SELECTION FOR BULB MATURITY IN ONION

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ABSTRACT: It is possible to produce onions (*Allium cepa*) all over the year in Brazil, but most of the Brazilian cultivars have poor quality bulbs, a fact that favours onion imports from Argentina, a producer of Valenciana type cultivars that does not bulb in Brazil, but please Brazilian consumers. To study the effect of selection for bulb maturity, seventeen half sib progenies selected for early maturity and twenty five for late maturity, from the intervarietal triple cross [Crioula x (Pira Ouro x Valenciana Sintetica 14)] were grown, along with the triple cross itself and the cultivars Pira Ouro (short-day), Crioula (intermediate-day) and Armada (long-day). A total of forty six treatments were tested in a randomized block design with three replications of 32 plants per plot. The progenies selected for earliness had cycles from 67 to 83 days, whereas those selected for lateness had cycles of 85 to 103 days. This difference was evident when comparisons were made for the percent thick neck bulbs, which varied from 0 to 6.2% and from 8.1 to 59.8% for the early and late progenies, respectively. High heritability estimates were obtained for all characters and they varied from 0.65 (thick neck percentage, in the late selection) to 0.80 (average bulb weight, in the early selection). Progenies of higher bulb weight and maturity similar to the standard cultivars were obtained. Selection for maturity was highly efficient and the population selected for early maturity has potential to originate adapted cultivars, with bulb yield and quality superior to the available cultivars.
Key words: *Allium cepa*, cycle, bulbification, breeding

SELEÇÃO PARA MATURIDADE DE BULBOS EM CEBOLA

RESUMO: Embora seja possível produzir cebola (*Allium cepa*) o ano inteiro no Brasil, a maioria dos cultivares nacionais apresentam bulbos com baixa qualidade, o que proporcionou grande importação de cebola da Argentina, do tipo Valenciana, que não bulbifica no Brasil, mas que agradou os consumidores brasileiros. Para estudar o efeito da seleção para maturidade de bulbos baseada em progênies de meios irmãos obtidas do híbrido triplo intervarietal [Crioula x (Pira Ouro x Valenciana Sintética 14)] foram semeadas 17 progênies selecionadas para maturidade precoce e 25 para tardia, além da geração F_1 e dos cultivares Pira Ouro (dias curtos), Crioula (intermediários) e Armada (dias longos), totalizando 46 tratamentos. O delineamento foi em blocos ao acaso, com três repetições de 32 plantas por parcela, cultivadas em bandejas de isopor. As progênies precoces apresentaram ciclo médio variando de 67 a 83 dias e as tardias de 85 a 103 dias. Na comparação da porcentagem de plantas improdutivas esta diferença também foi evidente, variando de 0,0% a 6,2% nas precoces e de 8,1% a 59,5% nas tardias. Os coeficientes de herdabilidades obtidos foram elevados, variando de 0,65 (porcentagem de plantas improdutivas, na seleção tardia) a 0,80 (peso médio de bulbo, na seleção precoce), sendo, em média, superiores na população selecionada para maturidade precoce. Foram obtidas progênies com peso de bulbo superior às testemunhas ‘Pira Ouro’ e ‘Crioula’ e com ciclo que não diferia destas. A seleção para maturidade foi altamente eficiente e a população selecionada para maturidade precoce apresenta grande potencial de originar cultivares adaptados, com produção e qualidade de bulbos superiores às disponíveis no mercado brasileiro.
Palavras-chave: *Allium cepa*, ciclo, bulbificação, melhoramento

INTRODUCTION

Onion is one of the economically most important olericultural products in Brazil. In 1999, 762.643 ha of onions were planted, yielding a total production of 953.357 t (FNP Consultoria & Comércio, 2000).

