA' was selected from 'Valenciana Synthetic 14'; this cultivar requires photoperiods longer than 14 h to produce bulbs, and has medium size globe-shaped bulbs, with two to three dark-brown scales (Galmarini 2000). 'Baia Periforme' is a descendant of a Portuguese germplasm, introduced by the Portuguese immigrants, and is the most used germplasm in Brazilian breeding programs (Gomes and Maluf 1995).

Onion plant transplanting was carried out 30 days after sowing, when seedlings presented from 15 to 20 cm tall. Crop management procedures recommended to commercial onion fields in the region were applied, including fertilization with 800 kg ha^{-1} NPK of the mixture 06-24-12, before transplanting. The elements N and K (100 kg ha^{-1} N, split in five

Table 1. **'**Valenciana' onion populations assessed to estimate genetic gains in the Brazilian northeast

Treatment	Identification	Selection cycle	Origin	Year
1	25CA10	VI	Embrapa – Semiárido	2010
2	25CA10	VII	Embrapa – Semiárido	2011
3	25CA10	VIII	Embrapa - Semiárido	2012
4	25CA10	IX	Embrapa - Semiárido	2013
5	25CA10	X	Embrapa - Semiárido	2014
6	T811CR13	V	Embrapa - Semiárido	2009
7	T811CR13	VI	Embrapa - Semiárido	2010
8	T811CR13	VII	Embrapa - Semiárido	2011
9	T811CR13	VIII	Embrapa - Semiárido	2012
10	T811CR13	IX	Embrapa - Semiárido	2013
11	T811CR13	X	Embrapa - Semiárido	2014
12	CNPH6400	-	Embrapa - Hortaliças	2007

applications; and 60 kg ha^{-1} K, split in two applications) were also applied during plant development, up to 50 days after transplanting.

Statistical analysis

Two characteristics were assessed: 1) Commercial Yield (Procom), which was obtained by the total weight of bulbs with diameter greater than 35 mm, in t ha^{-1}; 2) total yield (Prototal), which was obtained by the total weight of the bulbs harvested in the plot, in t ha^{-1}. Data regarding Prototal were corrected by covariance, according to the mean plant stand in each experiment. One factor was generated to adjust the commercial yield. Correction was necessary in order to adjust errors during manual plant transplanting in each plot.

Analyses considered the populations separately. Individual analysis of variance were carried out in Petrolina, PE and in Juazeiro, BA, with five cycles of the 25CA10 population, of the control CNPH6400 population, together with other analyses of six cycles of the T811CR13 and CNPH6400 populations.

Analyses of variance were carried out by the GLM procedure, which is available in the SAS (SAS Institute 1996). Original data were transformed to log (10+1) to attend normal distribution presuppositions. Broad-sense heritability (h^2) resulted from the variance components, according to broad domain formula. Parameters differential selection (DS), genetic gain (G), and genetic gain percentage (G%) of each population in all environments evaluated were based on equations of broad domain formula.

RESULTS AND DISCUSSION

Total and commercial bulb yield differences (p-value<0.05) were observed only in Petrolina between CNPH6400 population and five cycles of the 25CA10 population, indicating the presence of improved populations of 'Valenciana' onion type (Table 2). PROCOM mean of the CNPH6400 control population, in Petrolina, was of 2.35 t ha^{-1}, whereas the mean of the five recurrent selection cycles of the 25CA10 population was of 13.74 t ha^{-1}, or 6x greater than the mean of the base population. These results show that selection effectively improved this population throughout the selection cycles. Mean gains in this population in Juazeiro were below those observed in Petrolina, and significant differences were not observed between treatments (Table 2). No conclusion can be inferred for 25CA10 evaluated in Juazeiro, since there were no differences between cycles.

Analysis of variance of the six cycles of T811CR13 population and of the control population were statistically different for total and commercial bulb yields in both environments (p<0.05) (Table 4). PROCOM mean of six cycles of the T811CR13 population were of 12.37 t ha^{-1} in Petrolina, and of 8.29 t ha^{-1} in Juazeiro, or 5,5x and 1,7x greater than the mean of the base population (Table 4). These results also show that selection effectively improved the T811CR13 population throughout the selection cycles.

