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Correlation and Sequential Path Model for Some Yield-related Traits in Melon (*Cucumis melo* L.)

E. Feyzian[1], H. Dehghani[1*], A. M. Rezai[2], and M. Jalali[1]

ABSTRACT

Investigation of the interrelationships between yield and its components will improve the efficiency of a breeding program with appropriate selection criteria. In this study, the relationship among yield components and their direct and indirect influences on the total yield of melon were investigated. The study was based on evaluation of 49 entries generated from a 7×7 diallel involving Iranian melon landraces under two conditions of cultivation, pruning and non-pruning. A sequential path model was used for ordering the various variables in first and second-order paths based on their maximum direct effect and minimal colinearity. Two first-order variables, namely the number of fruits per plant and average weight of fruits per plant accounted for 91% and 83% of total variation in total weight per plant under the pruning and non-pruning conditions, respectively. The direct effects of these two variables on total weight per plant under non-pruning conditions were nearly equal, but the direct effect of average weight of fruits per plant in the pruning data set was much higher than the number of fruits per plant (1.14 vs. 0.73). All direct effects were found to be significant as indicated by bootstrap analysis. The results indicated the utility of the sequential path model for determining the interrelationships between yield and related traits in melon.

Keywords: Colinearity, Correlation, *Cucumis melo L.*, Sequential path analysis.

INTRODUCTION

Melon (*Cucumis melo* L. 2n= 2x= 24) is an economically important vegetable species, which is subdivided into six cultivar groups-Cantaloupensis, Inodorus, Flexuosus, Conomon, Chito–Dudaim and Momordica (Munger and Robinson, 1991). In Iran, the Cantaloupensis and Inodorus groups are most important for commercial production.

Path coefficient analyses have been widely used in plant breeding to determine the nature of the relationships between yield and its contributing components. Wright (1921) proposed a method called path analyses which partitions the estimated correlation in direct and indirect effect; Dewey and Lu (1959) first carried out this analysis on plants. In melon, yield is correlated with several traits including days to anthesis, number of fruits, average fruit weight, primary branch number, number of nodes on the main stem, stem length, internode length and fruit shape index (Lippert and Hall 1982; Vijay 1987; Abdalla and Aboul-Naser 2002; Taha *et al*., 2003). Lippert and Legg (1972) evaluated the gene action of yield traits in melon and reported that both additive and non-additive variance components were important in the genetic control of yield-associated traits. Kalb and Davis (1984a, b) evaluated the combining ability,

[1] Department of Plant Breeding, College of Agriculture, Tarbiat Modares University, Tehran, Islamic Republic of Iran.
[2] Department of Plant Breeding, College of Agriculture, Isfahan University of Technology, Isfahan, Islamic Republic of Iran.
[*] Corresponding author, e-mail: dehghanr@modares.ac.ir

heterosis and genetic variance for yield, maturity and fruit quality through the use of a 6-parent diallel and reported greater variance of GCA than that of SCA for all traits. Taha *et al*. (2003) evaluated 13 variable lines representing different melon types and reported a positive and significant association between the number of fruits/vine with the number of primary branches, and between fruit weight with plant length. Zalapa *et al*. (2006, 2007 and 2008) conducted a generation mean analysis, F_3 analysis and QTL mapping to investigate the inheritance of some characteristics related to melon yield and estimated correlation, variances, heritability and the number of effective factors for these characteristics. However, few studies have examined the direct and indirect effects of related characteristics on melon yield (Vijay, 1979; More *et al*., 1987).

In most studies involving path analysis, researchers considered the predictor characters as first-order variables in order to analyze their effects over a dependent variable such as yield. This approach might result in multi-colinearity for variables, and there may be difficulties in interpretation of the actual contribution of each variable (Hair *et al*., 1995). Samonte *et al*. (1998) adopted a sequential path analysis for determining the relationship between yield and its related characteristic in rice. Mohammadi *et al*. (2003) used this method to determine the association between grain yield and related characteristics in maize by applying the model to different data sets.

Our objectives were to determine the usefulness of a sequential path model in melon, and to analyze the associations between yield and related characteristics in melon.

MATERIALS AND METHODS

Experiments

Six Iranian melon landraces (*Cucumis melo.* L.) Eyvanaki, Abasali, Tashkandi, Hose-sorkh, Mashhadi and Mirpanji from the Inodorus group and one exotic melon cultivar, Ananassi, from the Cantaloupensis group- were selected to be used in a complete diallel and crossed using five plants per cross.

