horticultura brasileira

Scientific communication

SILVA, GO; PEREIRA, AS; AZEVEDO, FQ; CARVALHO, ADF; PINHEIRO, JB. 2018. Selection of potato clones for tuber yield, vine maturity and frying quality. *Horticultura Brasileira* 36: 000-000. DOI: http://dx.doi.org/10.1590/S0102-05362018020?

Selection of potato clones for tuber yield, vine maturity and frying quality

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ABSTRACT

Development of Brazilian potato cultivars adapted to different growing conditions, production systems and regions of the country is very important to increase the competitiveness of the national potato chain. In this sense, the objective of this work was to verify the performance of advanced potato clones for tuber yield traits, vine maturity and frying quality. An experiment was carried out in Pelotas-RS in spring, 2014. A set of nine advanced potato clones and two control cultivars were evaluated using a randomized complete block design with four replicates. Plots consisted of single rows of 20 plants spaced at 0.80 m between rows and 0.30 m between plants. The data of each trait were submitted to the deviance analysis, estimated the genetic values and selected the best genotypes using selection indices of the sum of ranks and the lowest distance from the ideotype. Clones F131-08-26 and F183-08-01, and the check ‘Asterix’ were distinguished for yield of marketable tubers. F183-08-01 and the control stood out for specific gravity and average tuber weight. Clone F161-07-02 ranked among the best for specific gravity, frying color and vine maturity. F97-07-04 and F183-08-01 and the check ‘Asterix’ were the best according to the selection indices, however, would result in losses in the frying color and vine maturity traits.

Keywords:*Solanum tuberosum*, selection index, genetic parameters.

RESUMO

Seleção de clones de batata para rendimento de tubérculos, ciclo vegetativo e qualidade de fritura

A obtenção de cultivares nacionais de batata adaptadas a diferentes condições de cultivo, sistemas e regiões do Brasil é muito importante para aumentar a competitividade da cadeia brasileira da batata. Neste sentido, o objetivo deste trabalho foi verificar o desempenho de clones de batata para caracteres de rendimento de tubérculos, ciclo vegetativo e qualidade de fritura. O experimento foi realizado em Pelotas-RS na primavera de 2014. Foi avaliado um conjunto de nove clones de batata e duas cultivares testemunhas, no delineamento experimental de blocos casualizados com quatro repetições e as parcelas constituídas de uma linha com 20 plantas, espaçadas em 0,80 m entre linhas e 0,30 m entre plantas. Os dados de cada caráter avaliado foram submetidos à análise de deviance. Foram estimados os valores genéticos e selecionados os melhores genótipos por índices de seleção da soma dos “ranks” e da menor distância ao tipo ideal. Para rendimento de tubérculos comerciais destacaram-se os genótipos F131-08-26, Asterix e F183-08-01, sendo os dois últimos genótipos também destaques para peso específico e massa média de tubérculos. O clone F161-07-02 foi classificado entre os melhores para peso específico, cor de fritura e ciclo vegetativo. Os clones F97-07-04 e F183-08-01 e a cultivar testemunha Asterix foram os melhores de acordo com os índices de seleção, que, no entanto, resultaria em perdas nos caracteres cor de fritura e ciclo vegetativo.

Palavras chave: *Solanum tuberosum*, índice de seleção, parâmetros genéticos.

Received on June, 5, 2017; accepted on February 16, 2018

Most of the potato cultivars currently used in Brazil was developed in Europe. Because they do not have a good adaptation to Brazilian soil and climatic conditions, they require a high amount of inputs to reach high yields (Silva *et al*., 2014a). Therefore, the use of national cultivars adapted to the growing conditions of the different producing regions of the country is considered an important strategy to make the crop more productive and profitable to farmers (Silva *et al*., 2014a).

In temperate regions, potato cultivars with a later maturity (>130 days) show higher yield in relation to the early ones, which is also true for tropical conditions (Silva & Pinto, 2005; Rodrigues *et al*., 2009). However, farmers prefer early cultivars (Rodrigues *et al*., 2009) because they allow a greater number of crops per year and use of the area with other crops throughout the year, less time of plants exposure to adverse weather, lower risk of diseases and pests, and reduced demand for irrigation. In addition, these cultivars allow early harvesting of the crop to take advantage of good prices of the product on the market. Thus, earliness is a highly relevant trait for potato breeding programs, but it must be associated with tuber yield, among other traits.

