Brazilian Journal of Genetics, 19, 3, 459-463 (1996)
(Revista Brasileira de Genética)

Selection for yield, tuber specific gravity and high 2n pollen production in potato hybrids between *Solanum tuberosum* L. and the wild species *Solanum chacoense* Bitt.*

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ABSTRACT

Hybrid clones between dihaploid *Solanum tuberosum* x wild potato species were developed to allow the introgression of desirable genes from wild germplasm into cultivated species, to increase the allelic diversity and to obtain maximum heterozygosity. A total of 167 hybrids were assessed in two experiments carried out in Lavras, State of Minas Gerais, to select hybrids with high tuber yield and greater than 5% 2n pollen production. There were highly significant differences among the clones, demonstrating wide genetic variability for all the assessed traits. The broad sense heritabilities at the level of clone means were relatively high for the traits assessed, indicating that gain with selection may be obtained. Selection was very efficient for tuber yield but the other traits showed relatively low gains, probably due to the low correlations found between tuber production and the other agronomic traits assessed. However, with the exception of specific gravity, significant gains would be obtained if selection was carried out directly on the individual traits.

INTRODUCTION

The narrow genetic base of the cultivated potato (*Solanum tuberosum* L.) has resulted in low genetic gains in breeding programs that use only intraspecific crosses. More than 70% of the tuber bearing *Solanum* species are diploid (2n = 2x = 24), and these provide an array of diversity that could be introgressed into the genome of the cultivated species. Introgression may be accomplished by reducing the ploidy level of tetraploid cultivars to the diploid level through dihaploid production; dihaploids can then be crossed with a diploid species forming the dihaploid x species hybrid. These 2x hybrids, after undergoing selection for traits of interest, are crossed with an adapted cultivated tetraploid species giving rise to a tetraploid progeny (Iwanaga and Schimiedich, 1989). Following hybridization involving unreduced gametes (2n pollen), the genetic diversity present in the diploid species will be directly combined in the tetraploid cultivated species, maximizing heterozygosis (Mendoza and Haynes, 1974). The exploitation of 4x-2x crosses depends basically on the production of non-reduced gametes in the hybrid to transmit the necessary allelic variability for maximum heterozygosity, guaranteeing vigorous, highly productive tetraploid progenies. Nevertheless, undesirable traits such as long stolons, late tuber formation and maturity and little adaptation to tropical conditions may also be inherited from the wild parents.

* Part of a thesis presented by O.M.M. to Universidade Federal de Lavras (UFLA) in partial fulfillment of the requirements for the Master's degree.

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Breeding at the diploid level is done to develop clones with specific characteristics, suitable agricultural performance and 2n pollen production (Peloquin *et al.*, 1989). These hybrids show simple disomic inheritance and provide for the possibility of introducing genes from wild species into the cultivated tetraploid germplasm. They are vigorous, have great variability, many have good fertility and also increase tuber formation in wild species that do not normally produce tubers under long-day conditions (Peloquin and Ortiz, 1991).

The objective of this study was to select clones with high tuber yield along with high 2n pollen production and other desirable traits from hybrid populations obtained from crosses between dihaploid *S. tuberosum* x *S. chacoense*.

MATERIAL AND METHODS

One hundred and sixty seven clones obtained from open pollination among 25 hybrids between dihaploid *S. tuberosum* x *S. chacoense*, derived from the material of Cunha *et al.* (1994), were assessed after selection for increased vigor and low susceptibility to foliar diseases during two generations. Two experiments were carried out in Lavras, MG, Brazil. In the first experiment the clones were planted from March to May 1993 in plastic bags, in a randomized complete block design, with five replications. Each experimental unit consisted of a single plant. Only three replications were used in the assessment of pollen amount in the anthers, 2n pollen frequency and viability of 2n and n pollen. To assess these traits the anthers were collected 48 h after the flower opened, stored in 70% alcohol and put in a refrigerator. Pollen amount was evaluated through a scale from 1 (very reduced amount of pollen) to 4 (abundance of pollen). Frequency and viability were determined from samples of approximately 200 pollen grains stained with 2% acetic carmine and observed under 200X magnification. Pollen grains with diameters between 26 and 33 µm were considered 2n (Quinn *et al.*, 1974). The formulas used to determine the viability and frequency of 2n pollen were: viability = number of stained 2n pollen grains/number of stained and non-stained 2n pollen grains and frequency = number of stained 2n pollen grains/total number of stained pollen grains. Assessment of stolon length (cm) was carried out 65 days after planting, using the five replications. Individual plants were harvested without damaging the stolon and the measurement of the longest stolon was obtained. The second experiment was carried out from May to October 1993 under field conditions. A Simple 13 x 13 lattice design was used. Each plot included three plants spaced at 0.80 x 0.35 m. The following traits were assessed: yield per plant (kg), average tuber weight (g), maturity (days between emergence and natural haulm drying) and tuber specific gravity (determined on hydrostatic scales by the formula weight in air/(weight in air - weight in water). In both experiments the potato cultivars Monalisa and Bintje were used as controls. Genotypic and phenotypic parameters and the expected gain from selection were calculated from the expected mean squares following the method presented by Vencovsky and Barriga (1992). The genetic, phenotypic and environmental correlation coefficients among tuber yield per plant, tuber specific gravity, average tuber weight and maturity characteristics were determined.

