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Selection of Chilean potato clones for tuber yield, frying quality, plant vigor and vegetative cycle

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ABSTRACT

The objective of this study was to evaluate the yield potential, frying quality, plant vigor, and vegetative cycle of Chilean potato clones, aiming to identify those with potential to become new cultivars or to be used in breeding programs. The experiments were conducted in Pelotas-RS and Canoinhas-SC, Brazil, in spring 2017. A set of 37 advanced potato clones belonging to the Agricultural Research Institute of Chile (INIA) was compared to commercial cultivars Agata, Asterix and Atlantic. A randomized complete block design with three replications of two rows with 10 plants each was used. Tuber yield, frying quality, plant vigor and vegetative cycle traits were evaluated. The data were submitted to analysis of variance, test for grouping means, and the selection differential. In this set of clones there are some presenting superior quality in relation to marketable tuber yield and frying quality, but the vegetative cycle was not shorter nor plant vigor was lower. Clones CH 27 and CH 44 were the best for marketable tuber yield and frying quality at both locations.

Keywords: *Solanum tuberosum*, frying color, specific gravity, early maturity.

RESUMO

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

O objetivo do presente trabalho foi verificar o potencial produtivo, a qualidade de fritura, vigor de planta e ciclo vegetativo de clones chilenos de batata, visando identificar aqueles com potencial para se tornarem novas cultivares ou serem utilizados em cruzamentos. Os experimentos foram realizados em Pelotas-RS e Canoinhas-SC, Brasil, na primavera de 2017. Foi avaliado um conjunto de 37 clones pertencentes ao Instituto de Investigações Agropecuárias do Chile (INIA), em comparação com as cultivares testemunhas Agata, Asterix e Atlantic. O delineamento experimental foi blocos casualizados com três repetições e parcelas com duas linhas de 10 plantas. Foram avaliados caracteres de rendimento de tubérculos, de qualidade de fritura, além do vigor e ciclo vegetativo das plantas. Os dados foram submetidos à análise de variância, agrupamento de médias e diferencial de seleção. Verificou-se que neste conjunto de genótipos existem clones superiores em relação à produtividade comercial e qualidade de fritura, mas não foi possível associar também maior precocidade e menor vigor de planta. Para rendimento comercial e qualidade de fritura os clones CH 27 e CH 44 foram os melhores para ambos os locais.

Palavras-chave: *Solanum tuberosum*, cor de fritura, peso específico, precocidade.

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The demand for potato cultivars for French fry processing is increasing in Brazil, due to changes in the eating habits of the population, which seeks more practical food products (Garcia *et al.*, 2015). However, there are few cultivar options suitable for this purpose. These factors, added to the narrow genetic base of the species (*Solanum tuberosum*), make it important to search for new cultivars, and for germplasm with the potential to add superior characteristics.

The clones evaluated in this work were originated from the Agricultural Research Institute of Chile (INIA), in a region close to Chiloé, which is considered one of the centers of potato origin, and therefore having potential to add variability to breeding. In Chiloé region, due to the low temperature conditions, potato crop is carried out only from October to March. In this period the average photoperiod is between 12 to 15 hours light, and temperatures between 7 and 20ºC, but can vary from 1 to 30ºC (Haverkort *et al.*, 2014). In south Brazil, there are two main crop seasons; the spring crop season, escaping from very high temperatures in the summer, and the autumn crop season, anticipating frost in the winter. The average photoperiod in these periods is close to 12 hours light and temperatures between 8 and 26ºC (Pereira & Daniels, 2003).

A set of characteristics are required for processed French fry potatoes, such as high specific weight, low content of reducing sugars and absence of physiological disorders (Pereira & Daniels, 2003). Specific gravity is an important trait, as it is directly related to the dry mass content, and higher content provides higher processing yield, less fat absorption, besides influencing positively the texture and flavor of the final product. Low reducing sugar content prevents browning during frying, which compromises the appearance and taste of the product (Garcia *et al*., 2015).