The potato can be marketed *in natura* or used for industrial processing. Consumers give great important to tuber appearance, while processors require tuber traits that confer frying quality, like high specific gravity, low content of reducing sugars, besides absence of physiological disorders.

The specific gravity is an important trait, because it is related as dry mass content in the tubers. Potatoes of high specific gravity yield more final product in industrialization, less absorption of fat during frying, besides influencing positively texture and taste. In turn, low sugar content prevents the darkening of processed products that compromise the appearance and taste of the fried product (Silva *et al*., 2014b).

The inferences about genetic materials in field experiments for classifying those clones to be released as cultivars should be based on true genotypic values, that is, on genotypic and non-phenotypic means. Genotypic means are future means, when cultivars will be grown as commercial crops. Since this prediction requires the true values of the variance components, it is important to use the best unplanned linear prediction (BLUP) and the maximum restricted likelihood (REML) methods. For this, the consideration of effects of treatments as random is essential, since only then genetic selection can be done, otherwise selection is phenotypic (Borges *et al*., 2010). Although when the experimental precision is adequate the phenotypic values are similar to the genotypic ones. However, in potatoes are still incipient studies using this theory.

In relation to the selection of superior genotypes for multiple traits, the selection process can be more efficient with the use of selection indexes, which allow combine multiple information from the experimental unit, so that selection is based on a complex of variables that gather several attributes of interest (Cruz *et al*., 2012). Several selection indexes have been described in the literature, being some based on the establishment of economic weights or desired gains for the traits. However, the difficulty and subjectivity to assign the necessary weights in the use of these methods, has led to the proposition of methods that exempt such determinations, such as the shortest distance in relation to the ideal genotype or ideotype and sum of the ranks (Cruz *et al*., 2012).

Silva *et al.* (2014b) evaluated the efficiency of selection index for yield components and frying quality, and found that the index of the shortest distance to the ideotype was superior to the other methods for identifying the best clones and obtaining higher gains.

Thus, the objective of this work was to verify the performance of advanced potato clones for tuber yield traits, vine maturity and frying quality.

MATERIAL AND METHODS

The experiment was carried out in Pelotas-RS (31ºS, 52ºW, 50 m altitude), in the 2014 spring season. Tubers were planted on August 26 and harvested 106 days later.

A set of nine advanced clones (F97-07-04, F161-07-02, F110-07-01, F37-08-01, F131-08-26, F156-07-19, F183-08-01, CL310, and CL316) and two check cultivars (Agata: early maturity; Asterix: frying quality) were evaluated.

A randomized complete block design with four replicates was used. Plots consisted of single rows of 20 plants spaced at 0.80 m between rows and 0.30 m between plants.

Planting rows were fertilized with 3.8 t ha^{-1} of NPK commercial formula 05-30-10. Cultural and phytosanitary treatments followed the recommendations for the region (Pereira, 2010). Earthing up was done 30 days after planting, and no top-dressing of nitrogen was added.

Maturity of each plot was visually assessed 100 days after planting, using a nine-point scale (1-late, 9-early). Note 1 was ascribed for plots with plants showing the later green leaves and with less prostrated stems, and note 9 for plants with more yellowish leaves and stems prostrated, indicating proximity of vine maturity. For other plots intermediate grades were given, comparing with the two extremes, according to Silva *et al.* (2012).

After harvesting, tubers of each plot were graded as marketable (transversal diameter >45mm) and non-marketable (transversal diameter ≤45mm), counted and weighed, for obtaining data of the following traits:

Marketable tuber yield (kg plot^{-1});

Marketable tuber number;

Average tuber weight (g), obtained by dividing the total tuber weight plot^{-1} by the total tuber number.

The marketable tuber number and marketable tuber yield were converted to tuber number ha^{-1}/1000 and marketable tuber ha^{-1}, respectively.

