Genotypic relationships between components of postharvest resistance of cherry and salad tomato

Relações genotípicas entre componentes da resistência pós-colheita em tomate Cereja e Salada

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Abstract

This study aimed to evaluate the need for individual path analysis of Cherry (*L. esculentum* var. *cerasiforme*) and Salad (*L. esculentum*) tomatoes type, seeking information about which variables are associated with post-harvest resistance (PHR), so guiding the selection of material for breeding programs. We performed the analysis of variance, genotypic correlations, multicolinearity diagnosis, and the display of genotypic correlations through path analysis. More explicatory variables of PHR in Salad tomatoes type were the peduncle scar diameter (PSD) and the fruit mean diameter (FMD); the mesocarp thickness (MST) and fruit mean weight (FMW) in cherry type. For Cherry tomatoes, gains can be obtained in the PHR through indirect selection by MST. This will be greatest if those fruits with lower FMW are selected from among the fruits with more MST. In the case of Salad, fruits with lower PSD should be indirectly selected, and from among these, the fruits with the most FMD. The path analysis should be performed considering each type of tomato, since the explicatory variables differ between them.

Keywords: Genetic correlation; genetic breeding; multicolinearity*; Lycopersicon esculentum; Lycopersicon esculentum* var. *cerasiforme.*

Resumo

Este trabalho objetivou avaliar a necessidade de realizar análise de trilha individualizada para tomates tipo Salada (*L. esculentum*) e Cereja (*L. esculentum* var. *cerasiforme*), visando obter informações sobre quais variáveis estão relacionadas com a resistência pós-colheita (RPC), e orientar a seleção de materiais para programas de melhoramento. Realizaram-se análises de variâncias, correlações genotípicas, diagnóstico de multicolinearidade e o desdobramento das correlações genotípicas por meio de análise de trilha. As variáveis mais explicativas da RPC em tomates tipo Salada foram o diâmetro da cicatriz do pedúnculo (DCP) e o diâmetro médio do fruto (DMF); a espessura do mesocarpo (ESP) e o peso médio dos frutos (PMF) em tipo Cereja. Em tomates Cereja, ganhos podem ser obtidos na RPC por meio de seleção indireta via ESP. Estes serão maiores se dentre os frutos de maior ESP forem selecionados os de menor PMF. No caso de Salada, deve-se selecionar indiretamente os frutos de menor DCP e dentre estes os de maior DMF. A análise de trilha deve ser realizada considerando cada tipo de tomate, visto que as variáveis explicativas diferem entre estes.

Palavras-chave: Correlação genotípica, melhoramento genético, multicolinearidade, *Lycopersicon esculentum*, *Lycopersicon esculentum* var. *cerasiforme*.

Introduction

The tomato is amongst the most highly consumed horticultural products in the world, being a source of the vitamins A and C and of minerals such as potassium and magnesium. It is a fruit with origin in the Andean countries, from the north of Chile to Colombia. It pertains to the family Solanaceae, which also contains the capsicum, egg-plant and sweet potato.

Amongst the different types of tomato the most common are the Salad tomato (*Lycopersicon esculentum*) and the Cherry tomato (*Lycopersicon esculentum* var. *cerasiforme*). The cherries are characterized by their reduced size, low weight and higher levels of soluble solids. The Salad type tend to present greater post-harvest resistance (Alvarenga, 2004). Cherry type tomatoes are usually picked ripe in order to express maximum flavor. Salad type tomatoes are picked semi-ripe, being transported and sold in inadequate conditions (Wills & Ku, 2002; Jha & Matsuoka, 2005). In both cases it is necessary to study in greater detail the characteristics linked to post-harvest resistance.

Information regarding the correlation between traits is relevant to breeding programs, especially if selection is hampered due to low heritability and / or measurement and identification problems (Cruz et al., 2004). However, this study only reports on the association between characters, and does not determine cause and effect. To understand this association Wright (1921) proposed an analysis of path coefficients, which reveals genotype correlations between the direct effects and indirect explanatory variables on a basic variable.

This work aimed to 1. Evaluate the need to perform individualized path analysis for the tomato types Salad and Cherry, seeking information about which variables are related to post-harvest resistance in each variety and 2. Guide the selection of material for breeding programs.

Materials and methods

This experiment was conducted in 2006 in the Federal University of Espírito Santo (UFES), (20º 45' 48" S, 41º 31’ 57" W, 210 masl) using 33 accessions of tomato, 18 of the Salad variety (*L. esculentum*) and 15 Cherry (*L. esculentum* var. *cerasiforme*). An experimental design was implemented of completely randomized blocks with three replications and 10 fruits per plot. Planting was performed in a greenhouse in 12 lt pots according to Filgueira (2003). Fruits were harvested once mature, and characterized based on the morphological descriptors of the International Plant Genetic Resources Institute (IPGRI, 1996). Post-harvest resistance was evaluated in a laboratory at ambient conditions A (26°C and 65% relative humidity) based on a non-destructive planing method (Calbo & Nery, 1995).