For a potato clone to be promoted to a new processing cultivar, besides having processing traits, it is necessary to present several other traits, including high yield potential. In addition, considering the adaptation traits, it is important to show adequate vegetative cycle and plant vigor. Long-vegetative cycle genotypes (>130 days) are more productive than the early ones (<100 days), probably due to the longer time to synthesize and store photoassimilates (Silva & Pinto, 2005; Rodrigues *et al*., 2009). However, growers prefer early cultivars, as they allow higher number of crops per year in the same area, shorter exposure of plants to bad weather, less risk of diseases and pests, and less demand for irrigation.

Plant vigor (plant size) is another important trait. Silva *et al*. (2007) reported medium magnitude positive correlations between vigor with number of marketable tubers and tuber yield, in a potato population of the first field generation. Likewise, Pereira *et al*. (2017) reported medium to high positive correlations between plant vigor and total and marketable tuber yield, in an experiment of advanced potato clones, suggesting that more vigorous plants produce larger tubers, greater number and higher yield. In practice, however, it is noted that care is needed in selecting for plant vigor, as very vigorous clones usually have a longer cycle (Bradshaw *et al.*, 2004).

Thus, the objective of this work was to evaluate yield potential, frying quality, plant vigor and vegetative cycle of Chilean potato clones, aiming to identify those with potential to become new cultivars or to be used in crossings.

MATERIAL AND METHODS

Experiments were carried out in Pelotas-RS, Brazil (31ºS, 52ºW, 50 m altitude) and Canoinhas-SC, Brazil (26°S, 50°W, 839 m altitude), representative places as far as the climatic diversity of potato crops in the Southern region of the country. The first location is at low altitude, and the second location is at high altitude.

According to Köppen, the climate of the Canoinhas region is classified as Humid Mesothermal, and of the Pelotas region is classified as Temperate (Silva *et al*., 2015). Weather conditions during the period of these experiments were normal, in both locations. The soil of Canoinhas is Haplic Cambisol, and of Pelotas is Red-Yellow Podzolic (Embrapa, 2006).

Soil chemical analyses for the experimental areas, revealed: organic matter = 3.9%; pH (SMP)= 4.7; available P= 56 mg dm^{-3}; available K= 250 mg dm^{-3}; Al^{3+}= 3.0 $cmol_c$ dm^{-3}; Ca^{2+}= 2.5 $cmol_c$ dm^{-3}; Mg^{2+}= 0.9 $cmol_c$ dm^{-3}; CTC= 22.5 $cmol_c$ dm^{-3}; SB= 4.2 $cmol_c$ dm^{-3}, for Canoinhas; and organic matter= 1.8%; pH (SMP)= 5.6; available P= 35 mg dm^{-3}; available K= 150 mg dm^{-3}; Al^{3+}= 0.0 $cmol_c$ dm^{-3}; Ca^{2+}= 2.3 $cmol_c$ dm^{-3}; Mg^{2+}= 1.2 $cmol_c$ dm^{-3}; CTC= 7.4 $cmol_c$ dm^{-3}; SB= 4.9 $cmol_c$ dm^{-3}, for Pelotas.

A set of 37 clones belonging to the Agricultural Research Institute of Chile (INIA), Remehue, Osorno, Chile, and Agata, a widely grown cultivar for fresh market, and Asterix and Atlantic, used for processing, were evaluated.

A randomized complete block design with three replications of two rows with 10 plants each was used. Plants were spaced 0.75 m between rows and 0.35 m within row. Planting took place on August 22, 2017, in Pelotas, and on August 11, 2017, in Canoinhas.

Fertilizer was applied in the planting furrow, 3 t ha^{-1}, of the commercial formula NPK 05-20-10 in Pelotas, and 3 t ha^{-1} of the commercial formula NPK 04-14-08 in Canoinhas. Earthing up was carried out 30 days after planting. The other cultural and phytosanitary treatments followed recommendations for the region (Pereira, 2010).

Seventy days after planting, at full bloom of most clones, the plant vigor of each plot was evaluated, using a 1 to 9 scoring scale (1= low; 9= high), according to Pereira *et al*. (2017). At 100 days after planting, preceding harvest, the vegetative cycle of the plants of each plot was assessed using a 1 to 9 scoring scale (1= late; 9= early), according to Silva *et al*. (2012).

