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Clonal selection in arracacha breeding

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ABSTRACT - *Twenty-nine arracacha clones were evaluated in 2002/2003, at the Horticultural Research Garden of the Federal University of Viçosa. A randomized complete block design with 30 treatments and three replications was used. Each plot contained 75 plants in three 10 m long rows (rows spaced 1 m apart and plants 0.40 m). Six competitive plants were picked eight months after planting. Sprouts were collected from the remaining plants eleven and a half months after planting. Ten quantitative and four qualitative traits were evaluated. Variance analyses showed significance of all but one quantitative trait (non-commercial root weight). Genetic distances were estimated by Mahalanobis' generalized distance and clones grouped by clustering, applied to quantitative traits. Our goal was to identify early high yielding, healthy, and genetically diverging clones. Clones BGH 4550, BGH 5742, and BGH 6425 seemed to be promising future varieties, and 10 clones are interesting for further breeding work.*

Key words: *Arracacia xanthorrhiza*, yield, genetic divergence, grouping, clonal selection.

INTRODUCTION

Arracacha (*Arracacia xanthorrhiza* Banc.), indigenous to the Andes, is probably the oldest cultivated crop in South America (Casali and Sediyama 1997). Mean yield in the State of Minas Gerais, Brazil, is 10.95 t ha^{-1} (Torres 1997), higher than the national mean of 9.00 t ha^{-1} or the Andean mean of 6.00 t ha^{-1} (Silva 1997), although there are clones yielding up to 25.00 t ha^{-1} (Santos 1997). It is also possible and opportune to consider these arracacha clones for Minas Gerais.

The objective of this work was to select the early high yielding and healthy clones which are of such central importance for producers. The selected clones should be genetically so divergent as to make their possible use in a future genetic breeding program that includes artificial crossings. Since there is no sexual reproduction in commercial crops, any identified characteristic will be maintained in the following generations, which makes clonal selection an adequate breeding method for this crop.

MATERIAL AND METHODS

Twenty-nine arracacha clones from the Horticultural Germplasm Bank of the Federal University of Viçosa (UFV), Minas Gerais State, Brazil were evaluated in the Horticultural Research Garden of the UFV. Control clone was ´Amarelo de Senador Amaral´ with good commercial characteristics. A randomized complete block design with 30 treatments and three replications was used. Each plot contained 75 plants in three 10 m long rows (rows spaced 1 m apart and plants 0.40 m). Four quantitative traits were evaluated, during the post-emergence period, of six competitive plants randomly sampled from the central row of each plot: ST63D - stand 63 days after planting; PH83D - plant height 83 days after planting (distance from soil to highest tip of superior leaf in cm); PW83D - plant width 83 days after planting (greatest plant diameter across plant center in cm); LN83D - leaf number 83 days after planting. At harvest time, six quantitative traits were evaluated in six competitive plants randomly sampled from the central row of each plot: PH - plant

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height (distance from soil to highest part of superior leaf in cm); PW - plant width (largest distance between leaf tips across plant center in cm); CRW - commercial root weight (weight of roots 10 to 18 cm long or more and 3 to 5 cm or more in diameter, in t ha^{-1}); NCRW - non-commercial root weight (weight of roots shorter than 10 cm and less than 3 cm in diameter, in t ha^{-1}); CW - crown weight (weight of central root with its lateral roots, in t ha^{-1}); SLW - stem, leaf, and sprout weight, in t ha^{-1}. Three qualitative traits not submitted to variance analysis were evaluated in each replication: DR - diseased roots (any visible disease symptom in commercial roots at harvest time); HS - healthy sprout production (disease symptom-free sprouts, crowns, stems, leaves and roots, eleven and a half months after planting); SS - sufficient sprouts (production of 10 to 30 sprouts $plant^{-1}$ or more eleven and a half months after planting).

It was necessary to define several criteria *a priori* when choosing the clones at the Horticultural Germplasm Bank for trial. Considering three main constraints (human and financial resources available and appropriate area available at the Horticultural Research Garden), 30 clones including control could, maximally, be evaluated. Since there are approximately 100 arracacha clones in that Bank, one third underwent evaluation. The same number was evaluated by Soares (1991), the greatest found in literature. Every clone should have yellow roots in view of consumers' preference (Vieira et al. 1998). Any clone presenting disease symptoms or root knots considered nematode symptoms should be excluded. Clones previously evaluated by other authors and considered promising should be preferred: clones BGH 5746 (Amarelo de Carandaí, commonly used in the region of Viçosa), BGH 6309 and BGH 6310 were singled out for their high yield when harvested seven and nine months after planting in Dourados, MS State (Vieira 1995). Clones BGH 6309, BGH 6444, BGH 6490, BGH 6491, BGH 6521, and BGH 6525 were chosen for their remarkable characteristics (Soares 1991). Eleven clones were picked because they had been derived from botanical seeds and ten others, not evaluated beforehand, from different origins. The aerial parts of all chosen clones were well developed, since Vieira et al. (1998) considered this trait positively correlated to high yield.

