

Insect Resistance and Horticultural Trait Genetic Values of Potato Families

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Abstract

This work aimed to evaluate 11 potato families for insect resistance horticultural traits. The families were derived from crosses between introduced insect resistant and adapted genotypes. A randomized complete block design, with three replications was used. The plot consisted of 25 genotypes of a family, summing up to 75 genotypes tested per family. Two susceptible cultivars were included in the experiment as controls. The genotypes were evaluated for insect resistance, tuber yield traits, tuber appearance, and tuber skin smoothness. The genetic value for the intensity of insect attack in the leaves and in the tubers was lower (higher resistance) in the 11 families than in the controls. For yield traits, there was no predominant effect among the families regarding the origin of the resistant donor species (*Solanum berthaultii* and/or *S. chacoense*). However, there was a large contribution of the C-1485-16-87 recurrent parent in crosses with resistant genotypes for tuber yield and tuber number. In relation to tuber appearance, only the family derived from the C-1485-16-87/ND140 (*S. berthaultii*) cross did not differ from the controls. For tuber skin smoothness, the genetic values of the families did not significantly differ from each other or from the controls.

Key words: *Solanum tuberosum*, *S. berthaultii*, *S. chacoense*, *Diabrotica speciosa*, breeding value.

Introduction

The lack of cultivars with resistance to the severe damage caused by insects in the potato crop is a limiting factor for increasing quality and yield. This factor is especially significant for tropical and subtropical agro ecosystems, where it is one of the major problems faced by farmers (Curzio 1993). It is estimated that damage caused by insects reduces the yield efficiency of potato cultivars up to 33%. For their control, farmers rely upon the application of insecticides that, besides raising production costs, many times have low efficiency in controlling insects (França 1999). Near 95.3% of phytosanitary expenses of the crop are due to the use of insecticides and fungicides, which lead potato to be ranked third among crops that use the most pesticides (Neves et al. 2003). Many insecticides are not selective, affecting natural predators, inducing resistance, and causing

negative environmental impacts (Gregory 1994).

Among the insects attacking the potato crop in the southern region of Brazil, those belonging to the *Chrysomelidae* family are the most common, with a predominance of corn rootworm (*Diabrotica speciosa*) (Grützmacher and Link 2000). The gray blister beetle (*Epicauta atomaria* - *Meloidae* family), also very often attacks the potato crop and causes permanent damage to leaves and tubers (Barbosa and França 1981). These insects, at the adult stage, feed on leaves, causing severe reduction to the canopy area, leading to a decrease in yield. However, permanent damage is caused by the larvae, which feed on developing tubers, opening tunnels that lead to a decrease in the product quality, as well as opening holes that lead to soil fungi and bacterial infections (Barbosa and França 1981; Grützmacher and Link 2000).

These insect attacks result in lack of yield stability and loss of quality, harming tuber visual aspect and handling. As a consequence, either production costs are increased or the final product

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suffers devaluation. Therefore, the selection of genotypes which are adapted and resistant to these insects, is one of the most effective ways to improve crop quality, with direct benefits to farmers and consumers.

The aim of this work was to evaluate potato families for resistance to insect attacks to leaves and tubers, and to characterize them for horticulturally important traits.

Materials and Methods

The work was conducted at Embrapa Clima Temperado, Pelotas, RS (31°S, 52°W), as a part of the potato breeding program. Eleven potato families were studied. They were derived from crosses between introduced insect resistant(*) and adapted genotypes, as follows: C-2335= ND140*/CRI1149-1-78; C-2337= White Lady/ND140*; C-2339= C-1485-16-87/ND5873-16*; C-2340= C-1485-16-87/ND140*; C-2341= Eliza/ND140*; C-2346= ND263-32*/CRI-1149-1-78; C-2360= C-1750-15-95/NYL235-4*; C-2362= Cristal/NYL235-4*; C-2363= Eliza/NYL235-4*; C-2364= C-1226-35-80/NYL235-4*, and C-2365= C-1485-16-87/NYL235-4*. Among the resistant parents, only 'ND5873-16' has in its pedigree the *Solanum chacoense* wild species, in which insect resistance is conferred by leptines (Sinden et al. 1986). The other resistant parents have *S. berthaultii* in its genetic background, which is the source of insect resistance based on glandular trichomes (Yencho and Tingey 1994).

