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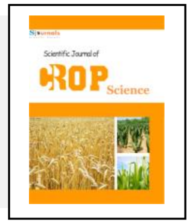

Original article

Multivariate analysis to determine relationship between phenological traits with yield components in native melon population (*Cucumis melo. L*)

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Canonical correlation analysis (CCA), factor analysis and simple correlation analysis were used to estimate relationships between plant characters [X set- days number for flowering, fruit formation, fruit maturity, harvesting, number of seeds per fruit, thousand seeds weight, seed length, seed width, plant length], and yield components [Y set- fruit weight (F.WE), fruit length(F.L), fruit width (F.WI) and number of fruits per plant (N.F.P)] of 41 native melons (Ghandak) collected from the Sistan region in the south eastern of Iran. The results of the canonical analysis showed that a high canonical correlation is observed between yield components and plant characters in first pairs of canonical variables (0.78). The findings obtained from the CCA indicate that fruit width (F.WI) had the largest contribution for the explanatory capacity of canonical variables estimated from yield components of the melon population. Thousand seeds weight and number of days to fruit formation had the largest contribution to explain the canonical variables estimated from X-set when compared to other characters. The correlation coefficient analysis indicated that number of days to fruit ripening had the most significant positive effect on fruit length. Factor analysis results revealed that six factors could explain approximately 77% of total variation; those factors were strongly influenced by number of seed per fruit, thousands seed weight, fruit width, number of days to flowering, fruit length, number of days to fruit ripening and seed width.

Abbreviations

CCA-canonical correlation analysis; Day.Fl-number of days to flowering; Day.FR- number of days to fruit forming; Day.H- number of Days to harvest; N.S.F- number of seed per fruit; TH.S.W- thousands seed weight; S.L- seed length; S.W- seed weight; P.L- plant length; D.F.R- number of days to fruit ripening; F.WE-fruit weight; F.L- fruit length; F.WI- fruit width-N.F.P-number of fruits per plant.

1. Introduction

Identifying characters contributing to yield is important to increase breeding efficiency. Therefore, having easily measurable characters and useful relationship with yield are important to practice indirect selection for the high yield (Gashaw et al., 2007). Selection for more yields by considering useful traits as indirect selection criteria is an alternative breeding approach. This has come to be known as analytical breeding and implies a better understanding of factors controlling the development, (Aparicio et al., 2000). Different statistical techniques have been used in modelling the crops yield, including canonical correlation analysis, regression, path analysis, factor analysis, factor components and cluster analysis (Leilah and Al-Khateeb, 2005). Correlation coefficient is an important statistical procedure to evaluate breeding programs for high yield, as well as canonical correlation analysis is a procedure to determine the strength of relationships among physiological, morphological or chemical traits of plants or animals (Keskin and Yasar, 2007). Canonical correlation analysis is one of the most popular multivariate analysis techniques. The goal of canonical correlation is to determine simultaneous relationships between two sets of variable such as X and Y, In other words, canonical correlation analysis is a procedure to determine the strength of relationships among physiological, morphological or chemical traits of plants or animals. It may be useful to think of one set as independent variables and other set as dependent variables (Tabachnick and Fidell, 2001). The application of canonical correlation analysis in plant breeding has increased with the availability of related computer packages, canonical correlation measure of the strength of the overall relationships between the linear composites (canonical variates) for the independent and dependent variables but correlation analysis is a method for measuring the covariance of two random variables in a matched data set and covariance is usually expressed as the correlation coefficient of two variables X and Y (Tavares et al., 1999). Factor analysis is a multivariate analysis method, which aims to explain the correlation between a large set of variables in terms of a small number of underlying independent factors. It is assumed that each of the variables measured depends on the underlying factors but is also subject to random errors. The principal factor analysis method explained by Harman (1976) was followed in the extraction of the factor loadings. The array of communality, the amount of the variance of a variable accounted by the common factors together, was estimated by the highest correlation coefficient in each array (Seiller and Stafford, 1985). The number of factors was estimated using the maximum likelihood method of Rao (1952). The Varimax rotation method (an orthogonal rotation) was used in order to make each factor uniquely defined as a distinct cluster of intercorrelated variables (Rao, 1952). The factor loadings of the rotated matrix, the percentage variability explained by each factor and the communalities for each variable were determined. Melon production in Sistan shows a steady increase, they are commonly grown in the most of the region of this place, and north of the province is a producer in this area. As in all cultivated plants, the main objective of melon growing is to grow high yield and high quality crops, the strategy of the melon breeder is to assemble a cultivar with superior genetic potential for yield and improved quality, on the other hand crop yield is affected by genotypic and environmental factors, For this reason, determination of the effects of genotypic factors in melon breeding is a primary concern, also determining effective characters will provide important benefits in melon breeding programs (Cankaya et al, 2010;Naroui Rad et al, 2010). More information is needed to clarify the relationships between plant and fruit characteristics. The purpose of this study is to investigate to which yield components are related to plant and fruit traits within native melon population of Ghandak by applying canonical correlation analysis and factor analysis.