Sprouts of each clone were separated from the crowns and prepared for planting. The apex and base were cut leaving approximately four centimeters long explants. Thereafter, they were immersed in a 10% sodium hypochloride solution for five to ten minutes. After drying in the shade, the explants were planted with uncovered apex (Sediyama and Casali 1997, Vieira et al. 1996) and the crop treated following the recommendations for cultivation of this crop (Santos 1997, Câmara 1997). At harvest time plants did not present yellow leaves, which is a physiologic sign of maturity (Santos et al. 1991). Harvest generally occurs 11 to 12 months after planting. In this study, it was realized eight months after planting in order to identify early yielding clones.

After harvesting, six remaining plants $plot^{-1}$ were left to produce sprouts for the next planting. Planting requires temperatures within a range of 14-21 ºC (Advisory Committee on Technology Innovation 1989) and it was necessary to wait for 11.5 months after planting until these temperatures were reached. Clones without nematode symptoms or disease symptoms in all three replications at harvesting and at sprout collecting time were considered healthy. Sprouts were collected only from healthy clones.

Variance analyses of 10 quantitative traits was carried out, and the means compared by the Scott-Knott and Dunnett tests, at 5% probability level. The Tocher clustering algorithm, using Mahalanobis' distances (Cruz and Regazzi 1994, Cruz 2001), was used to establish genetically diverging groups. It appeared important to verify whether the control clone was genetically divergent from the evaluated clones. Thus genetic divergence analyses were applied to the clones from the Horticultural Germplasm Bank, with or without the control clone. Software GENES (Cruz 2001) was used for all statistical analyses.

RESULTS AND DISCUSSION

Variance analyses of the traits were significant at 1% probability level by the F test for the traits ST63D, PH83D, PW83D, LN83D, PH, PW, CRW, and CW, which are the most important (Table 1). Trait SLW was significant at 5% by the F test and NCRW was non-significant. Significance indicates there are differences between clones regarding traits and recommends them for selection and breeding. The commercial root mean weight of the clones was higher than the mean in Minas Gerais State of 10.95 t ha^{-1}, although the control clone mean was even higher. Variation coefficients presented a high precision for ST63D, PH, and PW, medium for PH83D, PW83D, LN83D, CRW, and SLW, and were of low precision for NCRW and CW according to Gomes (1984)' criterion.

No clone presented roots with nematode symptoms at harvest, neither when sprouts were collected. Several clones presented disease symptoms on the roots, some at harvest, others at sprout collecting time and still others on both occasions. Eight months after planting, twenty-four clones yielded more than the Minas Gerais mean yield of 10.95 t ha^{-1} and nine clones yielded twice this mean yield or more. Table 2 presents clones organized according to commercial root weight and the Scott-Knott and Dunnet tests for this trait. Three clones, BGH 6309, BGH 6310 and Araponga were not statistically different from control clone according to Dunnett test. According to Scott-Knot test only BGH 6309 and BGH 6310 belong to control clone group. These three clones and clones BGH 4550, BGH 5742, BGH 5747, BGH 6425, BGH 6444, BGH 6507 and BGH 6525 can be considered high yielding since theirs yield is double or more than Minas Gerais yield mean. They can also be considered early because harvest was earlier than usual. Since in clonal populations these characteristics are maintained in the following generation these ten clones have two of the desired traits of this research. Eight clones supplied enough sprouts for the next crop cycle (Table 2). Although considered a crop with minor disease problems (Henz 2002), disease symptoms were the main constraint in selection, since highest yielding clones had to be discarded because of disease symptoms and of sprout

production affected by disease symptoms. At harvest, clones BGH 6309 and BGH 6310 presented oversized roots that suggest they could have been harvested even earlier, as they were in Dourados, MS (Vieira 1995). Eleven and half months after planting these plants were entirely rotten and it was impossible to get any sprout for a next planting from them.