Experiments were carried out in spring seasons of 2003 and 2004, using a randomized complete block design, with three replications. The plot consisted of 25 genotypes of a family, with a total of 75 genotypes tested per family. Two susceptible cultivars, Baronesa and Elvira, were also included in the experiment as controls. The genotypes were evaluated for insect resistance in the leaves and tubers, tuber yield, tuber number, average tuber weight, tuber appearance, tuber skin smoothness, and tuber shape.

After 60 days from plant emergence, the resistance was evaluated as the intensity of insect attack in the leaves (IAL) and in the tubers (IAT), using the formula adapted from Kwon et al. (1999). For IAL, the number of attacked leaflets on the fifth leaf from the top was counted, and using the formula adapted from Kwon et al. (1999): IAL (%) = (No. of attacked leaflets/No. of total leaflets) x 100.

The insect population present at 60 days from emergence was quantified using a method consisting of shaking the plants vigorously over a net. The species present at the moment of scoring for IAL. A total of eight shaking movements were performed per block, totaling up to 32 shaking movements in the experimental area. The collected insects *Diabrotica speciosa*, *Epicauta*

atomaria, *Empoasca kraemeri*, *Cerotoma arcuata*, *Epetrix hirtipennis*, and *Empoasca kraemeri* were stored at 70% ethanol.

For IAT, the number of medium-sized tubers with three or more holes, and calculating with the formula ITA (%) = (No. of attacked tubers/No. of total tubers) x 100.

At the tuber harvesting, the insect present in the soil surrounding each plant were counted. Again, eight soil samples were collected per block, each sample consisting of 20 x 20 x 20 cm diggings. The collected soil was sieved and the larvae present were stored at 70% ethanol and later identified.

Tuber appearance traits were evaluated using visual five point scales. Tuber appearance: 1 = excellent, 5 = poor; Skin smoothness, 1 = smooth skin, 5 = rough skin.

For tuber yield traits, the tubers from each plant were counted and weighed. The average tuber weight was obtained by dividing the total tuber weight by the number of tubers.

Data of discrete variables were tested for normality and adjusted, when necessary, using the transformation $\sqrt{x+0.5}$, in order to fulfill the analysis of variance assumptions. Data analysis was performed using SAS Learning Edition software (SAS Institute 2002), applying the Proc Mixed procedure (Littell et al. 1996), and the statistical model Reml/Blup (residual maximum likelihood/best linear unbiased predictor). The general mixed linear model described by Henderson (1984) is demonstrated by the formula:

$$y = Xb + Za + e,$$

in which the distributions and structures for mean and variance of $a \sim N(0, G)$, $E(y) = Xb$, $e \sim N(0, R)$, and $Var(y) = V = ZGZ' + R$, where:

y is the vector for observations;

b is the parametric vector for the fixed effects, with an incidence matrix of X ;

a is the parametric vector for the random effects, with an incidence matrix of Z ;

e is the vector of random errors;

G is the variance-covariance matrix of random effects;

R is the variance-covariance matrix of random errors;

O is the null vector.

Assuming G and R as known, the simultaneous estimation of fixed effects and the prediction of random effects was obtained by the mixed model equations, as follows:

$$\begin{bmatrix} Z'R^{-1}X & X'R^{-1}Z \\ Z'R^{-1}X & Z'R^{-1}Z + G^{-1} \end{bmatrix} * \begin{bmatrix} \hat{b} \\ \hat{a} \end{bmatrix} = \begin{bmatrix} Z'R^{-1}X & X'R^{-1}Z \\ Z'R^{-1}X & Z'R^{-1}Z + G^{-1} \end{bmatrix}$$

