Crop Breeding and Applied Biotechnology 6:73-78, 2006
Brazilian Society of Plant Breeding. Printed in Brazil

Early generation selection for tuber appearance affects potato yield components

Giovani Olegário da Silva[1], Velci Queiroz de Souza[1*], Arione da Silva Pereira[2], Fernando Irajá Félix de Carvalho[3], and Roberto Fritsche Neto[4]

Received 29 November 2005

Accepted 9 March 2006

ABSTRACT - *The aim of this study was to verify the influence of selection for tuber appearance on potato yield components. A potato hybrid population composed of 20 clone families from the Embrapa Clima Temperado breeding program was evaluated. The selection for tuber appearance had a positive effect on genetic gains in yield, while yield and its components (average tuber weight and tuber number) did not have influence on tuber appearance, due to the absence of significant genetic correlations. The expected response for yield by selecting for tuber appearance, however, does not surpass the expected response with direct selection for yield. Tuber yield as well as its components influenced the gains in tuber appearance and the genetic gain from selection for mean tuber weight even surpassed the direct gain for tuber appearance.*

Key words: *Solanum tuberosum* L., correlation, heritability.

INTRODUCTION

Potato breeding programs constantly need new strategies to improve efficiency by increasing the frequency of selected genotypes and reducing time and costs. The possibility of predicting genetic gains that can be achieved by a certain selection strategy is one of the most important contributions of quantitative genetics to plant breeding.

Breeders often select for several different traits at each selection stage. However, it is important to know which effect the selection for one specific trait may have on others (Pereira et al. 1994).

The existence of genetic associations between traits indicates that selection practiced for one trait may lead to changes in another. Depending on the direction, the association between traits may be of interest for breeding or not. Knowledge on the relationships between traits is therefore very important to choose a suitable selection strategy for a target trait. The strategy may be based on other very closely correlated traits, with higher heritabilities that are easier to measure or to identify (Goldenberg 1968, Baker 1986, Cruz and Regazzi 2001).

In potato, tuber appearance is normally selected in the early and yield in subsequent generations. The objective of this study was to verify the influence of selection for tuber appearance on yield components of potato.

MATERIAL AND METHODS

A hybrid population composed of 20 clone families, randomly picked from the potato breeding program of

[1] Departamento de Fitotecnia, FAEM/UFPel - Faculdade de Agronomia "Eliseu Maciel", Universidade Federal de Pelotas, C. P. 354, 96.001-970, Pelotas, RS, Brasil. *E-mail: velciq@gmail.com
[2] Embrapa Clima Temperado, BR 392, km 78, C. P. 403, 96.001-970, Pelotas, RS, Brasil
[3] Departamento de Fitotecnia, FAEM/UFPel
[4] FAEM/UFPel

Embrapa Clima Temperado, Pelotas, RS, Brazil, was used. The families were derived from crosses targeting cultivar development: C-1750-15-95/Panda, C-1485-6-87/Asterix, Asterix/C-1226-35-80, C-1750-15-95/Canoinhas, Columbus/Eliza, C-1485-6-87/Felsina, Asterix/C-1311-11-82, Agria/C-1226-35-80, C-1750-15-95/Felsina, Shepody/Eliza, Imola/C-1226-35-80, C-1714-7-94/Imola, White Lady/C-1311-11-82, C-1750-15-95/Divina, Divina/C-1226-35-80, Agria/2CRI-1149-1-78, White Lady/2CRI-1149-1-78, C-1750-15-95/Exquiza, C-1750-15-95/Asterix, and Asterix/2CRI-1149-1-78.

A population of 600 clones (30 of each family) was evaluated on the experimental field of the headquarters of Embrapa Clima Temperado (lat 31° S, long 52° W), using second generation clones in spring 2003, and using third generation clones in autumn 2004. The experiment had a randomized complete block design, with five plants per clone (plot) in three replications of 200 clones (10 clones of each family block^{-1}). The regionally recommended crop-specific management practices were applied.

The following traits were evaluated: yield (g plot^{-1}), number of tubers plot^{-1}, average tuber weight (yield number of tubers^{-1}), tuber appearance (1= excellent: clones with smooth skin, shallow eyes, less long shape, uniform shape, and size), skin smoothness (1= smooth, 5= rough), eye depth (1= shallow, 5= deep), tuber shape (1= long, 5= round), tuber size, and shape uniformity (1= uniform, 5 = non-uniform).