2. Materials and methods

This study was conducted in 2012 and 2013 in the field experiment of Agriculture and Natural Resources Research Centre of Sistan located 30 km from Zabol in South-eastern Iran. Forty one landrace melons were collected from four parts of Sistan (Zabol, Himand, Hamoon and Nimrooz). All landraces were grown in different lines and pollination was controlled by closing of selected flowers in each landrace, there were four furrows with 10.0 m long, 75 cm wide and 50 cm depth, each landrace was planted in two side of furrow as two lines, four to five fruits from each line were selected randomly, the fruits were harvested when they reached full maturity to calculate average fruit weight, mean fruit weight was found by dividing the total fruit weight by the fruit number, the following measurements were done: number of days to flowering, number of days to fruit forming, number of days to harvest, number of seed per fruit, thousands seed weight, seed length, seed weight, plant length, number of days to fruit ripening, fruit weight, fruit length, fruit width and number fruits per plant. The experiment was carried out for two consecutive growing seasons (2012 and 2013) at the Research Site of Sistan, Agricultural and Natural Resources Research Centre in Zabol, Iran. The plots were fertilized with 150 kg N ha-1 and 150 kg P2O5 ha-1 before planting and 60 kg N ha-1 in spring at the flowering time. The averages annual temperature, rainfall and relative humidity are 22.9ºC, 46mm and %33 respectively. The site is 482 m above sea level, in arid climate of Iran, where the summers are dry and hot while the winters are cool. The collected data were calculated and statistically analysed using SAS System for Windows 9.0 (SAS, 2008) by procedures of CANCORR and **FACTOR.**

3. Results

Descriptive statistics for the measured characters are presented in Table 1. Correlation coefficients showing relationship among the traits of melon genotypes are given in Table 2. The highest correlation was predicted between number days to fruit ripening and fruit length (r=0.45**) while the lowest correlation was obtained between fruit width and thousand seed weight (r=-0.58**). Results also indicated that there was a strong positive correlation between seed width and number of seed per fruit (r=0.44**). The highest negative correlation was predicted between fruit weight and fruit length and also positive correlation was predicted between plant length and fruit width (r=41**). After calculating individual correlation coefficient between yield components and plant traits, canonical correlation analysis was applied to the data. The results of the analysis showed that the first canonical correlation was significant with respect to the likelihood ratio test 0.78** (Table 3). We then focused on the relationship between the first pair of canonical variables (U1 and V1), which had a maximum coefficient. As seen in Table 3, the second and third canonical variables were not worthy of consideration due to the insignificant canonical correlations between them. Standardized canonical coefficients (canonical weights) and canonical loadings were given for the first pair of canonical variables as shown in Tables 4 and 5.

Table 1
Descriptive Statistics for studied traits.

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Day.Fl	41	33.00	58.00	48.0976	0.59141	3.78685
Day.FR	41	33.00	58.00	54.0244	0.69711	4.46367
Day.H	41	76.00	93.00	87.0976	0.41585	2.66275
N.S.F	41	30.00	405.00	255.7561	11.72556	75.08022
TH.S.W	41	22.30	77.60	33.4634	1.27610	8.17104
S.L	41	3.00	7.00	5.2439	0.14305	.91598
S.W	41	2.00	6.00	3.0976	0.11998	.76827
P.L	41	72.00	119.00	105.0244	1.49613	9.57990
D.F.R	41	71.00	80.00	75.2439	0.32718	2.09500
F.WE	41	2.00	980.00	594.2683	28.80477	184.44051
F.L	41	15.00	38.00	21.9024	0.78383	5.01899
F.WI	41	5.00	21.00	14.5366	0.43491	2.78476
N.F.P	41	1.00	3.00	2.4521	0.2341	1.34567

Day.Fl-number of days to flowering; Day.FR- number of days to fruit forming; Day.H- number of Days to harvest; N.S.F- number of seed per fruit; TH.S.W- thousands seed weight; S.L-seed length; S.W- seed weight; P.L- plant length; D.F.R- number of days to fruit ripening; F.WE-fruit weight; F.L-fruit length; F.WI- fruit width-N.F.P-number of fruits per plant.