The mean cycles of T811CR13 and 25CA10 in Petrolina were greater than those observed in Juazeiro, which can be related to the very loamy soil of Juazeiro. PROCOM of both evaluated populations were below the region onion

Table 2. Anova mean squares (MS) of total (Prototal) and commercial (Procom) bulb yield of five onion recurrent cycles applied to the CNPH6400 population, for the development of the yellow 'Valenciana' 25CA10 evaluated in two locations

Source of variations	Petrolina#		Juazeiro#	
	MS			
	Prototal	Procom	Prototal	Procom
Blocks	0.0351	0.0730	0.0018	0.0119
Treatments	0.0268*	0.0679*	0.0030	0.0119
Error	0.0054	0.0123	0.0020	0.0063
CV (%)	6.0	10.3	4.4	8.9
General mean	16.08	12.14	9.20	7.11
Mean CNPH6400	7.45	2.26	8.15	4.93
Mean Cycles	16.92	13.74	9.33	7.42

\# Original data transformed to $\log_{10}(x+1)$.
*Significant at 5% by the F test.

average, 30.6 t ha^{-1}, (IBGE 2016) mainly due the evaluation period, since the last months of the years present the highest temperatures, above 35°C. Santos et al. (2010) have reported commercial bulbs yield for cycle sixth of T811CR13 and 25CA10 populations of 29.3 t ha^{-1} and 37.7 t ha^{-1}, respectively, when were grown from May to September, which coincides with the lowest temperatures in the region.

The highest coefficient of variance among all the experiments analyzed was of 10.3%, recorded for the commercial bulb yield of the 25CA10 population in Petrolina (Table 2). This estimate was considered acceptable according to the classification of Pimentel Gomes (2000). Such classification is very extensive and does not take into account the particularities of the culture and the characteristic evaluated. The coefficient of variance in the experiments was higher

Table 3. Bulb yield mean, heritability (h^2), selection differential (SD), and genetic gain of five selection cycles of yellow Valenciana onion population 25CA10, regarding total bulb yield (Prototal) and commercial bulb yield (Prototal)

Genotype	**Environment**	**Characteristic**	**Mean** (t ha^{-1})	**h^2**	**SD** (t ha^{-1})	**Gain** (%)
25CA10CX	Petrolina	Prototal	15.33	0.79	7.88	83.56
25CA10CIX	Petrolina	Prototal	14.59	0.79	7.14	75.71
25CA10VIII	Petrolina	Prototal	16.78	0.79	9.32	98.93
25CA10VII	Petrolina	Prototal	19.01	0.79	11.56	122.58
25CA10VI	Petrolina	Prototal	18.90	0.79	11.45	121.41
CNPH6400	Petrolina	Prototal	7.45	0.79		
MeanCycles			15.43	0.79	7.98	100.44
25CA10CX	Petrolina	Procom	10.91	0.81	8.56	295.04
25CA10CIX	Petrolina	Procom	11.24	0.81	8.89	306.42
25CA10VIII	Petrolina	Procom	11.85	0.81	9.50	327.44
25CA10VII	Petrolina	Procom	17.16	0.81	14.81	510.47
25CA10VI	Petrolina	Procom	15.73	0.81	13.38	461.18
CNPH6400	Petrolina	Procom	2.35	0.81		
MeanCycles			11.54	0.81	9.19	380.11
25CA10CX	Juazeiro	Prototal	9.08	0.33	0.66	3.76
25CA10CIX	Juazeiro	Prototal	10.34	0.33	1.94	8.86
25CA10VIII	Juazeiro	Prototal	8.41	0.33	0.00	1.05
25CA10VI	Juazeiro	Prototal	9.49	0.33	1.08	5.42
CNPH6400	Juazeiro	Prototal	8.15	0.33		
MeanCycles			9.09	0.33	0.94	4.78
25CA10CX	Juazeiro	Procom	7.68	0.47	2.52	26.21
25CA10CIX	Juazeiro	Procom	8.53	0.47	3.37	34.32
25CA10VIII	Juazeiro	Procom	6.51	0.47	1.36	15.06
25CA10VI	Juazeiro	Procom	7.01	0.47	1.85	19.82
CNPH6400	Juazeiro	Procom	4.93	0.47		
Mean Cycles			6.93	0.47	2.0	23.86

Table 4. Anova mean squares (MS) of total (Prototal) and commercial (Procom) bulb yield of six onion recurrent cycles applied to the CNPH6400 population for the development of 'Valenciana' purple T811CR13 population evaluated in two locations

Source of variation	**Petrolina#**		**Juazeiro#**	
	MS			
	Prototal	**Procom**	**Prototal**	**Procom**
Blocks	0.0561	0.1313	0.0196	0.0423
Treatments	0.0187*	0.0534**	0.0148*	0.0268**
Error	0.0072	0.0094	0.0031	0.0041
CV (%)	7.0	9.0	5.4	6.9
General mean	15.95	11.98	10.08	7.97
Mean CNPH6400	7.45	2.26	8.15	4.93
Mean cycle	16.29	12.37	10.26	8.29

Original data transformed to log10 (x+1)
*, ** Significant at 5% and 1% by the F test, respectively.

than that reported by Santos et al. (2004) in a similar analysis carried out with an Alfa Tropical cultivar under São Francisco Valley conditions.