Plants were harvested 100 days after planting, at both locations. Tubers were graded according to their diameter in marketable (>45 mm) and non-marketable (≤45 mm), counted and weighed, obtaining data for the following traits: Total tuber mass (kg $plot^{-1}$); Mass of marketable tubers (kg $plot^{-1}$); Total number of tubers per plot; Number of marketable tubers per plot; Average tuber mass (g), obtained by dividing the total tuber mass by the total number of tubers. Specific gravity was measured in marketable sized tuber samples, using a hydrometer from the Snack Food Association (Arlington, VA, USA).

The frying color was accessed using samples of three marketable sized and healthy tubers per plot. Fifteen 2.0 mm thick slices were cut, fried in vegetable fat, at an initial temperature of 180°C until the bubbling ceased. Frying color was evaluated by assigning scores from 1 to 9 (1= dark; 9= light), according to the scale of Silva *et al*. (2019).

The tuber mass data were converted to t ha^{-1} and the tuber number data were converted to ha^{-1}/1000. The data were submitted to individual and joint analysis of variance; grouping means by Scott-Knott; and estimation of the selection differential of the best genotypes in each location, in percentage [Ds (%)], calculated by the difference between the means of the selected genotypes (Xs) and the general mean (Xo), in percentage in relation to Xo. Statistical analyzes were performed using the Genes software (Cruz, 2013)

RESULTS AND DISCUSSION

Individual and joint analyzes of variance showed significant ($p<0.05$) differences among genotypes for all traits. There were also significant genotype x environment interactions for all traits, indicating that in general the genotypes had differential response to the two environments. Thus, the analyze results were presented separately for each location.

The relationship between the coefficient of genetic variation and coefficient of environmental variation (CVg/CV) was greater than 80% for most traits (Tables 1 and 2), indicating great importance of the variation of genetic order in relation to the environmental variation, with a favorable situation for selection, mainly for traits where this relation was superior to the unit (Cruz *et al*., 2014). Phenotypic coefficients of variation were higher for traits related to tuber yield and plant vigor. Traits such as mass of tubers and number of tubers are quantitative in nature, subject to greater environmental influence (Pereira *et al*., 2017). Similarly, plant vigor is also a trait heavily influenced by environmental factors, which could explain the lower experimental precision.

The Canoinhas environment was more favorable for tuber yield, presenting 23.84 t ha^{-1} of marketable tubers (Table 1), which is close to the average yield of the Santa Catarina state (23.70 t ha^{-1}), while in Pelotas the average yield of marketable tubers was 10.19 t ha^{-1} (Table 2), which is higher than the average yield in that region (6.62 t ha^{-1}) (IBGE, 2018). Yields obtained in the experiments indicate that the environmental conditions were favorable for the expression of the performance of the genotypes.

Regarding specific gravity, the mean value for the two locations was between 1.071 to 1.072 for Asterix, 1.080 and 1.086 for Atlantic, and 1.056 to 1.060 for Agata, which were slightly lower than those reported by Pereira *et al*. (2015). These authors reported average values of 1.083 (1.075 to 1.096) and 1.092 (1.082 to 1.110) for Asterix and Atlantic, respectively, of seven environments carried on in the three Southern states of Brazil. Agata is characterized by low dry mass content, and is marketed only for the fresh market. The classification of the checks regarding to the frying quality was as expected, indicating that the environments were favorable for the expression of these traits, and highlighting the importance of the evaluation of frying patterns used in the industry in the selection of superior clones.

For Canoinhas, in relation to the yield of marketable tubers, which is the most important component of tuber yield, the most productive clones were CH11, CH13, CH 14, CH 15, CH 23, CH 26, CH 28, CH36 and CH 38 (Table 1). CH 3, CH 27, CH 37, CH 39, CH 44, CH 46, and CH 47 showing yields similar to the most productive check (Asterix). These clones had a mean mass of marketable tubers of 32.41 t ha^{-1}, which corresponds to 35.95% more than the general mean, and 84.46% higher than the average of the checks. Of particular note was the clone CH 38, which reached a yield of 40.60 t ha^{-1} of marketable tubers, and 46.78 t ha^{-1} of total yield of tubers. Clones CH 14, CH 15, and CH 28 had the highest average tuber mass, that is, larger tubers, ranging from 174.36 g to 186.16 g.