In order to ensure that the assumptions of the analysis of variance were met, tests of homogeneity and normality of error variance were performed. This was accomplished, and the existence of genetic variation, with estimates of genotypic correlations (Mode & Robinson, 1959) and coefficients of genotypic determination (Vencovsky & Barriga, 1992) being obtained.

The degree of multicolinearity of the X’X matrix was evaluated (Montgomery & Peck, 1981). In order to detect the variables that contributed to the emergence of multicolinearity an analysis of elements of eigenvectors associated with eigenvectors was performed (Belsley et al., 1980). Post-harvest resistance variable (PHR in kgf/cm^2) was considered as a basic variable, and the explanatory variables were : fruit mean weight (FMW in g), fruit mean diameter (FMD in cm), mean fruit length (FML in cm), peduncle scar diameter (PSD in mm); mesocarp thickness (MST in mm), level of soluble solids, (LSS in ºBrix), and pH (pH), performing the variable exclusion problems by obtaining the NC < 100, characterizing a weak multicolinearity that does not constitute a problem for the path analysis. The ramifications of the genotype correlations through direct and indirect effects were then made through path analysis (Wright, 1921).

For data analysis we adopted a causal diagram for each variety, with the following explanatory variables for the salad type: FMD, PSD, MST, LSS, and pH, where the unidirectional arrow indicates a direct effect (path coefficient) of each explanatory variable, while the bidirectional arrow represents the interdependence of two explanatory variables, whose magnitude is quantified by genetic correlations. The causal diagram for the accessions of the Cherry variety was similar, differing only by the replacement of FMD by FMW.

The results of the path analysis were interpreted according to Vencovsky & Barriga (1992). Statistical analysis was performed following the recommendations of Cruz et al. (2004), and processed using the computational resources of the GENES program (Cruz, 2001).

Results and Discussion

The existence of significant differences was verified for both groups of accessions at the level of 1% probability in the ´F´ test for all the variables evaluated.

Pathway analysis - Salad Variety

The diagnosis showed moderate to strong colinearity, with the variables FMW and FML being discarded. The explanatory variables used to form the causal diagram and the path analysis were FMD, PSD, MST, LSS and pH (Figure 1). The coefficient of determination of the path analysis was $R^2 = 0.766$ (Table 1), indicating that the variables used explain most of the changes in the PHR.

Table 1. Estimates of the direct and indirect effects of Mean Fruit diameter (MFD), Peduncle scar diameter (PSD), mesocarp thickness (MST), level of soluble solids (LSS) and pH (pH) on post-harvest resistance (PHR kgf/cm²) in the Salad variety of tomato, Alegre-ES, 2006.

Variable	Effect	Estimate	Variable	Effect	Estimate
FMD	Direct on PHR	1.266	LSS	Direct on PHR	-0.489
(cm)	Indirect via PSD	-1.490		Indirect via FMD	-0.689
	Indirect via MST	-0.057	(°Brix)	Indirect via PSD	0.608
	Indirect via LSS	0.266		Indirect via MST	0.089
	Indirect via PhF	-0.096		Indirect via PhF	0.128
	Total	-0.111		Total	-0.351
PSD	Direct on PHR	-1.650	pH	Direct on PHR	-0.188
(cm)	Indirect via FMD	1.143		Indirect via FMD	0.646
	Indirect via MST	-0.048	(pH)	Indirect via PSD	-0.681
	Indirect via LSS	0.180		Indirect via MST	-0.088
	Indirect via PhF	-0.077		Indirect via LSS	0.333
	Total	-0.452		Total	0.022
MST	Direct on PHR	-0.112	MST	Indirect via LSS	0.392
(mm)	Indirect via FMD	0.652		Indirect via PhF	-0.148
	Indirect via PSD	-0.715		Total	0.069
Coefficient of determination (R^2)			0.766		
Effect of residual variable			0.483		

For the variable FMD, with a negative correlation coefficient (-0.111) and high positive direst effect (1.266) of PHR, it was seen that, despite the high direct effect presented, intensified selection pressure on the FMD may not provide the give satisfactory genetic gains for PHR, because this genetic correlation is mainly caused by indirect effects,, and a cause-effect relationship was not observed. In this case, significant indirect causal characters must be considered simultaneously in the selection process (Cruz & Regazzi, 1997).