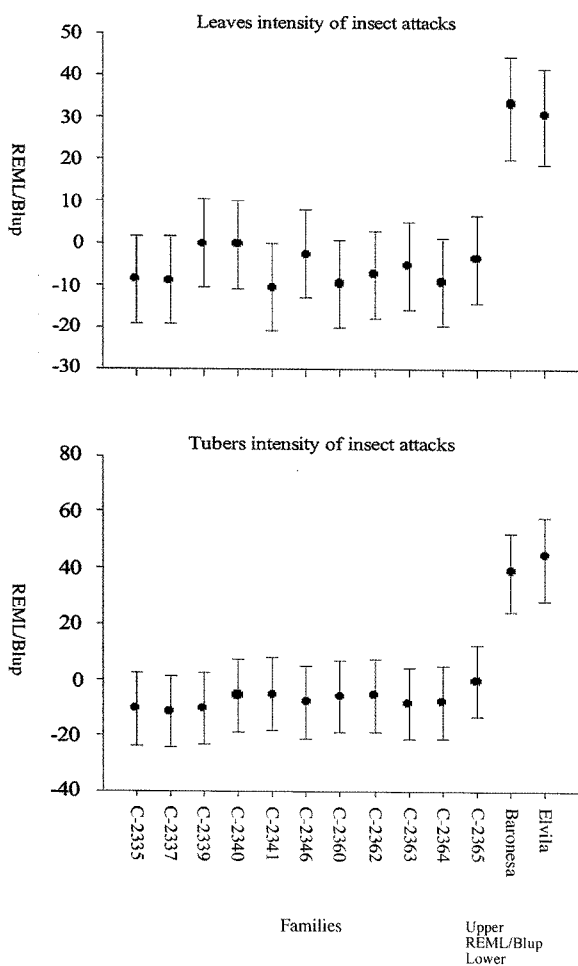


Fig. 1. REML/Blup values of 11 potato families and two check cultivars, for intensity of insect of attack in the leaves and in the tubers. Pelotas, 2006.

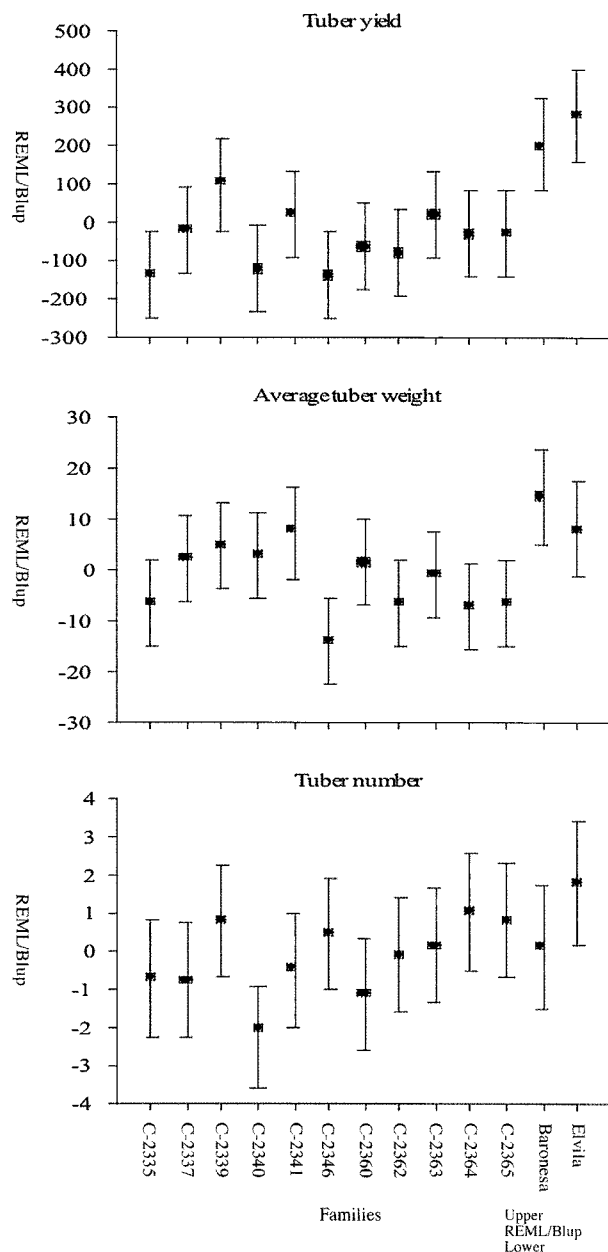


Fig. 2. Genetic values (REML/Blup) of 11 potato families and two check cultivars, for tuber yield, average tuber weight, and tuber number. Pelotas, 2006.