Regarding frying quality traits, specific gravity and frying color combined, it can be seen that, in Canoinhas, clones CH4, CH 22, CH 23, CH 27, CH 36, CH 44, CH 46, CH 47, CH 48, CH 49, and CH 50 had similar or superior performance than Asterix, but none was similar or superior to Atlantic (Table 1).

Therefore, in Canoinhas, for high yield of marketable tubers and good frying quality combined, clones CH 23, CH 27, CH 36, CH 44, CH 46, and CH 47, and the check Asterix were superior (Table 1). On average, these genotypes had a mass of marketable tubers 30% higher than the experimental mean, and a difference in specific gravity of 1.069 to 1.074, and a frying color score of 5.87 to 6.05.

Regarding plant traits, that are plant vigor and vegetative cycle, in Canoinhas, clones CH 22, CH 30 and CH 35, and the cultivar Agata showed less vigorous plants. Clones CH1, CH2, CH 3, CH5, CH15, CH 25, CH26, CH29, CH31, CH32, CH38, CH43, CH45, and CH 46 presented plants with vigor similar to Atlantic, which was the second less vigorous check (Table 1).

Regarding earliness, clones CH 12, CH 22, CH 31, CH 32 and CH 45 were earlier, with scores similar to the three check cultivars. Of the eight earliest and least vigorous clones, five were coincident, suggesting that there may be a relationship between these traits, in agreement with observations of Bradshaw *et al*. (2004) and Silva *et al*. (2007).

The best genotypes for plant vigor and vegetative cycle are not among the most productive and the best clones for frying in Canoinhas. The clone CH 46 was the only exception among the 20 best genotypes for plant trait, which also stood out for less vigorous plants (Table 1).

In Pelotas, the clones CH 3 and CH 16, followed by CH 2, CH11, CH14, CH15, CH 23, CH25, CH26, CH 27, CH28, CH 29, CH 31, CH 32, CH36, CH37, CH38, CH 39, CH41, and CH 44 showed the highest marketable yields, which presented yield similar to the best check (Atlantic). These clones produced an average of 14.44 t ha^{-1}, which corresponds to 41.71% more than the general environment average. This yield was below the average of the Rio Grande do Sul state (21.02 t ha^{-1}), but about 100% higher than the average yield of Pelotas (6.62 t ha^{-1}) (IBGE, 2018). All these clones were grouped among the genotypes with the highest total tuber yield, along with the check Atlantic. Among these genotypes with higher marketable tuber yield, clones CH 3, CH 16, CH 23, CH 25, CH27, CH29, CH 32, CH 36, CH 39, CH 41 and CH 44 showed an average mass of marketable tubers comparable to the best check, Atlantic (Table 2).

Regarding frying quality traits, the specific gravity and frying color, for Pelotas (Table 2), clones CH 5, CH 11, CH 13, CH 22, CH 27, CH 32, CH 37, CH 38, CH 41, CH 44, CH 46, CH 48 and CH 50 presented the best quality, with better or comparable standards to the check Asterix, in terms of specific gravity, and better than this cultivar for

Table 1. Grouping means for yield, frying quality, plant vigor and vegetative cycle of 37 potato clones and three cultivars, evaluated in the spring season, 2017, in Canoinhas-SC, Brazil. Canoinhas, Embrapa, 2019.