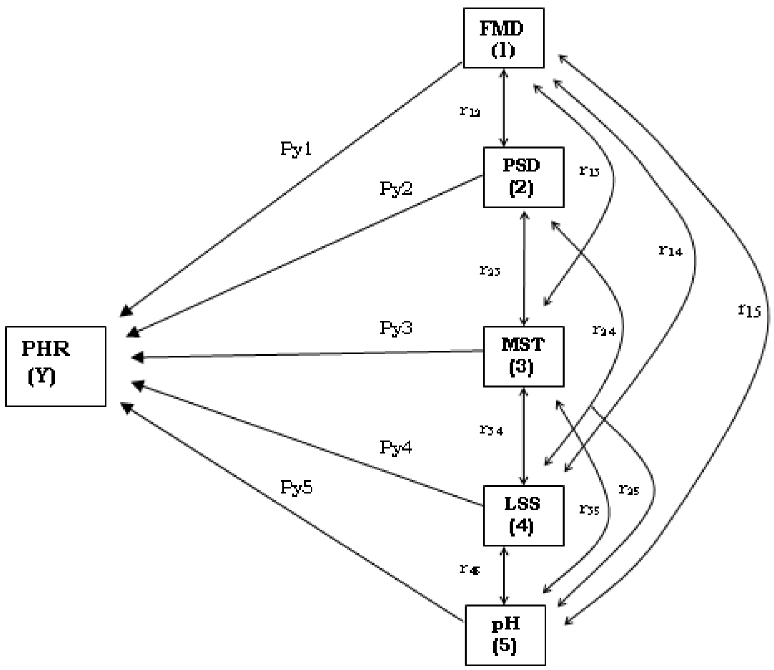

Figure 1. Causal diagram, showing the direct and indirect effects of explanatory variables: Fruit mean diameter (FMD) (1), peduncle scar diameter (PSD) (2), mesocarp thickness (MST) (3), level of soluble solids (LSS) (4) and pH (5) on the basic variable: post-harvest resistance of fruits (y). Pvi: direct effect of each one of five explanatory variables on the basic variable. Rij: coefficient of genetic correlation between the explanatory variables.

Among the indirect effects the elevated negative effect of the variable PSD is notable (-1.490). This indicates that indirect selection through the variable FMD would be sufficient to increase PHR, if the indirect effects of PSD are considered at the same time. In order to obtain increased PHR indirect selection via FMD should be carried out on fruits of larger mean diameter, followed by selection of fruits presenting lower PSD.

In PSD a negative correlation was observed (-0.452), associated with an high negative direct effect on the basic variable (-1.650), indicating its utility in indirect selection for PHR.
This result demonstrates that indirect selection for lower values of PSD will result in higher values of PHR, corroborating the results obtained by Freitas et al. (1999), which studied the characteristics of post-harvest preservation of tomato fruits, observing that the smallest peduncle scar diameter correlates with greater post-harvest resistance.

Among the indirect effects, the high effect of the variable FMD of PHR is notable (1.143). Here, it is necessary to apply restricted selection (Vencovsky & Barriga, 1992) to eliminate the effects of indirect reactions. Thus, the truncated selection on PSD will be less efficient in improving PHR than restricted selection, as the restriction allows the selection of fruits with lower PSD, and amongst these the selection of accessions with greater FMD, eliminating the unwanted influence of the indirect effect on the basic variable and so providing a greater increase to PHR. MST, LSS and pH presented low levels of correlations and direct effects and were discarded for indirect selection for gains in PHR.

PSD and FMD should be used to obtain indirect gains in PHR. Due to the higher values of correlation and direct effect seen in PSD, the selection of this should be prioritized, selecting accessions with lower PSD, and amongst these those that present greater FMD.

Pathway analysis – Cherry variety

The diagnosis showed moderate to strong colinearity, with the variables FMD and FML being discarded. The explanatory variables used to construct the causal diagram, after discarding two variables were: FMW, PSD, MST, LSS and pH.

The coefficient of determination of the path analysis model (R^2) was greater than unity (Table 2), showing that variation in the PHR are fully explained by this causal scheme. For FMW, with a positive correlation coefficient (0.495) and negative direct effect (-0.660), it is observed that the genetic correlation is caused principally by indirect effects, with no cause-effect relationship. In this case, significant indirect causal characters must be considered simultaneously in the selection process (Cruz & Regazzi, 1997).

Among the indirect effects, the elevated positive effect of MST is notable (1.410). Demonstrating that, although the FMW is positively correlated with PHR, this selection will only be efficient in increasing PHR if the indirect effects of MST are considered simultaneously. Indirect selection for PHR via FMW should be performed in fruits with low weight, and amongst these, those that present the highest thickness. PSD and LSS are not useful for indirect selection due to their low values of correlation and direct effect. The use of pH to make gains in PHR is also ruled out due to its reduced direct effect.