Even though it is possible to produce onions year round in Brazil, most Brazilian cultivars are of low-quality in relation to thin-scale bulbs, with a tendency to become greenish, and not being standardized (Costa, 1995). Due to this inferior quality and also because of the consolidation of the MERCOSUL, large amounts of onions have been imported, mainly from Argentina, which harvests a single crop per year during January/February, grown in dry climate and fertile soil areas. In addition, the variety Valenciana 14, of the Sweet Spanish type, has an excellent, multiple skin with good retention, and a bronze tanned coloration (Costa, 1995). Unfortunately, this is a long-day variety and does not produce bulbs under natural conditions when cultivated in Brazil. Consequently, this variety can be interesting in crosses with local cultivars in a genetic breeding program to obtain new adapted populations, by incorporating its retention and skin coloration qualities. In relation to adaptation and maturity, the environmental factors that affect them are known, but the genetic factors not. There is practically no information regarding response to selection when crosses between cultivars adapted and non-adapted to the conditions of the State of São Paulo are made.

Obtaining populations with broad genetic basis that segregate for different photoperiodic requirements and bulb quality is extremely important in breeding programs targeted at obtaining cultivars adapted to the various onion-producing regions in Brazil.

Many factors affect onion development, bulb formation and maturity, with environmental conditions and plant genotype as the two main components. There has been reference to the necessity of long days to begin bulb formation since the twenties of last century (Garner & Allard, 1923). These authors observed that plants from the cultivar Silverskin, when submitted to a 10 hour daily light regime, did not form bulbs during the 12 months of observation. However, with a 14 hour regime they obtained normal bulbs.

In most onion-producing regions throughout the world, bulb formation occurs under conditions of increasing photoperiod, and the minimal requirements are between 12 to 16 hours of light, varying from cultivar to cultivar (Jones & Mann, 1963; Brewster, 1990). However, most cultivars are not genetically uniform as to their response to photoperiod (Magruder & Allard, 1937).

Increasing day length enhances the speed of bulb formation and decreases the time between the beginning of bulb formation and bulb maturation (Steer, 1980).

The terms "long", "intermediate" and "short-day" are largely used by plant science technicians and onion breeders to describe the photoperiod requirements for bulb formation of different cultivars, but they can cause confusion since they can be erroneously applied. Cultivars referred to as "short-day cultivars" can form bulbs under photoperiodic conditions found at low latitudes (from 11 up to 13 hours of light), while "long-day cultivars" only form bulbs during summer in high latitudes (critical photoperiod above 15 hours). "Short-day cultivars" actually are, from a physiological point of view, long-day cultivars, since they produce bulbs with a photoperiod above a particular critical value, which is smaller only when compared to cultivars referred to as "long-day cultivars" (Jones & Mann, 1963; Brewster, 1990).

The minimum photoperiodic requirements can also be reduced with an increase in temperature (Heath, 1943). This interaction between photoperiod and temperature is so important that the minimum photoperiod for a cultivar should never be specified without the corresponding temperature specification (Jones & Mann, 1963). In general, higher temperatures accelerate, and lower temperatures delay bulb development.

The objective of this project was to study the effect of selection on bulb maturity in a segregating onion population, obtained from crosses between cultivars of different photoperiod requirements.

MATERIAL AND METHODS

The experiment was carried out under a protected environment located in Piracicaba, SP, Brazil. Half-sibing progenies were obtained from the first generation (F_1) of the triple intervarietal hybrid [Crioula x (Pira Ouro x Valenciana Sintética 14)]. Seeds of this population were sown in 1994, and some plants formed bulbs while others not. Plants that did not form bulbs were placed in pots and induced to bloom, in a cold storage chamber, and then planted again in the field to produce seeds.

Seed collecting was made individually for each plant, yielding 25 half-sibing progenies, selected for late maturity (T-1 to T-25). Plants that formed bulbs had their bulbs selected, vernalized (5°C/40 days) and planted.

After flowering, the plants produced seeds that were collected from each plant individually, of which 17 half-sibing progenies were obtained, and selected for early maturity (P-1 to P-17). No flowering coincidence occurred between plants selected for late or early maturity, and therefore no crosses between them occurred in the process of obtaining progenies.

Reference "short-day" ('Pira Ouro'), "intermediate" ('Crioula') or "long-day" ('Armada') cultivars were chosen adopted to evaluate the effect of selection toward maturity in this triple hybrid. The original F_1 generation of the triple intervarietal hybrid [Crioula x (Pira Ouro x Valenciana Sintética 14)] was also evaluated. Thus, a total of 46 treatments was evaluated.