The specific gravity and chip color were also evaluated. The specific gravity was measured directly on the tubers using a hydrometer from the Snack Food Association (Kumar *et al*., 2007). The chip color was assessed using samples of 15 slices per plot, prepared from three medium and healthy tubers. Five 1-mm thick slices were cut transversally from the middle part of each tuber, washed in running water, dried with paper towel and sifted into vegetable oil at the initial temperature of 180°C until bubbling stopped. Color was assessed visually to a standard set on grading scale from 1 (dark) to 9 (light), adapted from Silva *et al*. (2014b).

The data of each trait were submitted to analysis of deviance and estimation of genetic parameters, genotypic values (phenotypic mean corrected by genetic values) and confidence intervals of genotypic values, using the REML/BLUP method (Resende, 2002b). For the deviance analysis the following model was used:

$y = Xr+Zg+e$,

where y is the vector of observed data, r is the vector of effects of repetitions (assumed as fixed), g is the vector of genotypic effects (random), and X and Z, incidence matrices for these effects (Resende, 2002a). As the number of genotypes was greater than ten, the effects of genotypes were considered as random, following the criterion of Resende & Duarte (2007). Data analysis was done with SELEGEN software (Resende, 2002b).

The superior genotypes were selected by the index of the *sum of ranks* (Mulamba & Mock, 1978), which consists of ranking genotypes for each trait in an order that favors breeding. The selection index based on the distance between each genotype and ideotype (Schwarzach, 1972 cited by Wricke & Weber, 1986) was also used. This index is calculated using the least Euclidean distance of the ideal genotype, with the ideal genotype being the one with the maximum genotypic values for each trait. These analyzes were performed using the GENES software (Cruz, 2016).

RESULTS AND DISCUSSION

Deviance analysis revealed significant differences ($p<0.05$) among genotypes for all traits, indicating that there is difference in genotype performance for the evaluated traits (Table 1).

The phenotypic coefficient of variation (CV) was lower for specific gravity, 0.29%. The CV for the other traits varied from 7.76 to 19.59%, for average tuber weight and chip color, respectively. These results indicate that, in this experiment, adequate experimental precision was obtained, considering that, for example, traits related to tuber yield, which is a quantitative trait, normally has a great influence on the environment (Silva *et al*., 2006).

The genotype CV/phenotype CV relationship was greater than 1 for all traits, indicating that genetic variation exceeded the environmental, and, therefore, selection for these traits could be efficient (Cruz *et al.*, 2012). A large genetic effect on the phenotype can also be confirmed by the magnitudes of the genotypic variances in comparison to the phenotypic variances, by the accuracy in the selection, which exceeded 90% for all traits, and by the heritability coefficient in the broad sense. In the case of potato (asexual reproduction), the broad sense heritability exploits the additive, dominance and epistatic effects. This coefficient was not only elevated for the chip color trait (Table 1).

The appropriate experimental precision can also be attested by the mean of estimated heritability of the clones, or heritability to the genotypic mean, which was high for all the traits, being greater than or equal to 90%, and indicated along with the selective accuracy, that high effectiveness with the selection can be obtained (Table 1). According to Resende (2002a), the accuracy value of the selection, which is the square root of the average heritability of the clones, indicates high precision in the inferences of the genotypic values, showing that the experimental conduction was appropriate for the identification of superior genotypes.

Observing the genotypic values, which refer to the values of the phenotypic means corrected by the genetic values corresponding to the predicted performance of the genotypes when they are cultivated, it was noted that for number and yield of marketable tubers, the clone F131-08-26 had the highest genotypic value, with potential mean yield of 193.32 marketable tubers $ha^{-1}/1000$ and 19.31 t ha^{-1}(Table 2).

For the marketable tuber number, clones F183-08-01, CL316, F97-07-04, F161-07-02 and the check cultivar Asterix, belonging to the confidence interval of the best classified clone, with a lower limit of 163.90 tubers $ha^{-1}/1000$, stood out. For marketable tuber yield, the same genotypes, except F161-07-02, belonged to the confidence interval of the best clone.