The variable MST presents a high positive correlation (0.772) associated with a high positive direct effect (1.549), indicating a cause-effect relationship. According to Severino et al. (2002) it is important for crop improvement to identify from among the traits with high correlation to the basic variable those which present the greatest direct effect in a manner favorable to selection, so that the correlated response to indirect selection is efficient. The variable MST stands out as a principal variable to be used for indirect selection for gains in PHR.

The negative indirect effects of other variables causes the reduction in magnitude of the correlation. Amongst these the indirect effect of FMW is notable (-0.601). The presence of negative indirect effects shows the difficulties in selection based only on performance of the main variable.

Vencosvsky & Barriga (1992) relate that, apparently, there is not yet a suitable method for maximizing response to selection when considering only the principal components of the principal variable. In this case, these authors consider it necessary to apply a restricted selection to eliminate the undesirable indirect effects and exploit the existing direct effect.

Thus, the truncated selection on the variable MST will be less efficient in improving the

Table 2. Estimates of the direct and indirect effects of Mean Fruit weight (MFW), Peduncle scar diameter (PSD), mesocarp thickness (MST), level of soluble solids (LSS in °Brix) and pH (pH) on post-harvest resistance (PHR kgf/cm²) in the Cherry variety of tomato, Alegre-ES, 2006.

Variable	Effect	Estimate	Variable	Effect	Estimate
FMW	Direct on PHR	-0.660	TSS	Direct on PHR	0.336
(g)	Indirect via PSD	-0.117		Indirect via FMW	0.254
	Indirect via MST	1.410	(°Brix)	Indirect via PSD	0.043
	Indirect via LSS	-0.129		Indirect via MST	-0.586
	Indirect via pH	-0.006		Indirect via pH	0.139
	Total	0.495		Total	0.187
DCP	Direct on PHR	-0.161	pH	Direct on PHR	0.343
(mm)	Indirect via FMW	-0.482		Indirect via FMW	0.012
	Indirect via MST	0.981	(pH)	Indirect via PSD	0.001
	Indirect via LSS	-0.090		Indirect via MST	0.244
	Indirect via pH	-0.003		Indirect via LSS	0.136
	Total	0.243		Total	0.738
ESP	Direct on PHR	1.549	ESP	Indirect via LSS	-0.127
(mm)	Indirect via FMW	-0.601		Indirect via pH	0.054
	Indirect via PSD	-0.102		Total	0.772
Coefficient of determination (R^2)			1.145		

PHR than restricted selection, as the restriction will allow the selection of fruits with greater thickness, and amongst these the fruits that present lowest FMW, eliminating the influence of the undesirable indirect effects.

Discrepancies between path analyses

The diagnoses were concordant in discarding FML. However, the FMW while discarded in the diagnosis of the Salad variety, was one of the main variables for the Cherry variety. In contrast, the FMD was discarded from the Cherry analysis, but showed a high direct effect when fruits of the Salad variety were considered.

The variable PSD was not recommended for indirect selection for gains in PHR of the Cherry variety. However, in the Salad variety high direct effects indicate its utility. The MST also showed an important difference as a function of the group of accessions evaluated. For Salad variety fruits, its use was discarded for indirect selection, due to low correlation and direct effect values. In contrast, for Cherry variety the high values of correlation and direct effect were notable, making it the principal variable for selection for indirect gains in PHR for this variety.

The variable PSD and FMD were the variables that most explained changes in PHR for the Salad variety. For the cherry variety, the variables MST and FMW were primarily responsible for variation in the PHR. These results show the contribution of explanatory variables on PHR differs according to the accessions studied.

The coefficient of determination (R^2) of the model of path analysis for Cherry tomatoes was greater than unity, showing that amendments to the basic variable is fully explained by the causal scheme. In contrast, in the Salad variety, where the R^2 obtained shows that other variables, not considered in this work, may also explain the changes in the basic variable.

A review of the literature revealed no work applying path analysis to the post-harvest resistance of the salad or the cherry tomato varieties, highlighting the importance of this research. Most studies are related to the productivity of several crops (Marchezan et al., 2005; Lopes et al., 2007; Hidayatullah et al., 2008), with little attention paid to other variables such as post-harvest resistance. As components of yield, other traits must be considered due to the relevance and utility of this analysis for indirect selection of material, as elucidated by Falconer & Mackay (1996).

Conclusions

- In salad tomatoes, gains can be obtained in post-harvest resistance by means of indirect selection on the diameter of the peduncle scar. Gains will be greatest if fruits possessing the smallest peduncle scar are selected from amongst those with the largest fruit diameter.

- For Cherry tomatoes selection should favor fruits with the greatest mesocarp thickness, and from amongst these those with the least weight.
- Path analysis should be conducted taking into consideration each tomato variety, given that the explicative variables differ between them.

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