Seeds from the 49 entries (21 F_1, 21 reciprocal F_1 and 7 parents) germinated in plant bands in the greenhouse, and then transplanted to the field in Isfahan (Iran) on 4 April 2006. Two types of α-lattices were set up with four replications for two conditions of cultivation, namely pruning and non-pruning. Under the non-pruning condition, the plants were only thinned 3 weeks after transplanting but, under the other condition, in addition to thinning pruning operations were also performed. For each plant, just two primary branches and two fruits were left, and extra fruits were omitted. The pruning operation is fashionable in some regions in Iran so the farmers are able to grow bigger and more attractive fruits. Spacing was 2 m between rows and 0.5 m between plants (10,000 plants ha^{-1}). Each plot consisted of five single plant hills. All plots were hand weeded in order to maintain proper weed control. Mature fruits were harvested every day during July and August.

Data Collection

Fruit number (NF) and total weight of all fruits (TW; kg) were collected per plant using all fruits of at least 10 cm in diameter. The average weight (WT; kg) per fruit was calculated for each plant by dividing the total number of fruit per plant by the total weight per plant. The average length (L; cm), width (W; cm), cavity of fruits in length (SL; cm), cavity of fruits in width (SW; cm), were calculated for each plant by dividing the total number of fruit per plant by the total length, width, seed cavity of fruits in length and seed cavity of fruits in width per plant. Average leaf length (LL; cm) and width (LW; cm) were calculated for each plant using the three biggest leaves, 80 days after transplanting. Crown diameter (C; cm) was also calculated 80 days after transplanting for each plant. The average flesh

(F; cm) and skin (S; mm) thicknesses were calculated on the radial cross section for each plant by dividing the total number of fruit per plant by the total flesh and skin thickness per plant. The average distance of fruit formation from the crown (PF) for each plant, was calculated by dividing the total number of fruit per plant by the total distance of the formation of fruits from the crown in the internodes. The shape index of fruit (SI) was calculated using fruit length divided by the width. The average distance of internodes per plant (I; cm) was calculated using the four middle internodes 80 days after transplanting. The average number of days to maturity of fruits (D) was calculated for each plant by dividing the total number of fruit per plant by the total number of days to maturity of fruits per plant. In addition to these characteristics the number of primary branches was only recorded in the non-pruning experiment at the end of the harvest.

Abbreviations are going to be used in the proceeding text and tables.

Statistical Analysis

The data were tested for skewness, kurtosis and Q-Q plot for normality by SPSS (Ver. 14.0) statistical software. A preliminary analysis was performed by means of the conventional path model in which all yield–related characteristics were considered as first order predictor variables with TW. Correlation coefficients between various pairs of characteristics were estimated. Then, sequential stepwise multiple regressions were preformed to organize the predictor variables into first and second order paths based on their respective contributions to the total variation of total weight and minimum colinearity. Residual analysis showed that assumptions of normal distribution and homogeneity of error in multiple regression analysis were provided. Durbin-Watson statistics was calculated by means of SPSS 14.0 to diagnose sequent correlation among error terms. The level of multi-colinearity in each path was measured by the variance inflation factor (VIF) as suggested by Hair *et al*. (1995). VIF's indicates the extent of effects of other independent variables on the variance of the selected independent variable. [$VIF = 1/(1 - R_i^2)$, where R_i^2 is the coefficient of determination for the prediction of the ith variable by the predictor variables]. Thus, large VIF's values (above 10) indicate high colinearity (Hair *et al*., 1995).

Based on the VIF values and the magnitude of direct effect, WT and NF were considered as first-order variables among the various yield characteristics under study. This procedure was again performed separately taking NF and WT as dependent variable in order to identify the first order variables for these two response variables which shall be, consequently, second-order variables for TW. Fruit length was not considered in the path model for weight because of high multi-colinearity. Direct effects of the yield characteristics were estimated using the procedure described by Williams *et al*. (1990). The partial coefficient of determination (analogues to R^2 of linear regression) was calculated from the path coefficients for all predictor variables. To estimate the standard error of path coefficients, bootstrap analysis (Efron and Tibshirani, 1993) was performed by S-PLUS 2000 statistical software, followed by the standard t test to verify the significance of path coefficients.