The solution for this system for \hat{a} and \hat{b} can be obtained by:

$$\hat{a} = GZ'V^{-1}(y - Xb) = \text{Blup of } \hat{a} \text{ (best linear unbiased predictor);}$$

$$\hat{b} = (X'V^{-1}X)^{-1}X'V^{-1}y = \text{Blue of } \hat{b} \text{ (best linear unbiased estimator).}$$

Results and Discussion

Two species considered as crop pests: *Diabrotica* spp. and *Epicauta* spp. were detected both at 60 days from emergence as well as at harvesting point. The first species was present in higher populations than the second. These species were present as 2.32 and 1.12 insects per shaking movement and 4.11 and 0.42 larvae per hill, respectively. These results indicate the presence

of crop pests in the field conditions, suggesting that the environment was appropriate for the selection of resistant genotypes. The genetic values (Reml/Blup) of families and control susceptible cultivars for intensity of insect attacks are shown in Figure 1. As expected, the genetic value for the intensity of insect attack in the leaves and in the tubers was lower (higher resistant) in the 11 families than in the controls.

Since it is commonly accepted that leptines and glandular trichomes are present only in foliar tissues and would therefore only protect leaves, the results seen in Figure 1, where 11 potato

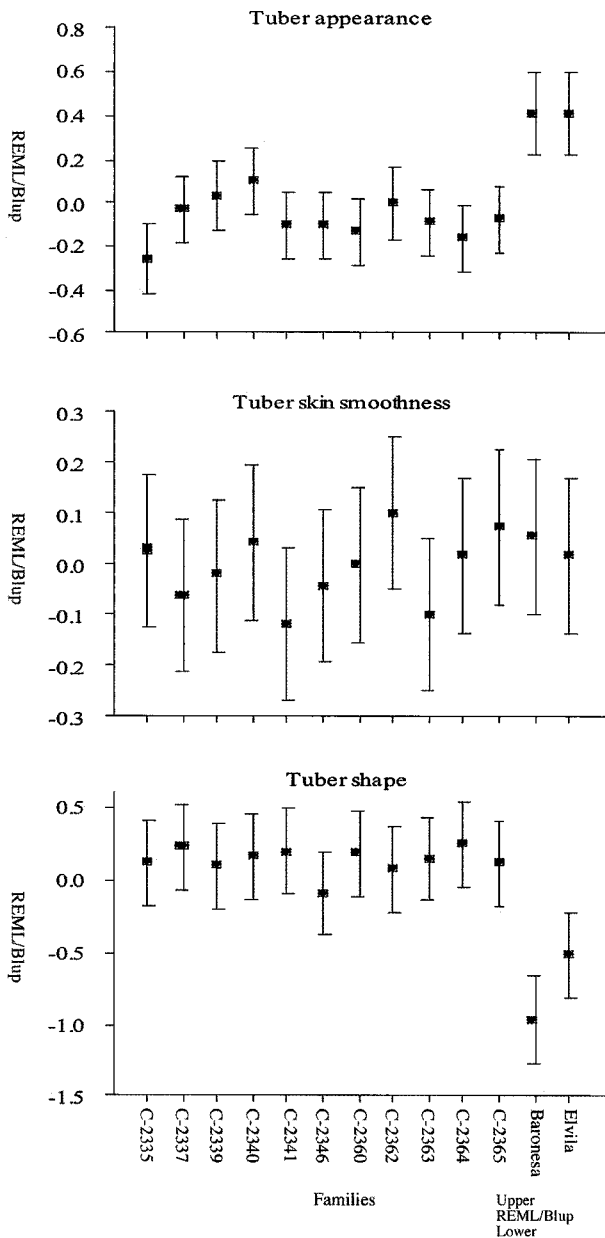


Fig. 3. Genetic values (REML/Blup) of 11 potato families and two control cultivars, for tuber appearance, tuber skin smoothness, and tuber shape. Pelotas, 2006.

families show resistance to insects attacking both leaf and tuber, are intriguing. One possible explanation is that individuals with leptin-based resistance can have a secondary route for the resistance that will trigger a systemic resistance. This is possible since leptines are elicitors that are responsible for a signal that triggers a MAPKinase, which will launch the expression of genes involved in the ABA and as a consequence Jasmonic and Salicylic acids (Kandath et al. 2007). As added supporting evidence, genes responsible for the final steps of leptine biosynthesis were found to have homology with genes involved in ABA biosynthesis (Silhavy et al. 1995).

