Crop Breeding and Applied Biotechnology 6: 278-284, 2006
Brazilian Society of Plant Breeding. Printed in Brazil

Correlations between insect resistance and horticultural traits in potatoes

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

Received 11 May 2006

Accepted 21 September 2006

ABSTRACT - *The objective of this study was to determine relationships between insect resistance and some horticultural traits and the implications on selection. A potato population of 11 clonal families derived from crosses between insect resistant and genotypes adapted to the southern region of Brazil was used. The following traits were evaluated: plant size and vigor, incidence of insect attacks on leaves and tubers, tuber yield and appearance components. Phenotypic and genotypic correlations between leaf and tuber resistance were not significant for the population, while phenotypic correlations between the two resistance types were significant for individual families, with exception of the family originated from the cross involving 'ND263-32'. The incidence of insect attacks on tubers was significantly correlated with tuber yield and appearance in families derived from crosses of 'NYL235-4'. The manifold correlations of leaf resistance with horticultural traits for all families were significant and unfavorable.*

Key words: *Solanum tuberosum; Solanum berthaultii; Solanum chacoense.*

INTRODUCTION

The lack of cultivars with resistance to damage causing insects is a constraint on higher potato yields. It is one the chief problems faced by potato growers, especially in tropical and subtropical agroecosystems. For insect control, growers rely on insecticide sprays, which not only boosts production costs, but is often little effective as well. Many insecticides are not selective to natural predators but induce insect resistance and have negative environmental impacts (Gregory 1994, França 1999).

Among the main insect pests of potato in the southern region of Brazil, *Diabrotica speciosa,* popularly known as corn rootworm, and *Epicauta atomaria*, known as gray blister beetle, are the most important (Grützmacher and Link 2000, Salles 2000, Lara et al. 2004).

Potato breeding programs have focused on combining the resistance of Bolivian species with horticultural traits of cultivated species (Plaisted et al. 1992). In Brazil, it was observed that potato hybrids (*Solanum tuberosum* L.) resulting from crosses with *Solanum berthaultii* are resistant to leaf and tuber attack by *Diabrotica spp.* (Lara et al. 1999).

Another source of insect resistance is the potato species *Solanum chacoense*, with leptine-based resistance (Kuhn and Löw 1961). Some authors claim that leptine-based resistance is the most favorable for leaf insect resistance and the least toxic of the known

[1] Departamento de Fitotecnia, Faculdade de Agronomia "Eliseu Maciel" (FAEM), Universidade Federal de Pelotas (UFPel), 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] Embrapa Hortaliças, Rodovia Brasília-Anápolis, BR 060, km 09, C. P. 218, 70.359-970, Gama, DF, Brasil
[4] FAEM/UFPel

glycoalkaloids. The reason is that leptines are more expressed in leaves than in tubers (Sinden et al. 1986a). This resistance source has been reported in hybrids of the species *S. chacoense* with the cultivated species, conveying resistance to leaf insects (Sinden et al. 1986b). Leptine-based resistance is controlled by one or a few genes, which makes transference by recurrent crosses easier (Ronning et al. 1998, Yencho et al. 2000).

One of the problems associated with the use of wild species was the presence of segregating progenies with low yield and other non-acceptable horticultural traits, such as tuber cracks, rough skin, and, very often, high glycoalkaloid contents (Kalazich 1991). This aspect must be taken into consideration when selecting for resistance. Therefore, it is important to verify relationships between insect resistance and horticultural traits.

The objective of this study was to determine relationships between insect resistance and some important horticultural traits, and the implications of these relationships on the selection procedure.

MATERIAL AND METHODS

The experiments were conducted on an experimental field of Embrapa Clima Temperado (Brazilian Agricultural Research Corporation – Temperate Agriculture) as part of a potato breeding program, in the spring of 2003 and of 2004.

A composite potato population was used with 11 clonal families derived from crosses between insect-resistant genotypes and adapted genotypes to the southern region of Brazil. Five families were derived from crosses of adapted genotypes with the resistant genotype 'NYL235-4', four with 'ND140', one with 'ND5873-16', and one with 'ND263-32'. Of these resistant genotypes, only *S. chacoense* 'ND5873-16' carries leptine-based resistance genes. The other resistant genotypes were exclusively originated from crosses with *S. berthaultii*, which conveys glandular trichome-based resistance (Yencho and Tingey 1994).