Sowing was made in expanded polystyrene trays with 128 cells, as recommended by Cardoso & Costa (1999), on 12/20/95, leaving a single plant per cell, which remained in the tray until the date of harvest. The experimental design consisted of random blocks with three replicates, and each plot consisted of 32 plants.

The sowing season in this experiment was chosen to open the possibility of obtaining more versatile populations for use in other systems and cultivation seasons when selection occurs in the summer (Costa, 1978). In addition, sowing in a tray under protected cultivation at the chosen time of year greatly reduces plant cycle without affecting the differentiation between genotypes (Cardoso & Costa, 1999). Consequently, populations obtained can be tested, in the future, in other seasons and locations, with a higher probability of becoming adapted to the normal conditions that prevail for bulb production.

Bulb harvesting started 49 days after sowing (Feb/07/96) and ended 54 days after (Apr/02/96), considering all plants not producing bulbs as unproductive, since the photoperiod and temperature were already low enough to prevent bulb formation in new plants. In each plot, only plants already presenting bulb formation and with a dead-back pseudo-stem were harvested. After each harvest, bulbs were cured for a week and their weight and diameter measured. The mean cycle for the plot was obtained through the arithmetic mean of the cycles of each plant producing a bulb, with unproductive plants disregarded.

The traits under evaluation had their means compared by the Tukey test at 5%. Since in breeding programs the comparison of progenies is made with regard to control cultivars, we chose to present only these differences in the table of results.

In addition, an estimate of the components of the genetic variance and heritabilities of traits under evaluation was obtained, and the analysis of variance was performed only for half-sibing progenies, according to the methodology described by Vencovsky & Barriga (1992). For these analyses, each selection for maturity was considered as a new population. Estimates were thus obtained for the early population, with 17 progenies, and other estimates were obtained for the late population, with 25 progenies.

RESULTS AND DISCUSSION

All 25 progenies selected for late maturity and the original F_1 generation had a longer cycle than cultivars Crioula and Pira Ouro, with the exception of progeny T-25, which was not different from cultivar Crioula (Table 1). Among the early progenies, none was different from Crioula, and 9 progenies had a cycle superior to that of the "short-day" cultivar Pira Ouro.

The divergent selection for maturity was efficient, providing evidence that plants that did not form bulbs in the previous cycle in fact gave rise to late progenies, while those that formed bulbs originated earlier progenies. In the comparison between progenies, T-25 was the only progeny selected for late maturity that did not present a cycle significantly superior than the early progenies.

Under photoperiod and temperature conditions above the critical point, the onion cycle is greatly reduced (Austin, 1972). Therefore, if sowing had occurred in a season with shorter photoperiod, starting in March, for example, the differences could have been more pronounced.

All progenies selected for early maturity were not different than the cultivars Pira Ouro and Crioula in relation to percentage of unproductive plants, which ranged from 0.0 to 6.2% (Table 1). This low rate of unproductive plants and the difference between early progenies and the original F_1 generation demonstrate that the selection for bulb formation was efficient.

Among the 25 late progenies, 14 had percentages of unproductive plants superior to that of the cultivar Pira Ouro. Consequently, these progenies are not

Table 1 - Mean cycle, percentage of unproductive plants and mean bulb weight of cultivars and progenies, and comparisons with control cultivars. Piracicaba-SP, 1996.