Genotype	NMT[1]	MMT	TNT	TTM	ATM	SG	Color	Vigor	Cycle
CH 1	67.00 e	7.50 d	380.00 d	19.98 d	53.75 e	1.065 h	7.00 b	2.67 b	5.00 d
CH 2	100.00 d	15.56 c	219.26 f	21.33 d	97.20 d	1.066 g	5.67 c	3.33 b	7.33 b
CH 3	157.42 c	28.11 b	310.51 e	34.57 b	112.91 c	1.065 h	5.00 d	2.67 b	1.00 g
CH 4	171.85 c	20.74 c	374.81 d	30.59 c	80.08 d	1.079 b	7.00 b	1.67 c	2.33 f
CH 5	119.99 d	23.99 c	218.15 f	28.74 c	131.31 c	1.064 h	5.00 d	2.67 b	6.67 c
CH 10	164.25 c	21.30 c	395.09 d	32.81 b	82.92 d	1.065 h	5.00 d	2.00 c	7.67 b
CH 11	197.78 b	38.52 a	292.59 e	43.93 a	150.17 b	1.068 f	6.00 c	1.00 c	7.00 c
CH 12	146.46 c	24.07 c	222.41 f	27.96 c	126.61 c	1.070 e	4.67 d	2.00 c	8.67 a
CH 13	162.28 c	38.58 a	283.04 e	45.59 a	162.92 b	1.063 i	4.00 e	2.00 c	1.00 g
CH 14	151.30 c	39.96 a	237.07 f	43.96 a	186.16 a	1.070 e	5.67 c	2.00 c	3.00 f
CH 15	156.88 c	33.93 a	190.25 f	36.45 b	185.73 a	1.069 f	4.00 e	3.00 b	1.33 g
CH 16	136.26 c	22.25 c	242.77 f	28.40 c	117.83 c	1.062 i	5.00 d	1.67 c	7.67 b
CH 22	22.22 e	3.47 d	180.79 f	10.85 d	59.02 e	1.079 b	8.00 a	5.00 a	8.33 a
CH 23	158.40 c	33.67 a	247.48 f	37.97 b	151.42 b	1.076 c	6.00 c	1.33 c	5.00 d
CH 25	151.85 c	21.26 c	271.11 e	28.00 c	103.78 d	1.070 e	6.00 c	3.00 b	7.67 b
CH 26	212.59 b	34.74 a	290.37 e	39.55 b	136.43 c	1.068 f	5.67 c	3.00 b	7.00 c
CH 27	148.15 c	29.56 b	254.07 f	35.11 b	137.16 c	1.073 d	6.67 b	2.00 c	6.33 c
CH 28	147.41 c	34.59 a	228.89 f	39.04 b	174.36 a	1.060 j	5.00 d	2.33 c	2.67 f
CH 29	114.07 d	22.65 c	278.84 e	29.56 c	107.36 d	1.067 g	5.00 d	2.67 b	5.67 d
CH 30	59.16 e	9.44 d	117.30 f	12.01 d	102.12 d	1.063 h	7.67 a	4.33 a	8.00 b
CH 31	117.12 d	18.76 c	215.87 f	23.89 c	110.90 c	1.064 h	7.00 b	3.00 b	8.67 a
CH 32	113.33 d	17.63 c	197.78 f	22.89 c	115.68 c	1.063 i	6.67 b	2.67 b	8.33 a
CH 34	162.22 c	20.52 c	360.74 d	31.63 b	87.44 d	1.066 h	5.33 c	1.33 c	7.00 c
CH 35	92.40 d	15.01 c	227.32 f	20.51 d	94.07 d	1.060 j	4.00 e	4.00 a	7.33 b
CH 36	214.81 b	32.74 a	565.19 c	46.15 a	82.02 d	1.075 c	6.00 c	1.00 c	4.67 d
CH 37	165.18 c	26.81 b	529.63 c	42.22 a	79.91 d	1.070 e	5.67 c	1.33 c	2.67 f
CH 38	205.41 b	40.60 a	316.02 e	46.78 a	151.78 b	1.068 f	6.67 b	3.00 b	2.33 f
CH 39	146.67 c	25.63 b	232.59 f	30.08 c	129.26 c	1.065 h	8.00 a	2.00 c	6.67 c
CH 41	114.01 d	21.57 c	172.96 f	25.55 c	147.88 b	1.064 h	8.00 a	2.00 c	5.67 d
CH 43	102.72 d	19.68 c	221.98 f	25.24 c	116.18 c	1.062 i	4.00 e	2.67 b	4.33 e
CH 44	154.81 c	28.67 b	275.56 e	34.89 b	128.15 c	1.073 d	6.00 c	1.00 c	7.00 c
CH 45	142.96 c	17.41 c	508.89 c	32.74 b	64.31 e	1.065 h	6.67 b	2.67 b	8.33 a
CH 46	295.64 a	30.62 b	531.62 c	38.18 b	71.80 e	1.080 b	6.33 b	2.67 b	1.00 g
CH 47	285.18 a	26.45 b	519.26 c	35.41 b	68.63 e	1.072 d	5.33 c	1.67 c	1.67 g
CH 48	267.98 a	23.62 c	709.63 b	36.78 b	52.03 e	1.081 a	6.00 c	1.33 c	1.00 g
CH 49	219.76 b	17.10 c	741.24 b	32.63 b	44.56 e	1.082 a	5.33 c	1.67 c	1.00 g
CH 50	188.89 b	14.15 c	980.74 a	32.74 b	33.17 e	1.073 d	6.00 c	1.67 c	1.00 g
Agata	79.35 e	6.71 d	332.94 e	15.03 d	45.88 e	1.060 j	4.00 e	4.00 a	9.00 a
Asterix	185.93 b	27.85 b	422.96 d	37.92 b	92.76 d	1.072 d	6.00 c	1.67 c	9.00 a
Atlantic	123.71 c	18.15 c	288.15 e	26.82 c	93.01 d	1.080 a	7.67 a	2.67 b	9.00 a
Mean	153.09	23.84	339.65	31.61	106.7	1.069	5.87	2.36	5.38
CV (%)	21.06	25.75	19.40	21.28	19.69	1.73	9.39	25.65	13.22
CVg/CV	1.67	1.38	2.62	1.20	1.79	5.26	2.00	1.42	3.98