Two field experiments were conducted in a randomized complete block design, with three replications. A sample of 75 genotypes per family was used, in plots of 25 genotypes. In the field, the genotypes were evaluated for plant size and vigor, and incidence of insect attacks on leaves. After harvest and cure, the tubers were evaluated for incidence of insect attacks and for horticultural traits: yield, average weight, number, appearance, uniformity, shape, and skin smoothness.

Incidence of insect attacks on leaves (IAL) and on tubers (IAT) were assessed using formulae adapted from Kwon et al. (1999): IAL = (Number of attacked leaflets / Total number of leaflets) x 100, where the leaflets from the fifth leaf from the apex downwards were counted to obtain the total number and the number of attacked leaflets, without taking the causing agent into consideration. IAT = (Number of attacked tubers / Total number of tubers) x 100, where tubers with three or more holes were considered attacked, and the number of tubers produced per plant was considered the total tuber number.

A five-point scale was used for all traits: plant vigor: 1 = high vigor (strong stem and leaf development) and 5 = low vigor; plant size: 1 = high height (erect) and 5 = low height (prostrated); Tuber uniformity: 1 = uniform tubers (regular size and shape) and 5 = non-uniform tubers; skin smoothness: 1 = smooth skin and 5 = rough skin; tuber shape: 1 = long tubers and 5 = round tubers. Tuber appearance and yield components were evaluated as described by Souza et al. (2005), in which 1 = excellent appearance and 5 = poor appearance.

The computer program used for the statistical data analysis was Genes (Cruz 2001). The family effect was considered random. The confidence intervals of heritability were calculated according to Tai (1983). The expected direct and correlated response to selection was estimated using the genetic correlation matrix (Simmonds 1979, Falconer 1989). The estimated values were expressed as percentage of the mean. The magnitudes of the correlation coefficients were classified according to Carvalho et al. (2004): r = 0 (null); $0 < |r| \leq 0.30$ (weak); $0.30 < |r| \leq 0.60$ (medium); $0.60 < |r| \leq 0.90$ (strong); $0.90 < |r| \leq 1$ (very strong) and r = 1.00 (perfect).

RESULTS

The joint analysis of variance of the data revealed significant differences ($P<0.05$) for all traits (Table 1). The coefficients of variation varied from 5.0% for tuber appearance to 29.4% for incidence of insect attacks on tubers.

The coefficients of heritability varied from 28.02% (1-61%) for tuber uniformity, to 87.33% (82-93%) for

Table 1. Mean squares for the joint analysis of variance, variation coefficients, genetic variation coefficients, means and heritability (confidence interval estimates – $IC_{95\%}$) of potato traits

Sources of variation	df	IAL[1]	IAT[2]	Horticultural traits[3]								
				Vigor	Size	Appear	Unif	Skin	Shape	Ntub	Yield	ATW
Genotype (G)	10	94.70*	665.52*	0.12*	0.30*	0.04*	0.07*	0.11*	0.34*	8.74*	29627*	266.97*
Year (Y)	1	574.33*	3271*	1.90*	0.56*	17.04*	5.37*	9.65*	0.01	116.17*	2741887*	9193.05*
G x Y	10	50.30*	471.32*	0.03	0.12*	0.04*	0.06*	0.04	0.27*	3.64*	18026*	125.79*
Error	40	19.30	84.31	0.05	0.07	0.02	0.05	0.07	0.20	2.85	9838.61	79.00
CV		21.96	29.44	9.24	12.84	5.00	8.60	11.66	14.11	13.74	15.30	15.95
CV_G	-	48.65	82.72	14.46	26.70	7.07	1.92	14.54	18.30	24.08	8.40	29.32
Mean	-	20.00	31.19	2.42	2.06	2.83	2.60	2.27	3.17	12.29	648.22	55.73
h^2	-	79.62	87.33	58.61	74.80	45.51	28.02	38.00	42.92	67.40	66.79	70.39
$(CI < h^2 < CI)$	(71-89)	(82-93)	(42-77)	(68-88)	(31-73)	(1-61)	(12-66)	(19-69)	(55-83)	(54-82)	(59-84)	