RESULT AND DISCUSSION

In the pruning condition, all characteristics except for NF, I, PF and SI showed significant correlation with TW (Table 1). The non-significant traits with TW under non-pruning conditions were I, SI, S and PB. The highest correlation for total weight was between WT and TW (r=0.73) in the pruning data set and W and TW (r= 0.5) in the non-pruning data set. The correlation of NF and TW was not significant under the pruning condition (r= 0.11) but was significant under the non-pruning condition (r= 0.34).

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Table 1. Correlation coefficients between characteristics[a] measured under both pruning (above diagonal) and non–pruning conditions (below diagonal).

	NF	Le.l	Le.w	I	WT	PF	D	L	W	SI	SW	C	S	F	TW
NF	-	0.13	0.12	-0.06	-0.55**	.15*	-0.16*	-0.56**	-0.41**	-0.28**	-0.40**	-0.20**	-0.16*	-0.32**	0.11
Lel	0.04	-	0.86**	0.21**	0.24**	0.10	0.10	0.13	0.26**	-0.05	0.06	0.12	-0.13	0.34**	0.37**
Lew	0.05	0.89**	-	0.04	0.21**	0.15*	0.14*	0.12	0.27**	-0.07	0.14	0.14	-0.14	0.31**	0.33**
I	-0.29**	0.21**	0.05	-	0.09	-0.06	0.00	0.24**	-0.01	0.26**	-0.01	0.04	0.17*	0.02	0.12
WT	-0.59**	0.24**	0.21**	0.14*	-	-0.23**	0.23**	0.72**	0.88**	0.11	0.60**	0.52**	0.24**	0.77**	0.73**
PF	.26**	0.02	0.06	-0.17*	-0.16*	-	0.06	-0.16*	-0.18*	-0.04	0.02	-0.14*	-0.07	-0.14*	-0.11
D	-0.21**	-0.01	0.02	-0.15*	0.29**	0.26**	-	0.20**	0.16*	0.10	0.10	0.15*	-0.23**	0.06	0.16*
L	-0.56**	0.04	0.02	0.25**	0.73**	-0.10	0.17*	-	0.42**	0.74**	0.39**	0.45**	0.32**	0.35**	0.46**
W	-0.45**	0.27**	0.24**	0.07	0.87**	-0.14*	0.30**	0.44**	-	-0.29**	0.61**	0.47**	0.17*	0.82**	0.69**
SI	-0.26**	-0.16*	-0.17*	0.22**	0.10	0.01	-0.04	0.72**	-0.30**	-	-0.03	0.13	0.19**	-0.22**	-0.03
SW	-0.37**	0.11	0.07	0.08	0.68**	-0.16*	0.25**	0.50**	0.74**	-0.04	-	0.42**	0.10	0.41**	0.38**
C	-0.09	0.14	0.14	0.01	0.51**	0.00	0.17*	0.38**	0.40**	0.12	0.31**	-	0.08	0.34**	0.46**
S	-0.35**	-0.13	-0.19**	0.32**	0.29**	-0.06	-0.14*	0.37**	0.25**	0.19**	0.25**	0.11	-	0.24**	0.20**
F	-0.41**	0.29**	0.28**	0.01	0.80**	-0.07	0.26**	0.35**	0.87**	-0.29**	0.53**	0.36**	0.26**	-	0.66**
TW	0.34**	0.28**	0.24**	-0.07	0.48**	0.15*	0.15*	0.30**	0.50**	-0.06	0.41**	0.42**	0.02	0.44**	-
PB	0.25**	0.02	0.04	-0.10	-0.17*	0.13	0.10	-0.21**	-0.13	-0.14	-0.18*	-0.04	-0.08	-0.08	0.03

* and ** , Significant at $P\leq 0.05$ and $P\leq 0.01$, respectively.
[a] Abbreviations are described in materials and methods.