[1]NMT= number of marketable tubers ($ha^{-1}/1000$); MMT= mass of marketable tubers ($t\ ha^{-1}$); TNT= total number of tubers ($ha^{-1}/1000$); TTM= total tuber mass ($t\ ha^{-1}$); ATM= average tuber mass ($g\ tuber^{-1}$); SG= specific gravity; Color: frying color (1= dark; 9= light); Vigor: plant vigor (1= high; 9= low); Cycle: plant vegetative cycle (1= late; 9= early). Means followed by same letters in the column belong to the same group by Scott-Knott test, 5% probability of error. CV%= phenotypic variation coefficient, CVg/CV= relationship between the genotypic and phenotypic variation coefficient.

Table 2. Grouping means for yield, frying quality, plant vigor and vegetative cycle of 37 potato clones and three cultivars, evaluated in the spring season, 2017, in Pelotas-RS, Brazil. Pelotas, Embrapa, 2019.

Genotype	NMT[1]	MMT	TNT	TTM	ATM	SG	Color	Vigor
CH 1	76.06 b	5.54 c	384.33 c	12.79 b	33.18 d	1.065 f	5.00 c	2.00 d
CH 2	128.19 a	11.37 b	338.32 c	18.92 a	50.82 c	1.071 e	4.67 c	2.33 c
CH 3	218.24 a	25.72 a	338.60 c	29.00 a	84.49 a	1.079 d	4.33 c	2.00 d
CH 4	138.83 a	8.85 c	386.12 c	16.56 a	43.17 d	1.074 e	5.00 c	2.67 c
CH 5	37.15 c	3.09 c	202.03 d	8.67 b	42.80 d	1.077 d	6.33 b	3.67 b
CH 10	97.90 b	8.46 c	221.60 d	12.00 b	52.15 c	1.070 e	5.33 c	2.67 c
CH 11	129.92 a	12.72 b	348.83 c	19.99 a	56.45 c	1.076 d	6.33 b	2.33 c
CH 12	128.01 a	9.46 c	293.05 c	14.24 b	49.23 c	1.064 f	5.33 c	2.67 c
CH 13	47.46 c	3.65 c	230.86 d	9.07 b	39.72 d	1.082 c	6.00 b	3.67 b
CH 14	154.97 a	13.15 b	434.69 c	23.86 a	54.68 c	1.067 f	5.67 b	2.33 c
CH 15	138.37 a	11.61 b	344.72 c	18.78 a	54.31 c	1.084 c	4.00 c	3.33 b
CH 16	213.33 a	20.22 a	328.15 c	24.42 a	74.37 b	1.061 f	3.33 c	1.67 d
CH 22	12.83 c	0.84 c	130.84 d	4.24 b	33.85 d	1.079 d	7.67 a	4.33 a
CH 23	118.52 a	13.65 b	283.70 d	20.10 a	70.30 b	1.079 d	4.33 c	2.67 c
CH 25	163.70 a	16.22 b	313.33 c	21.24 a	68.38 b	1.070 e	4.67 c	2.67 c
CH 26	157.37 a	11.65 b	370.29 c	18.20 a	47.53 c	1.057 g	4.67 c	2.67 c
CH 27	134.42 a	12.82 b	246.55 d	17.26 a	69.99 b	1.081 d	6.00 b	2.67 c
CH 28	124.07 a	11.85 b	277.87 d	16.68 a	54.43 c	1.056 g	5.00 c	2.00 d
CH 29	141.56 a	14.36 b	330.37 c	20.56 a	60.61 b	1.074 e	5.00 c	2.33 c