[1] IAL: incidence of attack on leaves
[2] IAT: incidence of attack on tubers
[3] Vigor: plant vigor (1 = high vigor, 5 = low vigor); Size: plant height (1 = tall – erect, 5 = short - prostrated); Appear: tuber appearance (1 = excellent appearance, 5 = poor appearance); Unif: uniformity of tuber (1 = regular tubers in size and shape, 5 = irregular tubers in size and shape); Skin: skin smoothness (1 = smooth skin, 5 = rough skin); Shape: tuber shape (1 = long, 5 = round); Ntub: number of tubers; Yield: yield of tubers (g $plant^{-1}$); ATW: average tuber weight (g)
* Significant at the 5% probability level of the error by the F test

incidence of insect attacks on tubers (Table 1). The coefficients of heritability for incidence of insect attacks on leaves (79.62%) and on tubers (87.33%) were relatively high.

The phenotypic and genotypic correlations between incidence of insect attacks on leaves and tubers were not significant for the population. The magnitude of the coefficient of phenotypic correlations between incidence of insect attacks on leaves and tubers with other traits varied from medium to weak (Table 2). It was observed that incidence of insect attacks on leaves was positive and significantly associated with plant size and tuber appearance. Incidence of leaf attacks and tuber uniformity were negatively correlated. Incidence of tuber attacks presented significant and positive phenotypic correlations with plant vigor, tuber appearance and skin smoothness and significant but negative association with tuber shape.

For the population, the magnitude of the genotypic correlations of incidence of insect attacks on leaves and tubers with the other traits varied from medium ($r = -0.33$) to strong ($r = 0.95$) (Table 2). Positive and significant associations with incidence of insect attacks on leaves were plant size, tuber appearance and shape; for plant vigor, the association was negative. Incidence of insect attacks on tubers was positively and significantly correlated with plant vigor, tuber number, yield, tuber appearance and skin smoothness and negatively with tuber shape and average tuber weight.

The expected response to selection for resistance to insect attacks on leaves and tubers was -43.4% and -77.3% in relation to the mean, respectively. The selection for insect resistance to attack on the leaves would cause an unfavorable expected correlated response for plant vigor, and a favorable one for plant height, tuber appearance and shape (Table 2). On the other hand, selection for resistance to insect damage on tubers would result in an unfavorable expected correlated response in tuber shape and yield, and favorable in vigor, tuber appearance, skin smoothness, tuber number and average tuber weight.

Phenotypic correlations of incidence of insect attacks on leaves with horticultural traits for each one of the 11 families composing the population are presented in Table 3.

There were no differences between families derived from the same resistant parent. However, the sets of

Table 2. Phenotypic and genotypic correlations for a population of 11 clonal families and expected correlated response to selection for horticultural traits by selection for resistance to insect attacks on potato leaves and tubers

	Horticultural trait[2]								
	Vigor	Size	Appear	Unif	Skin	Shape	Ntub	Yield	ATW
Selected trait[1]	**Phenotypic correlation**								
IAL	-0.13	0.53*	0.34*	-0.28*	0.08	0.15	0.07	0.07	-0.06
IAT	0.42*	0.15	0.22*	-0.06	0.37*	-0.32*	0.23*	0.14	-0.04
	Genotypic correlation								
IAL	-0.33*	0.62*	0.49*	0.11	0.02	0.74*	0.05	0.09	0.09
IAT	0.95*	0.09	0.60*	0.15	0.69*	-0.48*	0.92*	0.55*	-0.48*
	Expected correlated response to selection (% in relation to the mean)								
IAL	32.6 [2]	-128,0[2]	-20,8[2]	-1,0	-1,5	-79,0[2]	5.46	-5,3	20,1
IAT	-98,7[2]	-18,5	-26,7[2]	-1,4	-57,5[2]	54,2[2]	66.90[2]	-12,9[2]	110,1[2]