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The correlation of TW and WT under the pruning condition was greater than that for non-pruning (r= 0.73 vs. 0.48) .Significant (p≤ 0.01) negative correlation at both data sets were detected between NF and WT [r= -0.55 (pruning) and r= -0.59 (non-pruning)]. These results are in close agreement with Zalapa *et al*. (2006, 2007, 2008), who reported a negative association between fruit number and average weight per fruit (r=-0.58 at both Arlington and Hancock; r= -0.69 in California and r= -0.51 in Wisconsin; r= -0.76 in Arlington and r=-0.7 in Hancock, respectively). The correlation between TW and the number of primary branches was not significant in the non-pruning data set (r= 0.03). These results are not consistent with Taha *et al*. (2003) and Zalapa *et al*. (2006) who reported a positive and significant correlation between total weight and number of primary branches (r= 0.82 and r=0.22, respectively). Correlations of Le.l and Le.w with TW were significant in both data sets. This might be due to an increase in the rate of photosynthesis as the leaf size increased. Correlation of PF and WT was negative and significant for both data sets. These findings are consistent with Zalapa *et al*. (2008) who reported a positive and significant correlation (r= 0.41 in Arlington and r= 0.32 in Hancock, respectively) between WT and the percentage of plants with a predominantly crown fruit set. Increasing the distance of the fruit formation position from the crown postpones the formation of fruits and consequently decreases their weight. The correlation of crown diameter and WT was positive and significant for both conditions [r= 0.52 (pruning), r =0.51 (non-pruning)]. It seems that increasing crown diameter leads to an increase in the power of uptaking minerals and, therefore, to increases in fruit weight. The correlation of days to maturity of fruits and WT were positive and significant both conditions. [r= 0.23 (pruning) and r =0.29 (non-pruning)]. It is logical that late mature genotypes have a higher weight.

Estimates of direct effects in conventional path analysis, where the yield-related characteristics are considered as first order variables with TW as the response variable, are presented in Table 2. The multi-colinearity indices are presented in Table 3. High multi-colinearity is observed for some characteristics such as width (VIF 45.43 and 12.91 in the pruning and non-pruning data sets, respectively). High correlations between some predictor variables, namely W and WT (0.88 in the pruning and 0.87 in the non-pruning conditions) led to high multi-colinearity and a consequent inability to ascertain the total variation of TW due to mixed or confounded

Table 2. Direct effects of first-order predictor variables on total weight and measure of colinearity in model 1 (all predictor variables as first-order variables).

	Non pruning		Pruning	
Character	Direct effect	VIF[b]	Direct Effect	VIF
NF[a]	0.759	1.794	1.024	2.151
WT	0.927	16.08	0.515	14.012
W	0.446	45.429	0.569	12.901
SI	0.523	71.69	0.334	3.485
D	0.045	1.16	0.046	1.326
F	0.095	3.761	0.058	4.767
C	-0.001	1.548	-0.042	1.528
Le.w	-0.027	1.283		
SW	-0.006	1.897		
L	-0.388	88.314		
I			0.056	1.312
Le.l			-0.006	1.269
PF			0.041	1.281

[a] Abbreviations are described in materials and methods.
[b] Variance inflation factor.

Table 3. Variance inflation factor (VIF) values for the predictor variables in model 1 (all predictor variables as first-order variables) and model 2 (predictors grouped according to first- and second-order variables).

Predictor variables	Response variables	Pruning VIF M1[b]	Pruning VIF M2[c]	Predictor variables	Response variables	Non pruning VIF M1	Non pruning VIF M2
NF[a]	TW	1.794	1.441	N.F	T.W	2.151	1.529
WT		16.08	1.441	WT		14.012	1.529
W	NF	45.429	1.894	W	NF	12.901	4.896
SW		1.897	1.695	SI		3.485	1.33
C		1.548	1.456	C		1.528	1.307
Le.w		1.283	1.079	PF		1.281	1.183
L		88.314	1.372	D		1.326	1.277
W	WT	45.429	3.303	I		1.312	1.22
SI		71.69	1.121	Le.l		1.269	1.191
Le.w		1.283	1.129	F		4.767	4.248
F		3.761	3.188	W	WT	12.901	4.498
D		1.16	1.09	SI		3.485	1.198
				F		4.767	4.144
				C		1.528	1.29
				PF		1.281	1.041

[a] Abbreviations are described in materials and methods.
[b] Model 1.
[c] Model 2.

effects. In contrast to the above results, sequential path analysis (illustrated in Figures 1 and 2 for the pruning and non-pruning data sets, respectively) provided a better understanding of the interrelationships between the various variables and their relative contribution to TW. The mean direct effects estimated from a set of 200 bootstrap samples were in close agreement with the observed direct effects of various characteristics (Table 4). The low standard error for all of the direct effects and low bias also indicated the robustness of the sequential path model. The direct and indirect effects for response variables are shown in Table 5 for the pruning and non-pruning conditions.