After checking for normality by the Lilliefors test, and variance homogeneity by the Bartllet test, the data were subjected to analysis of variance to estimate genetic parameters. The estimates of variance components were calculated according to Cruz (2001). The environment was treated as fixed effect and the genotype as random effect. The phenotypic (r_p) and genotypic (r_g) correlations between traits were calculated according to the statistical model described by Cruz (2001).

The expected correlated response (CR) was estimated according to Falconer (1989)

$$CR_y = ih_x h_y r_g \sigma_{Py}$$

where

CR_y is the correlated response of trait y;

i is the selection index, standardized at 0.10;

$h_x h_y$ is the product of the square root of heritability of the traits x and y;

σ_{Py} is the standard deviation of trait y.

The gain from selection for traits was estimated according to Simmonds (1979)

$$GS_x = ih_x^2 \sigma_{Px}$$

where

GS_x is the gain from selection for trait x;

i is the selection intensity, standardized at 0.10;

h_x^2 is the heritability of trait ;

σ_{Px} is the phenotypic standard deviation of trait.

RESULTS AND DISCUSSION

The data presented normality and variance homogeneity for all traits. The analysis of variance presented statistical differences (P $\leq$ 0.05) for all traits, except for uniformity of tuber size. This indicates the efficiency of the traits to differentiate the genotypes. The genotype x environment interaction was significant for tuber appearance, number of tubers, skin smoothness, and average tuber weight, indicating that the environments caused differential responses of at least one genotype, i.e., the best genotype in one environment may not have been the best in another (Table 1).

The coefficient of genetic variation, which indicates

Table 1. Summary of analysis of variance of yield and tuber appearance traits in potato

Source of variation	df	Mean square								
		APP[1]	UTSi	SHA	UTSh	EDE	TSS	NTU	YIE	ATW
Blocks/environments	4	0.66	7.18	0.25	0.43	0.31	0.27	269	1308633	238.2
Family (F)	19	0.13*	15.28	0.13*	0.09*	0.06*	0.22*	225*	291264*	280.6*
Environment (E)	1	0.05	40.87	0.01	0.30	0.41	0.05	32443*	14340793*	3684*
F x E	19	0.09*	13.06	0.04	0.03	0.04	0.21*	118.2*	166861	168.6*
Error	76	0.05	14.29	0.04	0.04	0.03	0.06	65.4	99700	76.02

* Significantly at 5% probability of the error by the F test

[1] APP: tuber appearance; UTSi: uniformity of tuber size; SHA: tuber shape; UTSh: uniformity of tuber shape; EDE: Eye depth; TSS: skin smoothness; USI: uniformity of tuber size; NTU: number of tubers; YIE: yield; ATW: average tuber weight

the relative genetic variation, showed similar values among the traits, varying from 3.08% for uniformity of tuber shape to 14.09% for average tuber weight (Table 2).

The selection efficiency depends on the heritability, which indicates the phenotypic superiority of genetic origin that can be transmitted to descents, can be used to estimate response to selection (Tai and Young 1984). In the present study, heritability coefficients varied from moderate (0.52) to high (0.73). Only the value for uniformity of tuber size was very low (0.06). The results indicate that this population has genetic variability for most of the evaluated traits. So, tuber appearance and yield components can be inherited by the descents and estimates of selection gain could be effective at predicting genetic gains (Tai and Young 1984).

For uniformity of tuber size, the heritability estimate indicated that a selection strategy based directly on this trait would not provide considerable genetic gain. So, selection for other traits could promote higher gains in uniformity of tuber size than direct selection for this trait (Goldenberg 1968) (Table 2).

Environmental conditions can cause correlations of environmental nature only. The phenotypic correlation coefficients can therefore be partitioned into their components, the environmental and genotypic correlations, which improves the information content by visualizing the genotypic correlation (Vencovsky and Barriga 1992). The phenotypic and genotypic correlation coefficients are presented in Table 3. The highest number of significant associations are among the coefficients of genetic correlations, indicating that the environmental effect could be masking the effect of the genetic expression of correlation between traits (Barbosa and Pinto 1997).