[1] IAL: incidence of attack on leaves; IAT: incidence of attack on tubers
[2] Vigor: plant vigor (1 = high vigor, 5 = low vigor); Size: plant height (1 = tall – erect, 5 = short - prostrated); Appear: tuber appearance (1 = excellent appearance, 5 = poor appearance); Unif: uniformity of tuber (1 = regular tubers in size and shape, 5 = irregular tubers in size and shape); Skin: skin smoothness (1 = smooth skin, 5 = rough skin); Shape: tuber shape (1 = long, 5 = round); Ntub: number of tubers; Yield: tuber yield (g plant^{-1}); ATW: average tuber weight (g)
* Significant at a level of 5% probability by the t test with n = 64
[2] Values corresponding to significant correlations

Table 3. Phenotypic correlations between incidence of insect attacks on leaves and some horticultural traits, in 11 segregating potato families derived from four insect-resistant parents

Family	Horticultural trait								
Adapted / Resistant parent	Vigor[1]	Size	Appear	Unif	Skin	Shape	Ntub	Yield	ATW
2CRI-1149-1-78 / ND140	-0.37*	0.28*	0.55*	0.49*	0.61*	0.45*	0.16*	0.37*	0.63*
White Lady / ND140	-0.32*	0.25*	0.72*	0.28*	0.71*	0.66*	0.98*	0.70*	0.50*
C1485-16-87 / ND140	-0.24	*0.40*	0.69*	0.68*	0.83*	0.63*	0.70*	0.59*	0.56*
Eliza / ND140	-0.23*	0.46*	0.23*	0.34*	0.17	0.58*	0.35*	0.50*	0.44*
C1750-15-95 / NYL235-4	-0.21	0.25*	0.75*	0.77*	0.46*	0.36*	0.26*	0.69*	0.86*
Cristal / NYL235-4	-0.11	0.27*	0.45*	0.40*	0.28*	0.24*	0.39*	0.44*	0.49*
Eliza / NYL235-4	-0.17	0.44*	0.35*	0.31*	0.31*	0.44*	0.34*	0.42*	0.29*
C1226-35-80 / NYL235-4	-0.21	0.58*	0.70*	0.79*	0.25*	0.30*	0.87*	0.98*	0.96*
C1485-16-87 / NYL235-4	-0.16	0.38*	0.25*	0.32*	0.26*	0.55*	0.31*	0.40*	0.59*
C1485-16-87 / ND5873-16	-0.76*	0.69*	0.78*	0.54*	0.86*	-0.18	0.42*	0.75*	0.72*
2CRI-1149-1-78 / ND263-32	-0.52*	0.23*	0.86*	0.84*	0.84*	0.86*	0.55*	0.71*	0.59*

[1] Vigor: plant vigor (1 = high vigor, 5 = low vigor); Size: plant height (1 = tall – erect, 5 = short - prostrated); Appear: tuber appearance (1 = excellent appearance, 5 = poor appearance); Unif: uniformity of tuber (1 = regular tubers in size and shape, 5 = irregular tubers in size and shape); Skin: skin smoothness (1 = smooth skin, 5 = rough skin); Shape: tuber shape (1 = long, 5 = round); Ntub: number of tubers; Yield: tuber yield (g plant^{-1}); ATW: average tuber weight (g)
* Significant at a level of 5% probability by the t test with n = 73

families derived from 'NYL235-4', 'ND140' (*S. berthaultii)* and 'ND5873-16' (*S. chacoense*) all had medium and positive correlations between resistance to insect attacks on leaves and on tubers (data not shown). In the family originated from 'ND263-32' (*S. berthaultii*) the two traits were not significantly correlated

Incidence of insect attacks on leaves was positively and significantly correlated with plant height, tuber number, yield, appearance, shape, uniformity, skin smoothness and average tuber weight for all families, except for the one derived from ND5873-16, for tuber shape. Negative and significant correlations between incidence of attack on leaves and plant vigor were found for all families, except the five derived from 'NYL235-4'.

The phenotypic correlations of incidence of insect attacks on tubers with horticultural traits for each one of the 11 families of the population are presented in Table 4.