The average marketable tuber number observed in this experiment (144.70 $ha^{-1}/1000$) is similar to that reported by Silva *et al*. (2012) (145.83 $ha^{-1}/1000$), who evaluated a set of eight advanced clones and check cultivars Agata and Asterix, in autumn conditions at the same location. For the marketable tuber yield the authors observed a mean value of 19.53 t ha^{-1}, while in this study the mean was 13.97 t ha^{-1}. Silva *et al.* (2014b) evaluated seven advanced clones and the same checks in the

Table 1. Values of the likelihood ratio test (LRT) of deviance analysis and genetic parameters of the evaluation of 11 potato genotypes in Pelotas-RS, in spring 2014. Pelotas, Embrapa, 2018.

Trait	MTN	MTY	ATW	SG	Color	MAT
Genotype[1]	32.57*	35.82*	38.03*	64.06*	23.68*	50.05*
Genotypic variance	1474.01	19.96	71.16	0.001	1.12	2.34
Residual variance	431.15	5.04	16.31	0.001	0.51	0.33
Phenotypic variance	1905.16	25.00	87.47	0.002	1.62	2.67
Broad sense heritability	0.77	0.80	0.81	0.92	0.69	0.88
Average heritability of clones	0.93	0.94	0.95	0.97	0.90	0.97
Acuracy in the selection	0.97	0.97	0.97	0.98	0.95	0.98
CV genotypic (%)	26.53	31.98	16.22	1.02	29.04	26.82
CV phenotypic (%)	14.35	16.07	7.76	0.29	19.59	10.03
CV genotypic /CV phenotypic	1.85	1.99	2.09	3.48	1.48	2.67
General mean	144.70	13.97	52.01	1.08	3.64	5.70

[1]LRT values; Significant at *P= 0.01 by the χ^2 test with one degree of freedom. MTN= marketable tuber number $ha^{-1}/1000$; MTY= marketable tuber yield in t ha^{-1}; ATW= average tuber weight in g $tuber^{-1}$; SG= specific gravity, assessed directly using hydrometer; Color= frying color (notes of nine point scale, 1= light, 9= dark); MAT= vine maturity (notes of nine point scale, 1= late, 9= early).

spring 2012 conditions in Canoinhas, and found an average marketable tuber number of 114.43 ha^{-1}/1000 and average marketable tuber yield of 21.00 t ha^{-1}. Therefore, the experimental conditions of this experiment provided to the plants the adequate performance and similar to other studies with potato clones in the southern region of the country.

For average tuber weight, which is related to average tuber size, the clone F183-08-01, with 59.10 g $tuber^{-1}$, only had no genotypic value higher than the check Asterix (69.41 g $tuber^{-1}$), with value included in the lower limit of the confidence interval for this cultivar. However, most of the other clones belonged to the same confidence interval as clone F183-08-01, except F37-08-01 and the check 'Agata', which presented the lowest genotype values, that is, smaller tubers. This indicates that the majority of the clones presents large tubers, highlighting the clone F183-08-01, with sizes bigger than 'Agata', which is the most cultivated potato cultivar in the country.

In relation to vine maturity, clones F97-07-04 and F161-07-02 belonged to the same confidence interval of the check 'Agata', the earliest genotype, with note 7.92. The later maturity clones were CL316, F131-08-26 and F183-08-01. In a study reported by Silva *et al.* (2012), in autumn, in Pelotas, 'Agata' had also the earliest maturity genotype of ten genotypes evaluated. It is worth noting that 'Agata', which presents a yellowish skin, is the most cultivated cultivar in the country, highlighting by early maturity combined with good-looking tubers (Fernandes *et al.*, 2011; Peeten *et al.*, 2011).

For traits related to frying quality, the clone F183-08-01 presented the highest specific gravity (1.105), but belonging to the same confidence interval of the estimated value for the check 'Asterix' (1.098), which is the main cultivar used for frying. However, the majority of the other clones, except

Table 2. Predicted genotypic values (*u*+*g*) and their lower (LIIC) and higher (LICS) confidence interval limits of the evaluation of 11 potato genotypes in Pelotas-RS, in spring 2014. Pelotas, Embrapa, 2018.