Broad-sense heritabilities for bulb yield were quite high, ranging from 0.62 to 0.85 for both populations, except for25CA10 in Juazeiro (Tables 3 and 5). The present results are in agreement with those found by Pavlović et al. (2003), who reported broad-sense heritabilities of 0.73 and 0.77 in yield bulb in Serbia and Montenegro. Gashua et al. (2013) have also reported high broad-sense heritability (0.71) in a Nigerian onion landrace. All these broad-sense heritability estimates suggest that genetic progress can be achieved in onion bulb yield by methods of population improvement, such as recurrent selection.

The mean gain observed in the 25CA10 population for PROTOTAL in Petrolina was 100.4% and the mean gain for PROCOM was 380.1% (Table 3). The mean differential selection was 8.0 t ha^{-1}, or 1.8 t ha^{-1}/cycle of commercial onion bulbs. The highest PROCOM gain was observed for cycle VII, which was 1.7x greater than that observed for cycle X of the 25CA10 population (Table 3). These results may be attributed to the emphasis to Valencian standard bulbs in the last selection cycles.

The mean gains observed in the T811CR13 population for PROTOTAL were 70.2% and 16.5% in Petrolina and Juazeiro, respectively, and the mean gains for PROCOM were 366.8% and 63.1%, respectively, in Petrolina and Juazeiro (Table 5).

Table 5. Bulb yield, heritability (h^2), selection differential (SD), and genetic gain of five selection cycles of the yellow Valencian onion population (T811CR13), regarding total bulb yield (Prototal) and commercial bulb yield (Prototal), evaluated in two locations

Genotype	**Environment**	**Characteristic**	**Mean** (t ha^{-1})	h^2	**SD** (t ha^{-1})	**Gain** (%)
T811CR13CX	Petrolina	Prototal	15.41	0.62	7.77	63.05
T811CR13CIX	Petrolina	Prototal	20.26	0.62	3.31	102.41
T811CR13CVIII	Petrolina	Prototal	16.95	0.62	9.31	75.55
T811CR13CVII	Petrolina	Prototal	14.44	0.62	6.80	55.18
T811CR13CVI	Petrolina	Prototal	13.42	0.62	5.78	46.90
T811CR13CV	Petrolina	Prototal	17.24	0.62	9.60	77.90
CNPH6400	Petrolina	Procom	7.64	0.62		
MeanCycles			15.05	0.62	8.65	70.17
T811CR13CX	Petrolina	Procom	11.17	0.82	8.89	323.28
T811CR13CIX	Petrolina	Procom	16.65	0.82	14.39	522.11
T811CR13CVIII	Petrolina	Procom	13.80	0.82	11.53	418.70
T811CR13CVII	Petrolina	Procom	9.82	0.82	7.56	274.30
T811CR13CVI	Petrolina	Procom	9.15	0.82	6.89	249.99
T811CR13CV	Petrolina	Procom	13.62	0.82	11.36	412.17
CNPH6400	Petrolina	Procom	2.26	0.82		
MeanCycles			10.92	0.82	7.10	366.76
T811CR13CX	Juazeiro	Prototal	12.0	0.73	3.63	31.65
T811CR13CIX	Juazeiro	Prototal	12.3	0.73	3.93	34.27
T811CR13CVIII	Juazeiro	Prototal	9.02	0.73	0.65	5.66
T811CR13CVII	Juazeiro	Prototal	10.55	0.73	2.18	19.01
T811CR13CVI	Juazeiro	Prototal	9.15	0.73	0.78	6.80
T811CR13CV	Juazeiro	Prototal	8.57	0.73	0.20	1.74
CNPH6400	Juazeiro	Prototal	8.37	0.73		
MeanCycles			9.99	0.73	1.62	16.52
T811CR13CX	Juazeiro	Procom	10.01	0.85	4.92	97.04
T811CR13CIX	Juazeiro	Procom	10.79	0.85	5.71	112.40
T811CR13CVIII	Juazeiro	Procom	6.58	0.85	1.50	29.52
T811CR13CVII	Juazeiro	Procom	8.48	0.85	3.40	66.92
T811CR13CVI	Juazeiro	Procom	7.06	0.85	1.98	38.97
T811CR13CV	Juazeiro	Procom	6.80	0.85	1.72	33.85
CNPH6400	Juazeiro	Procom	5.08	0.85		
MeanCycles			7.84	0.85	2.76	63.12