CH 30	97.97 b	9.60 c	193.61 d	12.75b	67.21 b	1.063 f	5.00 c	3.33 b
CH 31	154.82 a	13.09 b	312.59 c	18.32 a	56.92 c	1.066 f	7.67 a	2.00 d
CH 32	137.78 a	13.15 b	247.41 d	16.70 a	65.42 b	1.073 e	5.67 b	2.67 c
CH 34	75.56 b	6.99 c	197.04 d	10.85 b	55.59 c	1.063 f	4.33 c	3.33 b
CH 35	98.05 b	9.67 c	237.12 d	16.99 a	71.95 b	1.073 e	5.00 c	3.67 b
CH 36	125.18 a	11.95 b	325.93 c	19.61 a	60.46 b	1.077 d	4.00 c	2.67 c
CH 37	136.61 a	11.79 b	354.19 c	19.03 a	52.57 c	1.079 d	6.67 b	2.00 d
CH 38	165.02 a	16.34 b	477.78 b	27.94 a	57.98 c	1.082 c	6.67 b	1.67 d
CH 39	124.56 a	14.40 b	173.33 d	15.96 a	91.83 a	1.064 f	5.00 c	3.00 b
CH 41	153.96 a	17.34 b	259.18 d	21.46 a	84.21 a	1.074 e	6.33 b	2.00 d
CH 43	94.07 b	8.60 c	205.92 d	13.04 b	63.48 b	1.070 e	4.00 c	2.33 c
CH 44	135.48 a	14.02 b	248.30 d	18.27 a	73.25 b	1.084 c	6.33 b	2.00 d
CH 45	88.89 b	7.52 c	291.85 c	13.47 b	46.43 c	1.057 g	4.33 c	2.67 c
CH 46	41.48 c	3.10 c	437.04 c	15.12 b	34.39 d	1.010 a	6.33 b	1.67 d
CH 47	48.15 c	4.05 c	405.93 c	14.41 b	35.81 d	1.099 b	5.33 c	1.67 d
CH 48	41.09 c	3.35 c	710.68 a	21.50 a	29.77 d	1.096 b	6.00 b	1.67 d
CH 49	35.17 c	2.63 c	562.50 b	19.18 a	40.19 d	1.095 b	5.33 c	1.67 d
CH 50	31.97 c	2.64 c	768.03 a	18.38 a	23.97 d	1.089 c	6.00 b	2.67 c
Agata	70.49 b	6.17 c	232.48 d	11.69 b	50.60 c	1.056 g	4.00 c	4.33 a
Asterix	34.70 c	3.11 c	154.44 d	7.39 b	47.40 c	1.071 e	5.00 c	3.33 b
Atlantic	157.78 a	12.88 b	248.89 d	16.03 a	64.66 b	1.086 c	9.00 a	2.67 c
Mean	110.24	10.19	321.21	16.87	55.36	1.075	5.42	2.59
CV (%)	37.15	44.43	25.47	29.84	19.13	6.34	17.09	18.49
CVg/CV	1.09	1.04	1.52	0.85	1.36	2.43	1.11	1.37

[1]NMT= number of marketable tubers (ha^{-1}/1000); MMT= mass of marketable tubers (t ha^{-1}); TNT= total number of tubers (ha^{-1}/1000); TTM= total tuber mass (t ha^{-1}); ATM= average tuber mass (g $tuber^{-1}$); SG= specific gravity; Color: frying color (1= dark; 9= light); Vigor: plant vigor (1= high; 9= low). Means followed by same letters in the column belong to the same group by the Scott-Knott test, 5% probability of error. CV%= phenotypic variation coefficient, CVg/CV= relationship between the genotypic and phenotypic variation coefficient.