NF and WT as first-order variables accounted for 91 and 83 % (Table 4) of TW in the pruning and non-pruning data sets, respectively. The regression coefficient for the pruning condition was *TW= -2.966+ 2.106NF+1.353WT*; for the non-pruning condition, the regression coefficient was *TW= -2.738+1.697NF+1.554WT*. The Durbin-Watson value was 1.864 and 1.762 for the pruning and non-pruning data sets, respectively, which means that auto-correlation among residuals did not exist. Vijay (1987), using path analysis, showed that these two characteristics have a strong direct effect on yield and recommended them as selection criteria. These findings are also consistent with Zalapa *et al*. (2006, 2007, 2008) and Lippert and Hall (1982) who reported high and positive correlations between NF and WT with TW. In our results, the direct effects of these two variables on TW for the non-pruning condition were nearly equal (1.042 vs. 0.96), but the direct effect of WT on the pruning data set was much higher than NF (1.14 vs. 0.73). Because of a high negative correlation between NF and WT [r= -0.55 (pruning) and r= -0.59 (non-pruning)], their indirect effect on TW was high and negative on both the pruning and non-pruning data sets.

The path analyses of second-order variables showed that five characteristics explained 93% (under pruning condition) and 92% (under non-pruning condition) of the total variation of WT (Table 4).

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Table 4. Estimation of standard error values for path coefficients using bootstrap analyses.

Pruning							Non Pruning						
				Bootstrap							Bootstrap		
Predictor variables	Response variables	R^2 adj	Direct effect	SE	Mean	Bias	Predictor variables	Response variables	R^2 adj	Direct effect	SE	Mean	Bias
NF[a]	TW	0.91	0.73	.037	0.735	0.001	NF	TW	0.83	0. 96	0.069	0.962	0.006
WT			1.14	.033	1.1397	0.004	WT			1.042	0.053	1.04	-0.002
W	NF	0.42	-0.25	0.086	-0.229	0.022	W	NF	0.49	-0.41	0.113	-0.404	0.010
SW			-0.16	0.089	-0.19	-0.03	SI			-0.42	0.057	-0.414	0.003
C			0.17	0.06	0.176	0.005	C			0.21	0.067	0.203	-0.006
Le.w			0.24	0.054	0.246	0.002	PF			0.2	0.059	0.188	-0.008
L			-0.49	0.065	-.485	0.005	D			-0.15	0.061	-0.154	-0.004
W	WT	0.93	0.88	0.041	0.879	0.002	I			-0.19	0.056	-0.19	-0.004
SI			0.39	0.023	0.391	0.004	Le.l			0.16	0.05	0.161	0.003
Le.w			-0.05	0.019	-0.049	0.000	F			-0.24	0.116	-0.247	-0.012
F			0.15	0.043	0.144	-0.002	W	WT	0.92	0.78	0.045	0.777	-0.002
D			0.05	0.026	0.048	0.000	SI			0.38	0.024	0.386	0.002
							F			0.2	0.055	0.197	0.000
							C			0.08	0.024	0.087	0.003
							PF			-0.04	0.020	-0.038	0.003

[a] Abbreviations are described in Materials and Methods section.

Table 5. Direct and indirect effects under pruning conditions for the predictor variables in model 2 (grouped into first and second-order variables).