Genotype	NMT			NMT			ATW		
	LIIC	*u+g*	LSIC	LIIC	*u+g*	LSIC	LIIC	*u+g*	LSIC
F97-07-04	131.87	161.29	190.71	13.02	16.35	19.68	50.26	56.45	62.64
F161-07-02	114.39	143.81	173.23	8.95	12.29	15.62	42.92	49.11	55.30
F110-07-01	72.65	102.08	131.50	6.76	10.09	13.42	41.56	47.75	53.94
F37-08-01	84.79	114.21	143.63	6.27	9.60	12.93	38.74	44.93	51.12
F131-08-26	163.90	193.32	222.74	15.98	19.31	22.64	49.66	55.85	62.04
F156-07-19	94.98	124.40	153.82	8.85	12.18	15.52	44.15	50.34	56.53
F183-08-01	156.62	186.04	215.46	15.27	18.61	21.94	52.91	59.10	65.29
CL310	97.89	127.31	156.73	8.91	12.25	15.58	42.50	48.69	54.88
CL316	138.18	167.60	197.02	13.78	17.11	20.44	46.24	52.43	58.62
Agata	55.18	84.60	114.02	3.40	6.73	10.07	31.86	38.05	44.24
Asterix	157.59	187.01	216.43	15.80	19.13	22.47	63.22	69.41	75.60
	SG			Color			MAT		
F97-07-04	1.079	1.086	1.093	2.40	3.29	4.18	5.91	6.96	8.00
F161-07-02	1.081	1.088	1.095	3.75	4.64	5.52	5.91	6.96	8.00
F110-07-01	1.081	1.088	1.095	3.52	4.41	5.30	5.67	6.71	7.76
F37-08-01	1.079	1.086	1.093	5.10	5.98	6.87	5.43	6.47	7.52
F131-08-26	1.077	1.084	1.091	2.40	3.29	4.18	2.53	3.57	4.62
F156-07-19	1.068	1.075	1.083	2.18	3.07	3.95	5.43	6.47	7.52
F183-08-01	1.098	1.105	1.113	2.18	3.07	3.95	3.25	4.30	5.34
CL310	1.077	1.084	1.091	2.18	3.07	3.95	3.98	5.02	6.07
CL316	1.069	1.077	1.084	1.95	2.84	3.73	2.53	3.57	4.62
Agata	1.053	1.061	1.068	1.73	2.62	3.50	6.88	7.92	8.97
Asterix	1.084	1.091	1.098	2.85	3.74	4.63	3.74	4.78	5.83

NMT= number of marketable tubers per ha^{-1}/1000; MMT= mass of marketable tubers t ha^{-1}; ATW= average tuber weight in g^{-1}; SG= specific gravity, assessed directly using hydrometer; Color= frying color (notes of nine point scale, 1= light, 9= dark); MAT= vine maturity (notes of nine point scale, 1= late, 9= early).

F156-07-19 and check 'Agata', are in the same confidence interval of the values obtained for this check 'Asterix'. The specific gravity is highly correlated with the dry matter content, and it is a non-destructive trait of the samples and of easy and rapid evaluation (Bhering *et al.*, 2009). Silva *et al.* (2012) verified specific gravity values of 1.082 for 'Asterix' and 1.062 for 'Agata'. Pinto *et al.* (2010), on average of three locations in the south of Minas Gerais, reported value of 1.056 for 'Agata' and 1.073 for 'Asterix'. Asterix is a red skin cultivar most cultivated in the country and is widely used for processing into French fries because of its elongated tuber shape, relatively high dry matter content and light colored fries (Pereira *et al.*, 2008).

For frying color, the highest genotypic value, that is, the lightest frying color, was obtained by clone F37-08-01, top mark, by the confidence limit, to the check 'Asterix'. Clones F161-07-02 and F110-07-01 were also within this range.