Tuber appearance showed significant genetic correlations with yield and its components (number of tubers and average tuber weight). It indicates that more appealing tubers were produced in plants with small number of tubers (0.83), higher average tuber weight (-0.99) and yield (-0.49). On the other hand, the magnitudes for phenotypic correlations were smaller and only significant for tuber appearance with number of tubers (0.65) and average tuber weight (-0.68) (Table 3).

Besides the association with tuber appearance, the only significant genetic correlation of yield was with average tuber weight (0.71), indicating that as the yield increases so does the average tuber weight (Table 3).

Except for the relationship described with tuber appearance, the trait number of tubers had significant genetic correlation with uniformity of tuber shape (0.56), uniformity of tuber size (1.00) and skin smoothness (0.68). These results allow the conclusion that the increase in number of tubers is associated with a reduction in tuber shape and uniformity of tuber size, resulting in tuber roughness. The phenotypic correlations had smaller magnitudes and were not significant. Thompson et al. (1983) also reported significant genetic correlations for these traits, indicating that the higher the number of tubers the less uniform they are (Table 3).

Tuber shape and eye depth did not present correlation with any other trait, showing that they must be considered individually in selection. Besides the previously described correlations, skin smoothness had a significant and negative genetic correlation with average tuber weight (-0.85), indicating that the selection for skin smoothness would result in an increase of the mean tuber weight.

The expected correlated response estimates for yield components by selecting for tuber appearance traits, and vice-versa, are shown in Tables 4 and 5. Considering the traits with significant genetic correlation, the yield would

Table 2. Estimates of genetic variance (σ^2_G), phenotypic standard deviation (σ^2_p), genetic coefficient of variation (CV_g), mean and heritability (h^2) of potato tuber appearance

Parameter estimate	APP[1]	UTSi	SHA	UTSh	EDE	TSS	NTU	YIE	ATW
σ^2_G	0.01	0.17	0.02	0.01	0.01	0.03	26.63	31927.22	34.09
σ^2_p	0.15	1.60	0.15	0.12	0.10	0.19	6.13	220.33	6.84
CV	6.57	11.76	6.98	7.30	8.59	10.60	17.31	17.77	21.03
CV_g	3.32	12.01	4.38	3.08	3.76	6.98	11.05	10.05	14.09
Mean	3.46	3.38	2.87	2.91	2.01	2.31	46.72	1776.89	41.44
h^2	60.5	6.48	70.19	51.63	53.44	72.22	70.94	65.77	72.90

[1] Coded as in Table 1

Table 3. Genetic (r_g) and phenotypic (r_p) correlation between tuber appearance traits and yield components in potato

Trait	Yield		Nr. of tubers		Average tuber weight	
	r_g	r_p	r_g	r_p	r_g	r_p
Tuber appearance	-0.49*	-0.38	0.83*	0.49*	-0.99*	-0.68*
Tuber shape	-0.17	-0.08	-0.12	-0.06	-0.05	-0.01
Uniformity of tuber shape	0.28	0.14	0.56*	0.29	-0.22	-0.11
Eye depth	0.22	0.20	0.16	0.09	0.08	0.14
Skin smoothness	-0.39	-0.23	0.68*	0.47*	-0.85*	-0.56*
Uniformity of tuber size	0.24	0.14	1.00*	-0.35	-0.21	-0.15

* Significant at a level of 5% probability of the error

be affected only when selecting for tuber appearance. This effect, however, would result in less than 50% of the estimated direct genetic gain in yield (Table 4). In a similar study that focused only on indirect gain in yield, Barbosa and Pinto (1997) did not find superior responses than with direct selection for this trait either.

The selection for tuber appearance, uniformity of tuber shape, skin smoothness, and uniformity of tuber size would result in changes in the number of tubers. Selection for tuber appearance traits, which would favor a larger number of tubers, would not be interesting. It would take a toll on the traits tuber appearance, skin smoothness, uniformity of tuber size and uniformity of tuber shape. Besides, gains with indirect selection for these traits would be lower than by direct selection (92.93%) (Table 4).

Average tuber weight would result in higher gain if tuber appearance and skin smoothness were selected. The selection for these two traits would result in gains of 109.65 and 101.88%, respectively. Nevertheless, these values do not exceed the gain expected by a direct selection for average tuber weight, which would be 120.33% (Table 4).