Treatment	Cycle	Unproductive plants	Ave. bulb weight	Ave. bulb diameter
	day	%	g	cm
Pira Ouro	60.1	1.0 a	2.91	1.50
Crioula	70.6	3.1 a	3.22	1.55
Armada*	---	100.0 p,c	---	---
F1	98.1 p,c	38.3 p,c	7.93 p,c	2.23 c,p
P-1	69.8	0.0 a	4.15	1.73
P-2	74.2	3.2 a	4.71	1.86
P-3	73.4	2.1 a	5.23	1.85
P-4	74.3	2.1 a	5.49	1.93
P-5	72.3	2.1 a	5.38	1.85
P-6	77.8 p	5.2 a	6.66 p,c	2.04 c,p
P-7	82.0 p	3.1 a	5.28	1.87
P-8	78.5 p	6.2 a	5.17	1.85
P-9	77.3 p	1.0 a	4.84	1.80
P-10	80.5 p	3.2 a	7.89 p,c	2.19 c,p
P-11	80.6 p	0.0 a	7.42 p,c	2.15 c,p
P-12	68.8	1.0 a	4.39	1.75
P-13	78.7 p	2.1 a	6.32	2.06 c,p
P-14	82.9 p	2.1 a	7.81 p,c	2.19 c,p
P-15	71.4	0.0 a	4.81	1.88
P-16	66.9	2.2 a	4.47	1.79
P-17	80.1 p	2.1 a	5.57	192
T-1	91.5 p,c	27.1 p	5.93	1.99 c,p
T-2	98.8 p,c	15.7 a	8.12 p,c	2.16 c,p
T-3	90.4 p,c	18.8 a	7.17 p,c	2.18 c,p
T-4	101.7 p,c	42.7 p,c	8.90 p,c	2.20 c,p
T-5	103.0 p,c	59.4 p,c	8.62 p,c	2.27 c,p
T-6	100.3 p,c	42.7 p,c	9.41 p,c	2.32 c,p
T-7	98.0 p,c	33.3 p	8.52 p,c	2.31 c,p
T-8	89.7 p,c	15.6 a	7.00 p,c	2.16 c,p
T-9	95.7 p,c	31.3 a,p	6.80 p	2.07 c,p
T-10	97.0 p,c	35.4 p	6.51	2.10 c,p
T-11	93.5 p,c	13.6 a	7.86 p,c	2.25 c,p
T-12	91.6 p,c	30.2 p	7.17 p,c	2.08 c,p
T-13	103.0 p,c	59.5 p,c	6.67 p,c	2.12 c,p
T-14	88.9 p,c	12.7 a	7.99 p,c	2.27 c,p
T-15	88.8 p,c	30.2 a,p	5.73	1.88
T-16	97.1 p,c	22.9 a	10.14 p,c	2.42 c,p
T-17	90.3 p,c	26.1 a,p	6.38	2.03 c,p
T-18	93.1 p,c	17.7 a	8.29 p,c	2.29 c,p
T-19	93.3 p,c	23.5 a,p	7.34 p,c	2.22 c,p
T-20	91.5 p,c	12.5 a	7.60 p,c	2.17 c,p
T-21	87.8 p,c	18.7 a	7.29 p,c	2.14 c,p
T-22	96.1 p,c	34.4 p	6.83 p	2.08 c,p
T-23	98.9 p,c	26.4 a,p	8.76 p,c	2.23 c,p
T-24	100.5 p,c	23.3 a	10.69 p,c	2.54 c,p
T-25	85.0 p	8.1 a	6.32	2.01 c,p
C.V.	5.10 %	23.20 %	16.91 %	6.29 %

[p] Differs from cultivar Pira Ouro by the Tukey test (5%),
[c] Differs from cultivar Crioula by the Tukey test (5%),
[a] Differs from cultivar Armada by the Tukey test (5%),
*Cultivar Armada did not produce bulbs, therefore its mean cycle, weight and mean bulb diameter could not be evaluated.

promising for obtaining a new population to be utilized as a basis for a "short-day" onion breeding program, since they did not form bulbs even under the maximum photoperiod and temperature conditions in the region of Piracicaba.

Costa (1978) and Brewster et al. (1987) reported a strong association between percentage of unproductive plants and late maturity, in agreement with what was observed in this work. Earliness in onions depends on their capacity to initiate bulb formation in a reduced photoperiod and to develop the bulb rapidly after the critical photoperiod is reached (Magruder & Allard, 1937).

Among the cultivars, only 'Armada', which is a "long-day" cultivar, did not present plants with bulbs, since the photoperiod and all other experimental conditions were not sufficient to induce production of bulbs.

In relation to mean weight and diameter of bulbs (Table 1), most late progenies and the original F1 generation had superior performances, since they must have a longer critical photoperiod to produce bulbs, so that not all plants formed bulbs. For this reason, they have an opportunity to produce a larger leaf area relative to the early varieties before beginning bulb formation, and therefore they can produce larger bulbs. Plants that always develop bulbs under a photoperiod much higher than their required minimum will produce small bulbs, because of the small leaf area available when they receive the stimulus to begin bulb formation (Austin, 1972).