RESULTS AND DISCUSSION

There were highly significant differences among the clones, demonstrating the existence of considerable genetic variability for all the assessed traits (Table I).

The broad sense heritabilities at the clone mean level (Table II) were relatively high for the assessed traits, indicating that gains from selection may be obtained in this population.

Table I - Analysis of variance for tuber yield/plant (kg), average tuber weight (g), tuber specific gravity, maturity (days after emergence), stolon length (cm), and amount of pollen in the anthers of 2x hybrids between dihaploids of *Solanum tuberosum* x *S. chacoense*.

		MS					MS		MS
Source of variation	d.f.	Tuber yield per plant	Average tuber weight	Specific gravity x 10^{-4}	Maturity x 10^{6}	d.f.	Stolon length	d.f.	Amount of pollen
Replications	1	0.021	0.056	1.249	16.765	4	2558.780	2	0.211
Clones	168	0.088**	1.434**	1.942**	4.276**	165	810.758**	154	0.170**
Error	168	0.017	0.227	0.493	1.136	660	248.273	308	0.056
CV(%)		34.13	11.59	0.64	16.10		34.68		15.29

** Significant at 1% level of probability by the F test.

Table II - Broad sense heritability at the clone mean level ($h^2_{A(m)}$), expected gains from selection of 14 potato clones ($\%G_{s(14)}$) based on tuber yield and 2n pollen production, and expected gains from selection for individual traits ($\%G_s$).

Individual traits	$h^2_{A(m)}$	$\%G_{s(14)}$	$\%G_s$
Yield/plant (kg)	80.68	58.10	79.69
Average tuber weight (g)	84.17	11.60	27.44
Tuber specific gravity	74.61	0	1.30
Maturity (days)	73.43	-0.55	-28.08
Length of stolons (cm)	69.40	6.62	-33.67
Pollen quantity (% 2n pollen)	66.67	3.82	15.48

Table III - Genetic (r_G), phenotypic (r_F) and environmental (r_E) correlations for production per plant (prod./pl.), average tuber weight (tuber weight), tuber specific gravity (gravity) and maturity in *Solanum tuberosum* x *S. chacoense*.

Pairs of traits	r_G	r_F	r_E
Prod./pl.:Tuber weight	0.75	0.67	0.30
Prod./pl.:Gravity	-0.05	-0.02	0.09
Prod./pl.:Maturity	0.20	0.10	-0.04
Gravity:Tuber weight	-0.55	-0.58	-0.73
Gravity:Maturity	0.0006	0.00008	-0.001
Tuber weight:Maturity	0.14	0.12	0.05

Selection gains (Table II) were estimated from the 14 most productive clones with a 2n pollen frequency higher than 5% ($G_{s(14)}$). The gain was high only for tuber production per plant and moderate for average tuber weight. The gains were low for the other traits because of the effects of selection for production and 2n pollen frequency. These results are due to the low genetic correlation coefficients among the traits (Table III), reducing the effects of indirect selection. However, if selection was carried out directly for each trait, the gains (G_s) would be high for all of them (Table II), except for tuber specific gravity. For this trait, good allelic combinations are already present in the population hampering the selection of superior individuals. For more expressive gains in this trait, it would be necessary to use a more intensive selection.

The trait averages of the 14 selected clones are presented in Table IV. In general, the clones show a relatively high tuber production. Eleven of the 14 selected clones produced, statistically, as much as the Monalisa cultivar and some significantly more than Bintje. These two controls are tetraploid cultivars, much used in commercial cropping because of high production and adaptation to local cultivation conditions. High tuber specific gravity with values ranging from 1.081 to 1.111 was associated with the 14 selected clones. The controls Monalisa and Bintje cultivars have reasonably good tuber specific gravity, which contributes to their excellent cooking properties. Vakis (1978) considers that suitable cultivars for processing should have a tuber specific gravity higher than 1.085. High specific gravity is a trait highly correlated (r = 0.91) with tuber dry matter (Schippers, 1976) which is considered very important to guarantee good quality in French fries. Growth under high temperatures tends to reduce tuber dry matter content (Smith, 1975), justifying the selection of high tuber dry matter content clones for tropical cultivation.