Pruning conditions	Response variable		TW			WT						NF							
			NF[a]	WT		W	F	S.I	Le.w	D		Le.w	L	W	C	S.W			
With pruning		NF	0.73	-0.41	W	0.88	0.72	-0.25	0.24	0.14	Le.w	0.24	0.03	0.7	0.03	0.03			
		WT	-0.63	1.14	F	0.12	0.15	-0.03	0.05	0.0	L	-0.06	-0.49	-0.21	-0.22	-0.2			
					S.I	-0.11	-0.08	0.39	-0.03	0.04	W	-0.07	-0.11	-0.25	-0.12	-0.15			
					Le.w	-0.01	-0.01	0.0	-0.05	0.0	C	0.02	0.08	0.08	0.17	0.07			
					D	0.01	0.0	0.0	0.01	0.05	S.W	-0.02	-0.06	-0.1	-0.07	-0.16			
	r		0.11	0.73		0.88	0.77	0.11	0.21	0.23		0.12	-0.56	-0.41	-0.2	-0.4			
	Response variable		NF[a]	WT		W	S.I	F	C	PF		W	S.I	C	PF	D	I	Le.l	F
With no pruning		NF	0.96	-0.56	W	0.78	-0.24	0.68	0.31	-0.11	W	-0.41	0.13	-0.16	0.06	-0.13	-0.03	-0.11	-0.36
		WT	-0.61	1.04	S.I	-0.12	0.38	-0.11	0.05	0.0	S.I	0.13	-0.42	-0.05	0.0	0.02	-0.09	0.07	0.12
					F	0.17	-0.06	0.2	0.07	-0.01	C	0.08	0.03	0.21	0.0	0.03	0.0	0.03	0.07
					C	0.03	0.01	0.03	0.08	0.0	PF	-0.03	0.0	0.0	0.2	0.05	-0.03	0.0	-0.013
					PF	0.0	0.0	0.0	0.0	-0.04	D	-0.05	0.0	-0.02	-0.04	-0.15	0.02	0.0	-0.04
											I	-0.01	-0.04	0.0	0.03	0.03	-.186	-0.05	0.0
											Le.l	0.04	-0.03	0.02	0.0	0.0	0.03	0.16	0.05
											F	-0.2	0.07	-0.08	0.02	-0.06	0.0	0.07	-0.24
	r		0.34	0.48		0.87	0.1	0.8	0.51	-0.16		-0.45	-0.26	-0.09	0.26	-.021	-0.29	0.04	-0.4

[a] Abbreviations are described in Materials and Methods section.

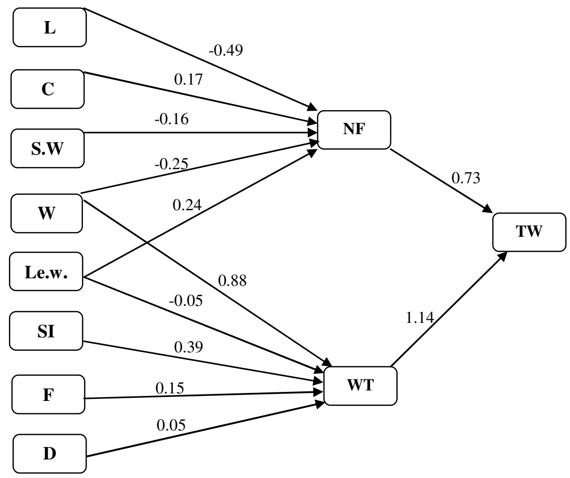

Figure 1. Sequential path model indicating interrelationships between total yield and related characteristics (pruning data set).
Abbreviations are described in Materials and Methods section.

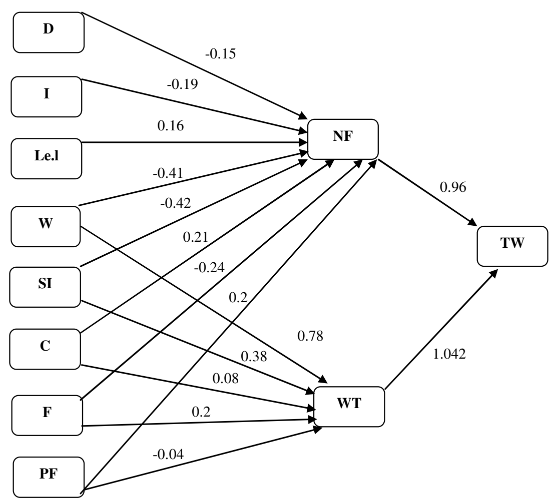

Figure 2. Sequential path model indicating interrelationships among total yield and related characters (non-pruning data set).
Abbreviations are described in Materials and Methods section.

The characteristics under the pruning condition were W, SI, Le.w, F and D but, for the non-pruning data set, they were W, SI, F, C and PF. The regression coefficient for the pruning condition was *WT= -6.427+0.41W-0.023Le.w+1.093SI+0.228F+0.008D* while, for the non-pruning condition, the regression coefficient was *WT= -5.951+0.344W+1.007SI+0.175C+0.278F-0.036PF*. The Durbin- Watson value was 1.64 and 1.86 for the pruning and non-pruning data sets, respectively, which means that auto-correlation among residuals did not exist.