Table 1. Summary of variance analyses, clone means, control mean, and environmental variation coefficient of traits evaluated in arracacha clones

Source	df	Trait mean squares									
		ST63D	LN83D	PH83D	PW83D	PH	PW	CRW	NCRW	CW	SLW
		day		cm				t ha^{-1}			
Blocks	2	528.41	90.25	28.03	7.70	330.74	7235.89	153.07	0.11	5.20	1857.88
Treatment	29	186.99**	9.18**	33.40**	126.78**	128.05**	276.47**	162.92**	0.28	1.24**	512.60*
Clones	28	89.28**	9.04**	34.59**	129.71**	129.30**	282.01**	135.54**	0.27	0.86**	488.52*
Cl vs C	1	2922.85**	12.91*	0.34	44.99	93.02**	121.43*	929.54**	0.70	12.03**	1186.78*
Error	58	33.87	2.07	5.71	24.57	11.48	25.66	19.66	0.19	0.29	251.37
Clone (Cl) means		65.08	9.05	18.11	41.44	49.44	75.08	17.88	0.99	1.54	60.47
Control (C) mean		33.33	6.94	18.12	37.50	55.11	81.55	35.78	0.50	3.58	80.70
VC (%)		9.09	16.03	13.19	12.00	6.82	6.73	23.99	44.70	33.68	25.93

**, * Significant at the 1% and 5% probability levels, respectively, by the F test.

Table 2. Commercial root weight (CRW, in t ha^{-1}) for three qualitative traits of arracacha clones

Clones		CRW		Origin	[1]DR	[2]HS	[3]SS
Code	Name						
30	Amarelo de Senador Amaral	35.78 a		Embrapa/CNPH		x	
19	BGH 6309	30.60 a	A	Colombia			
29	BGH 6310	29.79 a	A	Colombia	x		
21	Araponga	25.23 b	A	Araponga, MG	x	x	x
11	BGH 4550	24.63 b		Tuitinga, MG		x	x
4	BGH 6525	24.15 b		UFV, botanical seed	x	x	x
8	BGH 6507	24.09 b		UFV, botanical seed	x	x	
20	BGH 5742	23.65 b		Igarapé, MG		x	x
14	BGH 6425	23.05 b		UFV, botanical seed		x	x
16	BGH 5747	22.32 b		Araponga, MG	x	x	x
13	BGH 6444	21.44 b		UFV, botanical seed	x	x	
7	BGH 6467	20.39 b		UFV, botanical seed	x	x	
17	BGH 5745	19.46 b		ANDRADAS, MG		x	
24	BGH 6521	18.92 b		UFV, botanical seed	x	x	
26	BGH 6420	18.88 b		UFV, botanical seed	x		
1	BGH 7229	18.83 b		UFV	x		
3	BGH 6430	18.19 b		UFV, botanical seed	x		
15	BGH 4579	16.76 c		Domingos Martins, SS	x		
22	BGH 4555	16.29 c		Juiz de Fora, MG	x		
5	BGH 5746	15.69 c		Carandaí, MG	x	x	
18	BGH 5744	15.67 c		Andradas, MG	x	x	x
25	BGH 4556	14.26 c		Juiz de Fora, MG			
23	BGH 4554	14.12 c		Barbacena, MG			
27	BGH 6417	13.12 c		UFV, botanical seed		x	x
28	BGH 6436	11.53 c		UFV, botanical seed	x		
2	BGH 6532	10.16 d		UFV, botanical seed	x		
10	BGH 6490	9.74 d		UFV, botanical seed			
12	BGH 6491	8.18 d		UFV, botanical seed	x		
6	BGH 7228	6.28 d		UFV	x		
98	BGH 6537	2.99 d		UFV, botanical seed			

Means followed by the same Lowercase letter belong to same group, at 5% probability level by the Scott-Knott test. Means followed by the same Uppercase letter do not differ from countrol mean, at 5% probability level by the Dunnett test. [1] DR - presence of diseased roots at harvest time, eight months after planting, in any replication; [2] HS - production of healthy sprouts 11.5 months after planting, in all three replications; [3] SS - production of a sufficient amount of sprouts for a next crop cycle, 11.5 months after planting, from three replications.

The control clone yield outstripped all other clones at harvest time, though at sprout collecting time it was also entirely rotten.

Genetic distances between the 29 clones, with and without control clone, are expressive (Table 3). Some clones with a very close distance may represent duplicate clones in the germplasm bank. Clone 19 (BGH 6309) appears quite distant from many others. Control clone smaller distance is still quite great and that makes it quite distant from all the others. Genetic distances between the 30 clones, including the control clone, presented four diverging groups, the first one with 26 clones, the second with clones BGH 6309 and BGH 6310, the third with the control clone, and the fourth with clone BGH 6491 (Table 4). The control clone may be considered genetically divergent from all other 29 clones of the Horticultural Germplasm Bank since it forms a separate group. This can be explained by the greater Mahalanobis' distance between the 29 evaluated clones and the control clone than the distance among these clones (Table 3).