Considering the significant genetic correlation coefficients, the selection for tuber appearance traits via yield components can be outlined as follows: In relation to tuber appearance, the selection for yield components would result in changes in the gains for tuber appearance; the selection for average tuber weight would achieve higher gains for tuber appearance than direct selection. This response would occur due to the higher heritability estimate (0.73) of average tuber weight than of tuber appearance (0.61). However, if selection were applied to a high number of tubers, the gain for tuber appearance would be reduced (Table 5), as can be explained by the magnitude of correlation between the two traits (Table 3).

In relation to tuber shape uniformity, if selection were applied for number of tubers, the mean gain would be reduced by 13.95% in the next generation. The selection for any yield trait would allow higher gains in tuber shape uniformity than the selection for the trait itself, which would be 21.65% of the mean (Table 5).

Regarding skin smoothness, it would be easier to find genotypes with smoother tuber skin by selecting plants with higher average weight. However, if selection were applied to genotypes of higher tuber number, the mean skin smoothness of genotypes would be diminished by 40.04% in the next generation due to the indirect effect of tuber number on skin smoothness. The estimated gain with direct selection (59.39%) was higher than any gain by indirect selection using yield components. But it is very close to the gain expected from selection for average tuber weight (-51.00%) (Table 5).

Table 4. Correlated and direct response to selection in percentage of the mean of yield components by selecting for tuber appearance in potato

Selected trait	APP[1]	SHA	UTSh	EDE	TTS	USI	Direct Response
Yield	-38.98	-14.33	20.22	16.17	-33.34	6.13	81.55
Number of tubers	71.53	-11.14	44.39	12.93	63.87	28.06	92.93
Average tuber weight	-109.65	-5.91	-22.27	8.24	-101.88	-7.52	120.33

[1] Coded as in Table 1

For uniformity of tuber size, the selection practiced for number of tubers would provide higher gains than those expected from direct selection (Table 5). The expected correlated gains expressed that the selection for less complex traits, which are easier to measure and have higher heritabilities and high correlations, could favor selection for yield and tuber appearance. These two traits are complex and influenced by several individual traits and are therefore controlled by various genes and often under strong environmental influence (Wenzel et al. 1983, Vencovsky and Barriga 1992).

Table 5. Response to selection in percentage of the mean of tuber appearance trait by selecting for yield components in potato

Selected trait	Yield	nr. of tubers	Av. tuber weight	Direct response
Appearance[1]	-13.44	23.29	-28.42	26.24
Shape	-6.06	-4.42	-1.74	36.69
Shape uniformity	6.74	13.95	-5.57	21.65
Eye depth	6.47	4.48	2.49	26.75
Skin smoothness	-22.12	40.04	-51.00	59.39
Size uniformity	23.40	101.18	-21.57	30.68

CONCLUSIONS

Selection for tuber appearance modifies the genetic gains for yield positively, while yield components do not have any influence on yield due to the absence of significant genetic correlations. The expected response for yield by selecting for tuber appearance does however not surpass the direct response.

Yield as well as its components (average tuber weight and number of tubers) influence the gains of tuber appearance, but the larger the number of tubers the worse the tuber appearance.

ACKNOWLEDGEMENTS

The authors thankfully acknowledge the support of the staff of the Potato Breeding Program of Embrapa Clima Temperado; the co-workers and professors of Plant Breeding of Faculdade de Agronomia "Eliseu Maciel" and CAPES, CNPq and FAPERGS for the scholarships.

Seleção precoce para a aparência dos tubérculos afeta os componentes do rendimento em batata

RESUMO - *O objetivo do trabalho foi verificar a influência da seleção para a aparência de tubérculos nos caracteres de rendimento de batata. Foi avaliada uma população híbrida composta por 20 famílias clonais do programa de melhoramento genético de batata da Embrapa Clima Temperado, Pelotas, RS. Verificou-se que a seleção para a aparência de tubérculo afeta positivamente os ganhos esperados em rendimento de tubérculo, diferentemente de seus componentes que não mostraram influência no rendimento devido à inexistência de correlação genética significativa. Porém, a responda esperada em rendimento pela seleção para aparência de tubérculo não supera o ganho esperado por seleção direta para rendimento. Rendimento de tubérculos, bem como seus componentes (peso médio e número de tubérculos), influenciam os ganhos esperado em aparência de tubérculo, sendo que o ganho pela seleção para maior peso médio de tubérculo chega a superar o próprio ganho direto para aparência de tubérculo.*

Palavras-chave: *Solanum tuberosum* L., correlação, herdabilidade.

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