The highest direct effect was recorded for width (p= 0.88 and 0.78 for the pruning and non-pruning data sets, respectively). The direct effect of SI on WT was positive and noteworthy (0.39 for the pruning and 0.38 for the non-pruning conditions), indicating that long fruits have a higher weight than round fruits. The direct effect of flesh thickness on WT (0.15 for the pruning and 0.2 in the non-pruning conditions), indicating the usefulness of this trait as a selection criterion for increasing the weight of fruits. These findings are consistent with Lippert and Hall (1982), who reported a positive and significant correlation between flesh thickness and TW.

In the second order path for NF, five characteristics, namely W, SW, C, Le.w and L explained only 42% of observed variation under the pruning condition (Table 4 and Figure 1). The regression coefficient was *NF= 1.794-0.041L-0.156C-0.045SW-0.048W+0.049Le.w*. The Durbin-Watson value was 1.96 which means that auto-correlation among residuals did not exist. Because the fruits were intentionally removed under the pruning condition, this variation was not discussed.

In the non-pruning data set, 49% of the variation in NF was explained by eight characteristics, namely SI, C, PF, D, I, Le.l, W and F (Table 4 and Figure 2). The direct effects of SI, D, I, F and W were negative but those of C, PF and Le.l were positive. The regression coefficient was *NF= 6.053-0.018D-0.125I+0.06Le.l-0.153W-0.918SI+0.363C-.281F+0.149PF*. The Durbin-Watson value was 2.07 which means that auto-correlation among residuals did not exist. The highest direct effect was recorded for W and SI (-0.41 and -0.42, respectively). The negative direct effect of SI indicated that genotypes, which had round fruits, produced more fruits. The direct effect of I on NF was negative indicating that the genotype with short internodes produced more fruits. These findings are in consistent with Knavel (1988, 1991) who reported short-internode cultivars, regardless of spacing, produced significantly fewer fruit. This inconsistency probably arises from the nature of the genotype Abasali and its crosses, which produced more fruit, although they had short internodes. However, for understanding the effect of internode distance on fruit number, it is better to use melons from the Cantaloupensis group.

CONCLUSIONS

Several researchers have previously explored the correlation of yield components with yield in melon. The traits often highlighted in this regard were plant length and primary branch (Taha *et al*., 2003), primary branch, fruit number per plant, fruit weight per plant (Zalapa *et al*., 2006), length, width and shape index (Lippert and Hall, 1982).

In most of these studies, the number of primary branches is introduced as an important factor in melon yield (Nerson, *et al*., 1983; Taha *et al*., 2003; Zalapa *et al*., 2006). However, in our study no significant relationship was observed between this characteristic and total weight. This may be due to the nature of the genotypes used in this experiment. Since most Iranian landraces in the Inodorus group have the potential to produce big fruits (Feyzian, 2004; Zamyad, 2004), their yield component is less directly related to the number of fruits. The existence of such landraces in Iran is probably due to the cultural altitude among people for preferring big fruits and the selection of these types for many years.

In Iran, most melon producers eliminate the fruits which form near the crown and retain fruits after the sixth internode (Abedi, 1996). The position of the formation of fruits and their distance from the crown can be viewed from two perspectives. On the one hand, basally concentrated fruits use temperate weather and create plants that are not infected with pathogens at the beginning of the growth season. On the other hand, fruits formed after some internodes have a higher source of leaves to increase their weight. From these two perspectives, the higher role is related to the high temperature at the end of the growth season, the pathogenic factor and their control as well. Our result is consistent with that of Zalapa *et al*. (2008) who showed that, in general, the fruits near the crown are heavier. However, it is better to investigate this matter for each cultivar and in several environments.

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The basic assumption while carrying out a multiple regression is that the characteristics used as predictor variables are independent of each other, In reality yield-related characteristics are intricately interrelated, often leading to high multi-colinearity. A novel approach of organizing the variables into different order paths based on relationships between traits was indicated by earlier studies and was first adopted in crop plants by Samonte *et al*. (1998).