Genetic divergence analyses of the 29 clones without the control clone showed seven groups (Table 5). This happened because 26 clones from the first group of first divergence analysis were divided into five new groups, while groups 2 and 4 remained unchanged. Five groups within group 1 are identified with capital letters, from A to E. Clones BGH 6444, BGH 6491, BGH 6521, and BGH 6525, which were put in the same genetically diverging group by Soares (1991), are separated in this work, appearing in groups 1A, 1D, and in group 4. This means they are genetically divergent, regarding the traits used in this study. This happened because the clones used here are not identical to those used by Soares (1991), neither are the traits evaluated in this work the same.

Clones BGH 4550, BGH 5742, and BGH 6425 could be promising future varieties for the State of Minas Gerais, after undergoing adaptability and stability tests, for they have yellow roots, are healthy, produce enough sprouts, and their early yield does statistically not differ from the control clone.

Table 3. Mahalanobis' distances for 29 arracacha clones in relation to the control clone (D_1^2) and for 29 arracacha clones without control clone (D_2^2) based on 10 traits

Clones	Mahalanobis' distances for 29 clones and control clone (D_1^2)				Mahalanobis' distances for 29 clones without control clone (D_2^2)			
	Greatest D_1^2	Most distant clone	Smallest D_1^2	Most closer clone	Greatest D_2^2	Most distant clone	Smallest D_2^2	Most closer clone
1	112.17	19	4.91	15	119.41	19	5.13	15
2	188.51	19	10.34	10	201.67	19	10.34	10
3	105.16	19	1.82	13	108.15	19	2.07	13
4	116.14	19	2.54	8	117.13	19	2.45	16
5	137.32	19	5.85	17	140.35	19	5.90	17
6	172.37	19	12.32	15	182.03	19	12.24	15
7	132.59	19	1.91	8	134.04	19	1.88	8
8	115.01	19	1.91	7	116.24	19	1.88	7
9	265.69	19	10.81	10	286.24	19	11.79	10
10	201.50	19	5.70	28	215.39	19	6.19	28
11	126.80	19	6.89	14	130.80	19	6.80	14
12	236.48	19	17.48	9	258.87	19	16.99	9
13	109.04	19	1.82	3	110.65	19	2.07	3
14	127.67	19	2.13	13	129.43	19	2.09	13
15	132.21	19	4.91	1	139.38	19	5.13	1
16	108.14	19	2.54	4	109.80	19	2.46	4
17	122.52	19	1.92	7	124.73	19	1.89	7
18	142.63	30	10.07	27	124.85	12	10.14	23
19	265.69	9	10.75	29	286.24	9	10.80	29
20	95.66	12	6.39	8	106.63	12	6.24	8
21	107.74	19	3.99	16	108.09	19	4.69	16
22	123.13	19	5.63	25	126.20	19	5.94	25
23	129.54	30	5.34	17	116.10	19	5.16	17
24	123.14	19	10.61	11	127.71	19	10.40	11
25	118.01	19	3.08	3	124.9	19	3.69	3
26	128.73	19	3.63	7	129.62	19	3.52	7
27	153.52	19	10.07	18	153.44	19	10.23	18
28	172.28	19	5.70	10	180.42	19	6.19	10
29	218.19	9	10.75	19	238.15	9	10.80	19
30	148.06	6	65.56	11				

Table 4. Genetically diverging groups of 29 arracacha clones, and a control clone, using the Tocher clustering algorithm, and considering 10 traits

Groups	Clones
1	3, 13, 14, 26, 7, 17, 8, 16, 21, 4, 20, 25, 5, 23, 15, 1, 11, 22, 18, 27, 24, 2, 28, 6, 10, 9
2	19, 29
3	30
4	12

Table 5. Genetically diverging groups of 29 arracacha clones, without control clone, by Tocher clustering algorithm, and considering 10 traits

Groups	Clones
1A	7, 8, 17, 16, 4, 21, 13, 14, 3, 26, 20, 5, 23, 25, 15, 1, 11, 22
1B	10, 28, 2, 9
1C	18, 27
2	19, 29
1D	24
1E	6
4	12

Clones Amarelo de Senador Amaral, Araponga, BGH 4550, BGH 5742, BGH 5746, BGH 6309, BGH 6310, BGH 6425, BGH 6507, and BGH 6525 might be used in a diallele, in order to identify possible best hybrids for further arracacha breeding, since they are yellow, early high yielding and belong to several different genetic groups.