Among to progenies selected for early maturity, P-10, P-11 and P-14 were prominent, with higher bulb weight than the standard adapted cultivars Pira Ouro and Crioula, as well as P-6, with mean weight higher than 'Pira Ouro'. Considering that plants which receive an early bulb initiation stimulus produce small bulbs, sowing in seasons normally utilized for the crop could have favored the production of larger bulbs.

Progenies obtained were as early as the standard cultivars, and with bulb weights as high or higher than these, and great segregation for skin quality also occurred (visual observations), which makes the selection possible for this characteristic as well. This demonstrates the potential this population has to yield new cultivars, and with higher production potential than the cultivars available in the market.

The heritability coefficient estimates consisted of high values, especially for the early population, where they ranged from 0.71 to 0.80 (Table 2). The selection among progenies based on their mean should result in expressive gain for all traits under evaluation. However, the characteristics cycle and mean bulb diameter presented low genetic variation coefficients for both populations, ranging between 5.43% and 6.72%. Therefore, the expected gain in selecting among progenies for these characteristics should not be very high in absolute terms. In relation to cycle, a selection had already been conducted in a previous generation,

Table 2 - Heritability coefficient estimates in the restricted sense, at the level mean (h^2_m) and genetic variation coefficient (CV_g) of populations selected for early and late maturity, Piracicaba-SP, 1996.

Population	Characteristic	Mean	h^2_m	CV_g
	Cycle (days)	75.9	0.71	5.44
Early	Ave. bulb weight (g)	5.6	0.80	18.84
	Ave. bulb diameter (cm)	1.9	0.77	6.72
	Cycle	94.6	0.75	4.63
Late	Inproductive plants (%)	30.6	0.65	23.81
	Ave. bulb weight (g)	7.7	0.66	13.41
	Ave. bulb diameter (cm)	2.2	0.68	5.43

resulting in their further separation into two populations, restricting the genetic variability in each one. The variability coefficient estimates for the characteristic cycle (0.71 and 0.75 for early and late populations, respectively) do not differ from what was reported by Maluf et al. (1990), whose estimate was 0.725.

The adaptation of progenies evaluated through percentage of unproductive plants, presented small variability between progenies in the early population (0.0 to 6.2%), and most of them did not show unproductive plants (not producing a bulb). For this reason, no analysis of variance was performed for this characteristic in this population. This low rate of unproductive plants demonstrates that the selection for bulb formation was efficient and that the response was instantaneous, i.e., plants that formed bulbs in the previous generation generated progenies with nearly 100% plants bearing bulbs. The late population, in contrast, presented high heritability (0.65), and the greatest genetic variability was observed for this characteristic (CV_g = 23.81%). Even though there was genetic variability between these progenies, they are not very promising, as compared to the early ones, for obtaining a new population to be utilized as the basis for a "short-day" onion breeding program, as already said. The estimated heritability in this late population was similar to that reported by Candeia (1984), whose estimate was 0.65, but much higher than that reported by Buso (1978), with estimates of 0.40 and 0.52.

A high heritability coefficient estimate was obtained for mean bulb weight (0.80 and 0.66, in early and late populations, respectively), associated to a medium genetic variation coefficient (18.84% and 13.41%, in early and late populations, respectively). Again, these obtained estimates are higher than those reported by McCollum (1966; 1968), whose estimates ranged from 0 to 0.26, Buso (1978), with variation from 0.12 to 0.39, Candeia (1984), with an estimate of 0.44 and Maluf et al. (1990), with an estimate of 0.26.

In general, the heritability coefficient estimates obtained were high. However, these estimates are specific for each population, estimation methodology, location and cropping conditions. Probably, these high estimates are due to the broad genetic variability of the original population, a triple intervarietal hybrid involving cultivars with no, or little, skinship, in association to protected environment cultivation conditions, with uniform substrate, irrigation and fertilization, which reduce the error caused by environmental variation.

CONCLUSIONS

The selection for maturity in onion was highly efficient and the progenies selected for early maturity have a great potential to originate adapted cultivars, with production and bulb quality higher than those available in the Brazilian market.

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