Table 3. Estimates of selection differential for clones CH 23, CH 27, CH 36, CH 44, CH 46, and CH 47, in Canoinhas, SC, Brazil, and for clones CH 11, CH 27, CH 32, CH 37, CH 38, CH 41 and CH 44, in Pelotas, RS, for tuber yield, frying quality, plant vigor and vegetative cycle of 37 clones and three potato cultivars, in the spring season, 2017. Canoinhas, Embrapa, 2019.

Trait[1]	Xo[2]	Xs	Ds (%)
	Canoinhas		
MMT	153.09	209.50	36.85
MMT (t ha^{-1})	23.84	30.28	27.01
TNT	339.65	398.86	17.43
TTM (t ha^{-1})	31.61	37.95	20.06
ATM (g)	106.72	106.53	-0.18
SG	1.069	1.075	0.56
Color	5.87	6.05	3.07
Vigor	2.36	1.62	-31.36
Cycle	5.38	4.28	-20.45
	Pelotas		
MMT[1]	110.24	141.88	28.70
MMT (t ha^{-1})	10.19	14.02	37.59
TNT	321.21	311.75	-2.95
TTM (t ha^{-1})	16.87	20.09	19.09
ATM (g)	55.36	65.70	18.68
SG	1.075	1.078	0.28
Color	5.42	6.29	16.05
Vigor	2.59	2.19	-15.44

[1]NMT= number of marketable tubers (ha^{-1}/1000); MMT= mass of marketable tubers (t ha^{-1}); TNT= total number of tubers (ha^{-1}/1000); TTM= total tuber mass (t ha^{-1}); ATM= average tuber mass (g $tuber^{-1}$); SG= specific gravity; Color: frying color (1= dark; 9= light); Vigor: plant vigor (1= high; 9= low); Cycle: plant vegetative cycle (1= late; 9= early). [2]Xo= general mean; Xs= mean of the selected genotypes; Ds (%)= selection differential in percentage.

frying color.

Therefore, for Pelotas, the genotypes that add the highest marketable yield and frying quality were: CH 11, CH 27, CH 32, CH 37, CH 38, CH 41, CH 44 and Atlantic (Table 2). Regarding plant vigor, clones CH 5, CH 13, CH 15, CH 22, CH 30, CH 34, CH 35, and CH 39 showed plant vigor similar to the checks with less plant vigor, Agata and Asterix. Thus, of these 10 genotypes with less vigorous plants, none was also grouped among those with higher marketable yield and better frying quality.

The genotypes with best performance in both locations for marketable yield and frying quality were clones CH 27 and CH 44, and these are not among the earliest or less vigorous ones in these locations. For plant vigor, CH 5, CH 15, CH 22, CH 30, CH 35 and Agata showed less vigorous plants in both locations.

As high yield and good frying quality were not associated with less vigor and earliness, we selected those clones with higher marketable yield and better frying quality, which was the main objective of this work, and also to examine the effect of selection on plant traits. Genetic gains would be 27.01 and 37.59% for mass of marketable tubers and varying from 0.28 to 0.56% for specific gravity, and 3.07 to 16.05% for frying color. However, the selection of these clones would cause losses of 15.44 to 31.36% in lowering plant vigor, and 20.45% in reducing vegetative cycle (Table 3).

This trend of negative associations between tuber yield with vegetative cycle and plant vigor is in agreement with results found in other studies, indicating that more productive genotypes tend to be later (Silva & Pinto, 2005; Rodrigues *et al*., 2009) as well as having more vigorous plants (Silva *et al*., 2007; Pereira *et al*., 2017). Very vigorous plants usually have a longer cycle (Bradshaw *et al*., 2004; Silva *et al*., 2007).

It can be concluded that, in this set of clones there are some superior for marketable tuber yield and frying quality. However, it was not possible to combine early maturity nor lower vigor on these genotypes. For marketable tuber yield and frying quality, clones CH 27 and CH 44 were the best ones, for both locations. In Pelotas, besides these two clones, CH 11, CH 32, CH 37, CH 38, CH 41, and the check Atlantic showed high marketable yield and good frying quality; while, in Canoinhas, in addition to the first two clones, CH 23, CH 36, CH 46, CH 47 and the check Asterix were the best.

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