The clones showed late maturity (Table IV), and were all later than the controls Monalisa and Bintje. In general, the stolons were very long, varying from 11.8

Table IV - Means for yield/plant (kg), average tuber weight (g), specific gravity of tubers, maturity (days after emergence), stolon length (cm) and 2n pollen frequency (%) of the 14 most productive 2x hybrid clones (*Solanum tuberosum* dihaploids x *S. chacoense*) and two controls (potato cultivars Monalisa and Bintje).

Clones	Yield/ plant	Average tuber weight	Specific gravity	Maturity	Stolon length	2n pollen frequency
Monalisa	0.822	63.16	1.064	86.5	6.6	*
115	0.765	23.17	1.090	104.0	39.6	7.29
30	0.762	18.58	1.082	106.0	45.6	8.66
105	0.734	21.23	1.089	112.5	50.4	9.39
47	0.726	37.24	1.096	118.0	59.8	8.76
31	0.712	31.28	1.091	124.5	62.4	6.71
116	0.679	33.98	1.100	121.5	33.8	5.03
91	0.662	24.43	1.095	112.0	59.0	8.25
11	0.636	28.24	1.081	115.0	59.8	11.96
140	0.627	21.57	1.086	112.5	48.6	10.37
76	0.615	20.35	1.088	120.0	57.0	7.16
62	0.598	22.79	1.087	114.0	33.8	6.73
90	0.595	21.72	1.111	117.0	46.4	6.45
63	0.576	15.73	1.089	102.0	52.4	6.54
51	0.574	23.71	1.093	114.5	48.2	5.30
Bintje	0.428	41.81	1.076	86.5	1.8	*
Mean of all 167 clones	0.384	19.62	1.091	114.1	45.4	5.04

*Did not flower

to 74.5 cm. These undesirable traits were inherited from *S. chacoense*, which has long stolons and late maturity when cultivated under a day length of 13 h or more (Leue and Peloquin, 1980; Ortiz *et al.*, 1991). Cultivars with short stolons are desirable because they allow for easier cultural practices and more precise, economical harvest, without tuber loss. The selected clones produced tubers with an average weight of about 20 g, all lower than the controls Monalisa and Bintje. The relatively low average weight can be explained by the large number of tubers produced (data not shown). Rowe (1967) and Maris (1990) stated that dihaploid hybrids x 2x species usually produce a large number of small tubers while tetraploid materials produce a smaller number of large tubers. This is a common characteristic of wild species and must influence these hybrids, since 50% of their genome originates from the wild species *S. chacoense*. Despite the undesirable traits presented by all hybrids, they could be valuable in potato breeding because they have very high tuber specific gravity. However, these hybrids cannot be used directly as cultivars. Instead, they should be backcrossed to *S. tuberosum* for two or more generations and selected to eliminate undesirable traits. Clones originated from the backcross generations can present short stolons, early maturity and also reduced levels of glycoalkaloids (Sanford *et al.*, 1995).

The 2n pollen frequency in the selected clones varied from about 5-12%. Ortiz and Peloquin (1992) consider 1% of 2n pollen as the lowest production limit for a clone to be used in 4x-2x crosses.

According to Sanford *et al.* (1994), *S. chacoense* is a highly polymorphic species for glycoalkaloid synthesis, and usually has a high level of these compounds. The presence of glycoalkaloids in the leaves of some cultivars has contributed to their insect resistance (Tingey *et al.*, 1978; Sanford and Ladd, 1992). Nevertheless, levels higher than 10 mg/100 g in fresh tuber weight cause an unpleasant taste and are harmful to human and animal health (Ross, 1986). Progenies produced from these materials should be assessed for these compounds.

RESUMO

Híbridos entre dihaplóides de *Solanum tuberosum* e espécies selvagens têm sido desenvolvidos com o objetivo de permitir a introgressão de genes de interesse presentes no germoplasma selvagem na espécie cultivada, bem como para aumentar a diversidade alélica e promover heterozigose máxima. Desse modo, foram avaliados 167 híbridos de dihaplóides de *S. tuberosum* x *S. chacoense* em dois ensaios realizados na área experimental do Departamento de Biologia da Universidade Federal de Lavras visando à seleção de clones com alta produção de tubérculos associado à produção de pólen 2n acima de 5%. Os resultados mostraram diferenças altamente significativas entre clones, evidenciando a existência de ampla variação genética para todas as características avaliadas. As herdabilidades no sentido amplo a nível de médias de clones foram relativamente altas, indicando que ganhos com a seleção poderão ser obtidos. A seleção feita com base na produção de tubérculos foi muito eficiente mas os ganhos genéticos indiretos observados para as demais características foram relativamente baixos, devido às baixas correlações encontradas entre estes e a produção de tubérculos. Contudo, a seleção direta para os caracteres individualmente permitiria a obtenção de ganhos genéticos significativos, exceto para peso específico dos tubérculos.