The families originated from 'NYL235-4' showed negative and significant correlations only between insect attacks on tubers and plant vigor. The other families agreed in the associations (positive) of incidence of insect attacks on tubers with plant height, tuber appearance, uniformity and average tuber weight. With plant vigor, the correlations were negative for all families, except for the four derived from ND140 genotype. Number of tubers were positively associated with attack on tubers for the four families of segregating progenies derived from 'ND140', and for families derived from 'ND5873-16' and 'ND263-32'. Yield, besides not being associated with attack on tubers in the five families obtained from the cross with 'NYL235-4', was not significantly correlated in the family originated from 'ND263-32' either. In the set of families derived from 'ND140' and 'ND5873-16', the trait rough tuber skin was positively associated with insect attacks on tubers. The correlation of tuber shape with incidence of attack on tubers was only significant in the families originated from 'ND5873-16' and 'ND263-32' (negative in the first and positive in the second case).

DISCUSSION

The potato breeding program of the University of Cornell aimed to combine insect resistance of the Bolivian (*S. berthaultii*) potato species with horticultural traits of the cultivated species (Plaisted et al. 1992). Progress was made in transferring resistance, elimination and recovery of horticultural traits by means of recurrent selection with the commercially adapted cultivars, and with tubers that satisfy North American standards (Plaisted et al. 1992).

In this study, correlations between insect resistance to attack on leaves and tubers were not found in the population. However, when the individual families of the population were analyzed, according to the resistant genotypes that composed them, only the family derived from the ND263-32 genotype (*S. berthaultii*) was not significant. This result can be ascribed to the negative effect of this family on the magnitude of the correlation of the population. Significant correlations were expected only for families derived from *S. berthaultii*. According to Lara et al. (1999), this species presented resistance in the leaves as well as in the tubers, under tropical and subtropical conditions. On

Table 4. Phenotypic correlations between incidence of insect attacks on the tubers and some horticultural traits, in segregating families of four insect-resistant potato parents

Family	Horticultural trait								
Adapted / Resistant parent	Vigor	Size	Appear	Unif	Skin	Shape	Ntub	Yield	ATW
2CRI-1149-1-78 / ND140	-0.22	0.24*	0.24*	0.38*	0.23*	0.10	0.41*	0.68*	0.45*
White Lady / ND140	-0.13	0.28*	0.32*	0.53*	0.28*	0.22	0.24*	0.35*	0.40*
C1485-16-87 / ND140	-0.11	0.27*	0.82*	0.52*	0.55*	0.18	0.41*	0.62*	0.73*
Eliza / ND140	-0.18	0.76*	0.81*	0.64*	0.47*	0.17	0.76*	0.88*	0.61*
C1750-15-95 / NYL235-4	-0.40*	-0.16	0.13	0.16	0.18	0.10	-0.20	0.01	-0.22
Cristal / NYL235-4	-0.37*	0.18	0.15	0.04	0.17	0.08	0.17	0.11	-0.20
Eliza / NYL235-4	-0.58*	0.21	-0.14	-0.12	-0.12	-0.12	-0.09	-0.10	-0.18
C1226-35-80 / NYL235-4	-0.90*	0.18	-0.19	-0.15	-0.12	-0.18	-0.11	-0.22	-0.19
C1485-16-87 / NYL235-4	-0.13	-0.13	0.20	0.14	0.14	-0.09	0.09	0.15	0.16
C1485-16-87 / ND5873-16	-0.51*	0.82*	0.57*	0.81*	0.70*	-0.36*	0.42*	0.27*	0.75*
2CRI-1149-1-78 / ND263-32	-0.25*	0.25*	0.30*	0.33*	0.15	0.24*	0.25*	0.21	0.41*

[1] Vigor: plant vigor (1 = high vigor, 5 = low vigor); Size: plant height (1 = tall – erect, 5 = short - prostrated); Appear: tuber appearance (1 = excellent appearance, 5 = poor appearance); Unif: uniformity of tuber (1 = regular tubers in size and shape, 5 = irregular tubers in size and shape); Skin: skin smoothness (1 = smooth skin, 5 = rough skin); Shape: tuber shape (1 = long, 5 = round); Ntub: number of tubers; Yield: yield of tubers (g plant^{-1}); ATW: average tuber weight (g)
* Significant at a level of 5% probability by the t test with n = 73

the other hand, in the family originated from 'ND5873-16', which was derived from *S. chacoense*, no significant associations were expected between the two types of resistance. This result, however, does not agree with findings reported by Sinden et al. (1986a). According to these authors, the resistance of hybrids of *S. chacoense* with the cultivated species is leptine-based. These glycoalkaloids are expressed in great amounts in the leaves and in small quantities in the tubers.