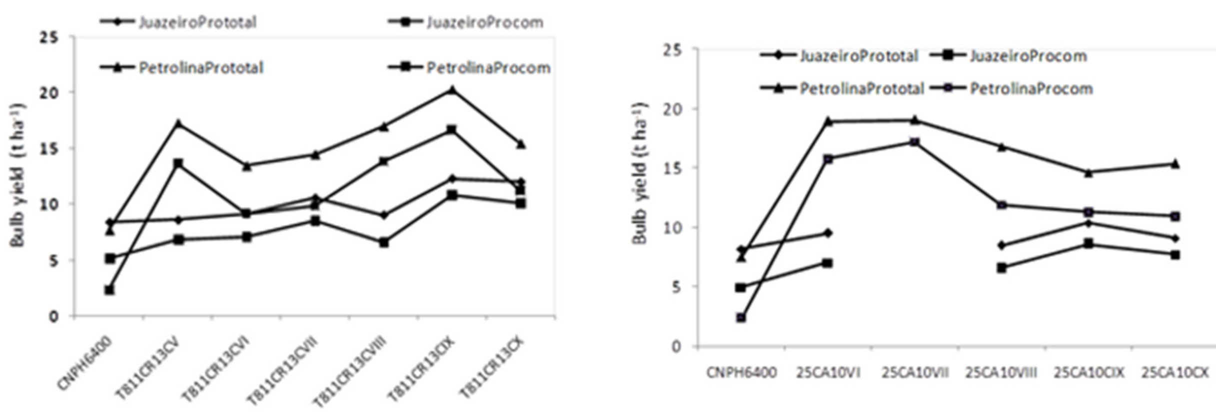

Figure 1. Total and commercial bulb yields (t ha^{-1}) in the T811CR13 and 25CA10Valenciana populations evaluated in two locations.

The mean differential selections of PROCOM were close to 1.2 t ha^{-1}cycle^{-1}, in Petrolina, and 0.46 t ha^{-1} cycle^{-1}, in Juazeiro. The highest PROCOM gain was observed for cycle IX in both locations (Table 5). The differences in genetic gain between locations may be attributed to the selection site, since all recurrent cycles were applied in Petrolina, which favors some specific adaptation and also to the very loamy soil of Juazeiro.

Nonlinear genetic gains were observed for both ‘Valenciana’ onion populations evaluated in this study. The highest bulb yields for T811CR13 were observed for cycle IX in both locations, and the highest yields for 25CA10, were observed for cycle VII, also in both locations (Fig. 1).These results could be attributed to genetic drift processes that occurred in the recurrent selection cycles, and also to the emphasis on the selection of bulbs of ‘Valenciana’ type in the last cycles, which may have reflected on the yield performance of subsequent cycle. Other authors have also reported these nonlinear mean one cycle after other, as it was also shown by Santos et al. (1999), who evaluated rice genetic improvement for 22 years, and by Dudley (2007), who evaluated 106 corn generations for oil content characteristics.

Gains in the commercial yield were higher than those obtained in total bulb yield, which showed effective improvement on bulbs uniformity, and which is of agronomic interest for onion production. Although the results of the evaluation carried out in Juazeiro were lower than those of the evaluation carried out in Petrolina, and more significant gains were observed in the commercial yield. Santos et al. (2004) also observed the prevalence of genetic gains in the commercial yield over the total bulb yield gains in the evaluation of three recurrent selection cycles in Alfa Tropical cultivar.

Recurrent selection methods are applied for the gradual increase in the frequency of favourable alleles at the time maintaining the genetic variability for future selection (Hallauer 1985). Heritability values ranging from 0.62 to 0.85 indicate that genetic progress for commercial yield of bulbs should continue in further recurrent selection cycles. Recurrent selection methods were applied by Galmarini (2000) to develop new cultivar, including INTA Valcatorce, and by Cramer and Corgan (2012) to develop NuMex Fabian Garcia cultivar. Unlike the present study, the authors mentioned have not estimated the genetic progress achieved with applied recurrent selection cycles.

Recurrent selection cycles will continue to be applied to both populations in order to increase the concentration of favorable alleles in commercial bulb yield, associated with the thickness and the dark yellow color of the cataphylls, as it was expected for a typical ‘Valenciana’ onion type. Overall, these results indicate the recurrent selection efficiency in the improvement of a base ‘Valenciana’ population, as well as the possibility of enhancing the ‘Valenciana’ onion type, in order to adapt this population to the short tropical days of northeastern Brazil, aiming to provide new cultivation options to the region and to consumers.

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