REFERENCES

Cunha, A.L., Pinto, C.A.B.P. and **Davide, L.C.** (1994). Flowering behavior and 2n pollen production in dihaploid *Solanum tuberosum* x *Solanum chacoense* hybrids. *Rev. Bras. Genet. 17*: 305-308.

Iwanaga, M.L. and **Schimiedich, P.** (1989). Uso de especies silvestres para mejorar los cultivares de papa. *Centro Internacional de la Papa Circular*, Lima, Perú, *17*: 1-7.

Leue, E.F. and **Peloquin, S.J.** (1980). Selection for 2n gametes and tuberization in *Solanum chacoense*. *Am. Potato J. 57*: 189-195.

Maris, B. (1990). Comparison of diploid and tetraploid potato families derived from *Solanum phureja* x dihaploid *S. tuberosum* hybrids and their vegetative doubled counterparts. *Euphytica 46*: 15-33.

Mendoza, H.A. and **Haynes, F.L.** (1974). Genetic relationship among potato cultivars grown in the United States. *HortScience 9*: 328-330.

Ortiz, R. and **Peloquin, S.J.** (1992). Recurrent selection for 2n gamete production in 2x potatoes. *Genet. and Breed. 46*: 383-390.

Ortiz, R., Freyre, R., Peloquin, S.J. and **Iwanaga, M.** (1991). Adaptation to day length and yield stability of families from 4x-2x crosses in potato. *Euphytica 56*: 187-195.

Peloquin, S.J. and **Ortiz, R.** (1991). Techniques for introgressing unadapted germplasm to breeding populations. In: *Plant Breeding in the 1990s* (Stalker, H.T. and Murphy, J.P., eds.). C.A.B. International, Raleigh, NC, pp. 485-512.

Peloquin, S.J., Jansky, S.H. and **Yerk, G.L.** (1989). Potato cytogenetics and germplasm utilization. *Am. Potato J. 66*: 629-637.

Quinn, A.A., Mok, D.W. and **Peloquin, S.J.** (1974). Distribution and significance of diplandroids among the diploid *Solanum*. *Am. Potato J. 51*: 16-21.

Ross, H. (1986). *Potato Breeding - Problems and Perspectives*. Verlag Paul Parey, Berlin, pp. 132.

Rowe, P.R. (1967). Performance and variability of diploid and tetraploid potato families. *Am. Potato J. 44*: 263-271.

Sanford, L.L. and **Ladd Jr., T.L.** (1992). Performance of populations derived by selecting for resistance to potato leafhopper in a 4x *Solanum tuberosum* x 2x *S. chacoense* cross. *Am. Potato J. 69*: 391-400.

Sanford, L.L., Deahl, K.L. and **Sinden, S.L.** (1994). Glycoalkaloid content in foliage of hybrids and backcross populations from *Solanum tuberosum* x *S. chacoense* cross. *Am. Potato J. 71*: 225-235.

Sanford, L.L., Deahl, K.L., Sinden, S.L. and **Kobayashi, R.S.** (1995). Glycoalkaloid content in tubers of hybrids and backcross populations from a *Solanum tuberosum* x *S. chacoense* cross. *Am. Potato J. 72*: 261-271.

Schippers, P.A. (1976). The relationship between specific gravity and percentage dry matter in potato tubers. *Am. Potato J. 53*: 111-122.

Smith, O. (1975). Effect of cultural and environmental conditions on potatoes for processing. In: *Potato Processing* (Talburt, W.F. and Smith, O., eds.). Avi, Westport, pp. 305-402.

Tingey, W.M., Mackenzie, J.D. and **Gregory, P.** (1978). Total foliar glycoalkaloids and resistance of wild potato species to *Empoasca fabae* (Harris). *Am. Potato J. 55*: 577-585.

Vakis, N.J. (1978). Specific gravity, dry matter content and starch content of 50 potato cultivars grown under Cyprus conditions. *Potato Res. 21*: 171-181.

Vencovsky, R. and **Barriga, P.** (1992). *Genética Biométrica no Fitomelhoramento*. Sociedade Brasileira de Genética, Ribeirão Preto, SP, pp. 486.

(Received October 6, 1994)