In general, the magnitudes of the genetic were higher than the phenotypic correlations for all traits, showing that the environment affected phenotypic correlations negatively. This means that the effects of one trait on the other could be higher under favorable conditions for the expression of these traits.

The phenotypic correlations of the 11 families showed that selection for resistance to insect attacks on leaves and tubers can reduce plant vigor, with exception of the four families originated from 'ND140' for tuber resistance and the families derived from 'NYL235-4' for leaf resistance. These two resistant parents were derived from the wild species *S. berthaultii*. Our results suggest that when selecting for insect resistance, plant vigor should be considered simultaneously. According to Fisher et al. (2002), selection for resistance to the leaf attack of Colorado potato beetle, over successive generations, results in reduced plant vigor in each generation.

Selection for resistance traits influenced tuber appearance, skin smoothness and tuber length positively and would therefore be beneficial for breeding for these traits. But on the other hand, it would reduce tuber number, yield and average tuber weight. Our results agree with those reported by Kalazich and Plaisted (1991), regarding the association between resistance and low yield, but disagree in relation to skin smoothness. The favorable association of resistance with skin smoothness found in this study might be a result of the successive recurrent cycles with the cultivated species these parents had gone through. This could have caused breakage of the possible gene links, in favor of the trait (Petr and Frey 1966).

Families derived from 'NYL235-4' (*S. berthaultii*) did not show significant correlation of incidence of insect attacks on tubers with yield and tuber appearance. This suggests that breeders can apply different selection levels for tuber resistance, since the level does not influence horticultural traits.

Incidence of insect attacks on leaves had a large number of significant and unfavorable correlations with horticultural traits in all families. This indicates that when selecting for insect resistance, the breeder must consider the associations with desirable horticultural traits. Otherwise, highly insect-resistant genotypes with poor performance for horticultural traits could be selected.

ACKNOWLEDGEMENTS

The authors acknowledge the McKnight Foundation for the financial support and CAPES, FAPERGS and CNPq for scholarships.

Correlações entre resistência a insetos-praga e alguns caracteres agronômicos em batata

RESUMO - *Este trabalho objetivou verificar as relações entre resistência a insetos-praga e alguns caracteres de importância agronômica e suas implicações na seleção. Foi utilizada uma população composta de 11 famílias clonais, oriundas de cruzamentos entre genótipos resistentes a insetos-praga e genótipos adaptados à região Sul do Brasil. Foram avaliados os caracteres porte e vigor de planta, incidência de ataque de insetos-praga nas folhas e nos tubérculos, caracteres componentes do rendimento e da aparência. As correlações fenotípicas e genéticas entre as formas de resistências não foram significativas para a população. Quando individualizadas as famílias, todas apresentaram correlação fenotípica significativa entre as duas formas de resistência, exceto a família oriunda de 'ND263-32'. As famílias derivadas de 'NYL235-4' não apresentaram correlações significativas da incidência de ataque aos tubérculos com caracteres de rendimento e aparência. A resistência ao ataque de insetos-praga nas folhas apresentou grande número de correlações significativas e desfavoráveis para todas as famílias.*

Palavras-chave: *Solanum tuberosum; Solanum berthaultii; Solanum chacoense.*

REFERENCES

Carvalho FIF, Lorencetti C and Benin G (2004) **Estimativas e implicações da correlação no melhoramento vegetal**. Editora Universitária da UFPel, Pelotas, 142p.

Cruz CD (2001) **Programa Genes - versão Windows 2001.0.0**. Editora UFV, Viçosa, 642p.

Falconer DS (1989) **Introduction to quantitative genetics**. Longman, New York, 438p.