Despite the low intensity of insect attack when compared to the susceptible cultivars, the families did not differ significantly in genetic value. According to Pelletier and Tai (2001), the lack of discrimination among resistant phenotypes can be due to conditions faced by plants in the field. The resistance can be influenced by many external factors to the experimental field conditions, such as the spatial distribution of insects. In these cases, due to a high frequency of resistant genotypes, it can lead to a non-preference in susceptible genotypes. This problem could be diluted by increasing the number of replications and the number of observations within the plot, causing a decrease in the experimental error.

The superior insect resistance performance shown by families when compared to susceptible controls, suggests that crosses between resistance gene bearing genotypes (ND140, ND263-32, NYL235-4, and ND5873-16) and adapted susceptible genotypes are efficient in transferring to their progenies considerable degree of resistance to the attack of locally occurring insects, as was verified for *Diabrotica speciosa* and *Epicauta* sp. These results support the reports of Flanders et al. (1997) that many wild *Solanum* species are resistant to a broad range of insects. Several authors have reported the identification of resistant genotypes to different insects, such as Colorado potato beetle - *Leptinotarsa decemlineata* (Pelletier et al. 2001), pea leafminer - *Liriomyza huidobrensis* (Sanford and Ladd 1985), potato tuberworm - *Phthorimaea operculella* (Arnone et al. 1998), green peach aphid - *Myzus persicae* (Lapointe and Tingey 1984), and corn rootworm - *Diabrotica speciosa* (Lara et al. 2004). The identification of crosses which enable the expression of resistance mechanisms is fundamental for the success in the selection of resistant progenies (Buso et al. 1999).

The genetic values of families and check cultivars regarding yield traits are shown in Figure 2. For tuber yield, the families did not differ from each other in genetic value. C-2339, C-2337, C-2341, C-2363, C-2364, and C-2365 families were not significantly different from the Elvira and Baronesa cultivars. For average tuber weight, the genetic values of families, except for C-2346, did not differ from Elvira, and six of the families also did not differ from 'Baronesa', which showed the highest genetic values. Regarding tuber number, only C-2340 showed lower genetic value than one of the controls.

There was no predominant effect among the families regarding the origin of the resistant donor wild species *Solanum berthaultii* and/or *S. chacoense*, for yield traits. However, a larger contribution of the adapted C-1485-16-87 parent was observed for tuber yield and number, when crossed to resistant genotypes. According to Darmono and Peloquin (1991), it is necessary that crosses be directed to those combinations in which the resistance is transmitted to the majority of progenies and the adapted parent is able to maintain the resistance at acceptable

levels and is also able to increase the horticultural quality of the progenies.

The genetic values for tuber appearance and skin smoothness are presented in Figure 3. For tuber appearance, the families showed no significant genetic value differences from each other. Only C-2340 family did not differ from the checks. This family was derived from the C-1485-16-87/ND140 (*S. berthaultii*) cross.

For tuber skin smoothness, the genetic values of the families neither differed significantly from each other nor from the control cultivars. This result indicates that even having as a near ancestor a wild species, resistant parents might originate progenies with smooth skin, provided that the adapted parent has a positive contribution to this trait. According to Buso et al. (2003), genotypes obtained from artificial hybridization between wild and cultivated species, can show an appearance similar to elite commercial cultivars, providing that the recurrent parent for adaptation has an excellent *per se* value for the target trait.

The results of this study allowed us to conclude that specific crosses between insect resistant potato genotypes derived from wild species and genotypes adapted to southern Brazilian conditions are efficient in generating progenies with considerable resistance levels and desirable horticultural traits. Subjecting the selected genotypes to further cycles of recurrent selection could increase the frequency of genotypes with high horticultural quality. This strategy can substantially contribute for the development of adapted cultivars with good insect resistance, which would enable them to be included in integrated pest management programs, and, as a consequence, would reduce the use of insecticides.

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