The search for early maturity clones and at the same time high yielder is a great challenge because, in general, late maturity genotypes tend to be more productive than the early ones (Silva & Pinto, 2005; Rodrigues *et al.*, 2009). Similarly, the selection of clones with high specific gravity and at the same time not too late is hampered by the existence of a positive relationship between later maturity and dry matter content in the tubers (Silva & Pinto, 2005). This relationship probably occurs due to the longer time for photosynthesis, which can also lead to higher yield (Silva *et al.*, 2012). Agreeing with this information, Pereira *et al.* (1994) found a negative correlation between early maturity, total and marketable tuber yield, and tuber size.

In this work, in general, the vine maturity and frying color were positively related, indicating a situation favorable to the selection, and that lighter frying color materials would be of early maturity. An example of it is the selection of clone F161-07- 01 among the best for both traits. Pereira *et al.* (1994) found a correlation between early maturity and lighter frying color, which was also verified by Pereira & Campos (1999). This relationship probably occurs because, for very late genotypes, at the harvest time tubers may still be immature, with a higher concentration of reducing sugars (Pereira & Campos, 1999), which have not yet been converted into starch. This positive relationship between better frying color and higher specific gravity was also observed in other studies (Pereira *et al.*, 1994; Pereira & Campos, 1999; Bisognin *et al.*, 2008).

For the relationship between the yield traits with frying quality traits, in this study it was possible to identify clones with high tuber yield and high specific gravity, but the same did not be true for high yield and good frying color. Bisognin *et al.* (2008) did not find significant associations between yield traits and frying quality traits. Likewise, Pereira & Campos (1999) concluded that there was no strong association between the reducing sugar content and yield traits, because in such study the associations were negative, but not significant.

Rodrigues & Pereira (2003), based on low magnitude correlations between frying quality and yield traits, concluded that the selection for both in relation to the frying color and the dry matter content would affect little the tuber yield of the sample population plants of selected clones. However, Terres *et al.* (2012) verified a correlation of low magnitude (r= 0.19), but significant, between the total tuber yield and the color, while Pereira *et al.* (1994) found a negative correlation between frying color and total yield and tuber size. This relationship between tuber yield, specific gravity and frying color also seems to be related to the vine maturity, since the later genotypes tend to be more productive and to accumulate more dry matter, but at an earlier harvest they tend to present higher reducing sugar. However, this relationship can be more or less evidenced depending on the set of genotypes evaluated, and other variables, such as length of photoperiod and temperature during the growing period. In a shorter photoperiod, the maturity is early (Rodrigues *et al.*, 2009) and under lower temperatures the sugar content is higher (Pereira & Campos, 1999).

The selection index allow the joint selection for the traits, i.e., the identification of the best genotypes for all the traits together. According to the index of selection of the lowest genetic distance to the ideotype, and also to the index based on the *sum of ranks,* the genotypes that best aggregated all the evaluated traits were clones F97-07-94 and F183-08-01, and the check 'Asterix'. In the comparison with the genotypes with the best performance for each trait, based on the genotypic values, the clone F183-08-01 and the check'Asterix' stood out mainly for the tuber yield traits and specific gravity; while F97-07-94 stood out for the traits average tuber weight and vine maturity; and 'Asterix' and F97-07-94 had genotypic values close to the three best genotypes for the frying color (Table 2).

Using selection indexes, which provide the possibility of selecting both for higher yield, shorter cycle and higher frying quality, these three genotypes (F183-08-01, F97-07-94 and check 'Asterix') present predicted genotypic values higher than the overall mean, in 23.09, 29.06, 18.54 and 0.92% for marketable tuber number, marketable tuber yield, average tuber weight, and specific gravity, respectively. However, there would be losses for the frying color (-7.50%) and vine maturity (-6.20%) traits. That is, there would be gains in yield of marketable tubers and specific gravity, but losses in the order of 6 to 7% in the frying color and of vine maturity.

So, clones F131-08-26 and F183-08-01 stand out in yield of marketable tubers, specific gravity and average tuber weight. F161-07-02 ranks among the three best clones for specific gravity, frying color and vine maturity. Clones F97-07-04 and F183-08-01 and check 'Asterix' showed to be the best according to index of selection, which, however, would result in losses in frying color and vine maturity traits.

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