Fisher DG, Deahl KL and Rainforth MV (2002) Horizontal resistance in Solanum tuberosum to Colorado potato beetle (*Leptinotarsa decemlineata* say). **American Journal of Potato Research 79**: 281-293.

França F (1999) Pragas. In: Lopes CA and Buso JA (eds.) **A cultura da batata**. Embrapa Hortaliças, Brasília, p. 108-122.

Gregory P (1994) The Potato's Global Potential. In: Zehnder W, Powelson M, Jansson R and Ramam K (eds.) **Advances in Potato Pest Biology & Management**. APS Press, Saint Paul, p. 652-655.

Grützmacher AD and Link D (2000) Levantamento da entomofauna associada a cultivares de batata em duas épocas de cultivo. **Pesquisa Agropecuária Brasileira 35**: 653-659.

Kalazich JC and Plaisted RL (1991) Association between trichome characters and agronomic traits in *Solanum tuberosum* L.) X *Solanum berthaultii* (Hawkes) hybrids. **American Potato Journal 68**: 833-847.

Kwon M, Hahm YI, Shin KY and Ahn YJ (1999) Evaluation of various potato cultivars for resistance to wireworms (*Coleoptera: Elateridae*). **American Journal of Potato Research 76**: 317-319.

Kuhn R and Löw I (1961) Zur Konstitution der Leptine. **Chemische Berichte 94**: 1088-1095.

Lara FML, Silva EA and Boiça Júnior AL (1999) Resistência de genótipos de batata, *Solanum* spp., a afideos (Homopera: Aphididae) e influência sobre parasitóides. **Anais da Sociedade Entomológica do Brasil 28**: 721-728.

Lara FML, Scaranello AL, Baldin ELL, Boiça Junior AL and Lourenção AL (2004) Resistência de genótipos de batata a larvas e adultos de Diabrotica speciosa. **Horticultura Brasileira 22**: 761-765.

Petr FC and Frey KJ (1966) Genotypic correlations, dominance, and heritability of quantitative characters in oats. **Crop Science 6**: 259-262.

Plaisted R, Tingey WM and Steffens JC (1992) The germplasm release of NYL235-4, a clone with resistance to the Colorado potato beetle. **American Potato Journal 69**: 843-846.

Ronning CM, Sanford LL, Kobayashi RS and Kowalski SP (1998) Foliar leptine production in segregating F_1, inter F_1, and backcross families of *Solanum chacoense* Bitter. **American Journal of Potato Research 75**: 137-143.

Salles LA (2000) Incidência de danos de *Diabrotica speciosa* em cultivares e linhagens de batata. **Ciência Rural 30**: 205-209.

Simmonds NW (1979) **Principles of crop improvement**. Longman, New York, 408p.

Sinden SL, Sanford LL and Deahl KL (1986a) Segregation of leptine glycoalkaloids in *Solanum chacoense* Bitter**. Journal Agriculture Food Chemistry 34**: 372-377.

Sinden SL, Sanford LL, Cantelo WW and Deahl KL (1986b) Leptine glycoalkaloids and resistance to the Colorado potato beetle (Coleoptera: Chrysomelidae) in *Solanum chacoense*. **Environment Entomology 15**: 1057-1062.

Souza VQ, Pereira AS, Fritche Neto R, Silva GO and Oliveira AC (2005) Potential of selection among and within potato clonal families. **Crop Breeding and Applied Biotechnology 5**: 199-206.

Tai GCC (1983) Confidence intervals of genetic parameters estimated from progeny test experiments in plant breeding. **Canadian Journal Genetic Cytology 25**: 502-508.

Yencho GC and Tingey WM (1994). Glandular trichomes of *Solanum berthaultii* alter host preference of the Colorado potato beetle, *Leptinotarsa decemlineata*. **Entomologia Experimentalis et Applicata 70**: 217-225.

Yencho GC, Kowalski SP, Kennedy GG and Sanford LL (2000) Segregation of leptine glycoalkaloids and resistance to Colorado potato beetle (*Leptinotarsa decemlineata* Say) in F_2 *Solanum tuberosum* (4x) x *S. chacoense* (4x) potato progenies. **American Journal of Potato Research 77**: 167-178.