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Seleção clonal no melhoramento de batata-baroa

RESUMO - *Vinte e nove clones de batata-baroa foram avaliados em 2002/2003, na Horta de Pesquisas da Universidade Federal de Viçosa. O delineamento foi em blocos casualizados, com 30 tratamentos e três repetições. Cada parcela continha 75 plantas em três fileiras de 10 m, espaçadas 1,00 m e 0,40 m entre plantas. Colheram-se seis plantas competitivas aos oito meses após o plantio. Foram retiradas mudas das plantas remanescentes aos onze meses e meio após o plantio. Avaliaram-se dez características quantitativas e quatro qualitativas. As análises de variância mostraram significância para as características quantitativas, exceto para peso de raízes não comerciais. As distâncias genéticas foram estimadas pela distância generalizada de Mahalanobis e os clones agrupados pelo método de agrupamento, envolvendo características quantitativas. O objetivo foi identificar clones precoces, produtivos, sadios e geneticamente divergentes. Os clones BGH 4550, BGH 5742 e BGH 6425 podem vir a ser futuras variedades promissoras e 10 clones poderão ser usados em futuros trabalhos de melhoramento.*

Palavras-chave: *Arracacia xanthorrhiza*, produtividade, divergência genética, agrupamento, seleção clonal.

REFERENCES

Advisory Commitee on Technology Innovation (1989) Arracacha. In: Advisory Commitee on Technology Innovation (ed.) **Lost crops of the Incas**. National Academy Press, Washington, p.47-55.

Câmara FLA (1997) Nutrição mineral e adubação da mandioquinha–salsa. **Informe Agropecuário 190**: 37-39.

Casali VWD and Sediyama MAN (1997) Origem e botânica da batata-baroa. **Informe Agropecuário 190**: 14-16.

Cruz CD (2001) **Programa Genes Versão Windows: aplicativo computacional em genética e estatística**. Editora UFV, Viçosa, 648p.

Cruz CD and Regazzi AJ (1994) **Modelos Biométricos Aplicados ao Melhoramento Genético**. Imprensa Universitária, Viçosa, 390p.

Gomes FP (1984) **A estatística moderna na pesquisa agropecuária**. Associação Brasileira para a Pesquisa da Potassa e do Fosfato, Piracicaba, 160p.

Henz G (2002) Doenças da mandioquinha-salsa e sua situação atual no Brasil. **Horticultura brasileira 20**:135-144.

Santos FF (1997) Clima, cultivares e época de plantio da mandioquinha-salsa. **Informe Agropecuário 190**:35-37.

Santos FF, Vieira JV, Pereira AS, Lopes CA and Charchar JM (1991) **Cultivo da mandioquinha-salsa (*Arracacia xanthorrhiza* Bancroft)**. Embrapa-CNPH, Brasília, 7p. (Instruções Técnicas 10).

Sediyama MAN and Casali VWD (1997) Propagação vegetativa da mandioquinha–salsa. **Informe Agropecuário 190**:24-27.

Silva HR (1997) Irrigação da mandioquinha-salsa. **Informe Agropecuário 190**:42-44.

Soares L (1991) **Melhoramento da batata-baroa (*Arracacia xanthorrhiza* Bancroft) II–Divergência genética entre clones com base em procedimentos multivariados e estimativas de parâmetros genéticos**. MSc. Thesis, Universidade Federal de Viçosa, Viçosa, 75p.

Torres G (1997) Mandioquinha-salsa: alimento energético. **Informe Agropecuário 190**:3.

Vieira MC (1995) **Avaliação do crescimento e da produção de clones e efeito de resíduo orgânico e de fósforo em mandioquinha-salsa no Estado de Mato Grosso do Sul**. PhD Thesis, Universidade Federal de Viçosa, Viçosa, 146p.

Vieira MC, Casali VWD, Cardoso AA and Mosquim PR (1998) Crescimento e produção de mandioquinha-salsa em função da adubação fosfatada e da utilização de cama-de-aviário. **Horticultura Brasileira 16**:319-332.

Vieira MC, Zárate NAH, Siqueira JG and Casali VWD (1996) Crescimento e produção de mandioquinha-salsa em função de características de mudas. **Horticultura Brasileira 14**:42-44.