Our study demonstrates the utility of the sequential path model in melon. When all the characteristics were used as first order variables in the conventional path model, we detected the occurrence of moderate to severe multi-colinearity for yield components. This highlighted the inadequacy of the conventional path model in determining the actual effect of each predictor variable on the response variable. Stepwise regression, in which characteristics with non-significant influence on the response variable are removed from the analysis, could probably reduce the amount of colinearity for the remaining characteristics in the model. However, in this process, some important information might be lost. Therefore, a better strategy would be to carry out a sequential stepwise regression in which characteristics removed after the first order path analyses are reanalyzed as possible predictor variables in the next order path. This strategy when adopted in the present study minimized the colinearity measures of the characteristics, and thereby facilitated the detection of the actual contribution of each predictor variable to different path components with negligible confounding effects and interference. The sequential path model not only indicated that other plant characteristics such as C, Le.w, Le.l and I exercise their influence as second order variables, but also provided a better understanding of their relative contributions to the first order variable. For instance, the analysis revealed that crown diameter, leaf width and flesh thickness have considerable influence on the first-order variable, with no direct effect on total weight.

In summary, the sequential path model presented in this study was efficient with respect to: (í) study of yield components under two conditions e.g. pruning and non-pruning, (íí) ordering of predictor variables in first and second order paths based on minimal colinearity using sequential stepwise regression and (ííí) use of bootstrap analysis to determine the standard error of the path coefficient for the consequent test of significance.

About 50% of total variation in NF was explained by related characteristics, indicating other characteristics must be chosen to improve the model in future studies. Character association revealed by path analysis could be influence by different factors including: (í) the germplasm used, (íí) the environment, (ííí) pruning method and (ív) the traits used in the analysis, as our results showed in the case of the number of primary branches. Plant competition (i.e. within row spacing) is a major factor that can affect melon productivity (Bhella, 1985; Knavel, 1988). Therefore, the general applicability of the present sequential path model can be ascertained by analysis of data from different sets of germplasms under different production conditions and different methods of pruning.

In Iran, people prefer the heavy (over 3 Kg) and elongated melon of the Inodorus group. Given the negative correlation between fruit number per plant and average fruit weight, the development of genotypes capable of supporting two to three fruits while simultaneously maintaining commercially acceptable fruit size for the Iranian market (3-4 Kg) may prove a challenge. Increasing the yield of melon through increasing the number of fruit is not a suitable choice. Therefore, a better strategy would be to keep to a maximum of two fruits on each plant via pruning operations and to increase their weight by selection indices such as flesh thickness and fruits width, leaf length and width, and crown diameter. Nevertheless Zalapa *et al*. (2007) reported two QTL associated with NF and one QTL associated with WT at the *a* locus which have independent effects and, therefore, could be used during marker assisted selection.

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همبستگی و تجزیه مسیر ترتیبی برای برخی از صفات وابسته به عملکرد در خربزه

ا. فیضیان، ح. دهقانی، ع. م. رضایی و م. جلالی

چکیده

بررسی روابط بین عملکرد و اجزای آن کارایی برنامه‌های اصلاحی را از طریق انتخاب شاخصهای مناسب افزایش می‌دهد. در این مطالعه رابطه بین اجزای عملکرد و آثار مستقیم و غیر مستقیم آن بر روی عملکرد در خربزه مورد بررسی قرار گرفت. این مطالعه بر مبنای ارزیابی ۴۹ ژنوتیپ که از یک تلاقی ۷×۷ از توده‌های بومی خربزه ایرانی به‌دست آمده بودند در دو شرایط هرس و غیر هرس بنا نهاده شد. از یک مدل تجزیه مسیر ترتیبی برای صفات مختلف براساس حداکثر اثر مستقیم و نیز حداقل چند همراستایی استفاده شد. دو صفت تعداد میوه و میانگین وزن میوه‌ها در هر بوته به عنوان صفات ردیف اول ۹۱ و ۸۳ درصد از تنوع موجود در صفت وابسته وزن کل میوه‌های (عملکرد) هر بوته را، به‌ترتیب در شرایط هرس و غیرهرس توجیه کردند. اثر مستقیم این دو صفت در شرایط غیرهرس تقریبا یکسان بود. اما در شرایط هرس اثر مستقیم میانگین وزن میوه‌ها بیشتر از اثر مستقیم تعداد میوه بود (۱/۱۴ در برابر ۰/۷۳). از طریق تجزیه بوت استرپ مشخص شد که تمام اثرهای مستقیم معنی‌دار هستند. نتایج نشانگر امکان استفاده از تجزیه مسیر ترتیبی برای مشخص کردن روابط بین صفات وابسته به عملکرد در خربزه می‌باشد.