The first pair of canonical variables, providing the largest canonical correlation of 0.78**, was U1=(-0.02FL)+(-0.50Day.FR)+(0.32Day.H)+(0.11NSF)+(-0.83TH.S.W)+(0.06S.L)+(0.09S.W)+(0.08P.L)+(-0.14F.R)
and
V1=(0.29F.WE)+(0.02F.L)+ (0.93F.WI)+ (-0.19N.F.P).

Accordingly, if the values of the plant characters (except for number of days to flowering, number of days to fruit forming, thousands seed weight and number of days to fruit ripening) increase, the fruit weight, fruit width and fruit length will increase. These results support the idea that the decrease in phonological traits except days number to harvest are important factors, as they are the primary determinant for fruit weight and size. The loadings for the yield components suggested that fruit weight and fruit width were more influential than others in forming V1 (Table 5) and the loading for plant length was more influential than other plant characters in forming U1.

Table 2
Simple correlation coefficients among studied traits.

	Day.Fl	Day.FR	Day.H	N.S.F	TH.S.W	S.L	S.W	P.L	F.R	F.WE	F.L	F.WI	N.F.P
Day.Fl	1												
Day.FR	0.06	1											
Day.H	0.403**	.349*	1										
N.S.F	-0.1	-0.228	0.036	1									
TH.S.W	0.123	-0.12	-0.133	0.034	1								
S.L	0.353*	-0.069	0.215	-0.263	0.2	1							
S.W	0.04	0.116	0.056	-0.05	0.114	-0.035	1						
P.L	-0.301	0.006	0.14	.449**	-0.301	-0.28	0.088	1					
F.R	.372*	0.248	0.238	0.058	-0.063	0.007	0.171	-0.195	1				
F.WE	-0.044	-0.207	-0.021	0.136	-0.234	0.055	-0.3	0.11	-.410**	1			
F.L	0.09	-0.132	-0.061	0.07	0.272	0.038	0.054	-0.081	0.45**	-.405**	1		
F.WI	-0.131	-0.238	0.209	0.208	-.584**	-0.151	0.092	.411**	-0.006	0.147	-0.191	1	
NFP	0.247	-0.08	-0.04	0.31*	0.14	-0.32*	0.28	0.27	0.03	-0.20	0.10	0.20	1

*and ** significant at %5 and 1% statistical levels respectively
Day.Fl-number of days to flowering; Day.FR- number of days to fruit forming; Day.H- number of Days to harvest; N.S.F- number of seed per fruit; TH.S.W-thousands seed weight; S.L-seed length; S.W- seed weight; P.L- plant length; D.F.R- number of days to fruit ripening; F.WE-fruit weight; F.L-fruit length; F.WI- fruit width-N.F.P-number of fruits per plant.

Table 3
Summary results for the canonical correlation analysis.

Pair of canonical Variables	Canonical correlation	Squared Canonical correlation	Eigenvalue	DF	Likelihood Ratio	P
U1V1	0.783881**	0.614470	1.64	36	0.24	0.004112
U2V2	0.643524	0.414123	0.69	24	0.49	0.154909
U3V3	0.484683	0.234917	0.32	14	0.83	0.501357

U and V canonical variables for X's and Y's respectively.

Table 4
Standardized canonical coefficients for canonical variables.

	X-variable set									Y-variable set				
	Day.Fl	Day.FR	Day.H	N.S.F	TH.S.W	S.L	S.W	P.L	F.R		F.WE	F.L	F.WI	NFP
U1	-0.02	-0.50	0.32	0.11	-0.83	0.06	0.09	0.08	-0.14	V1	0.29	0.02	0.93	-0.19
U2	-0.45	-0.34	0.29	0.01	0.38	-0.42	0.40	0.30	0.48	V2	-0.33	0.26	0.25	0.76
U3	0.03	-0.21	-0.01	-0.53	-0.14	0.22	0.05	0.17	0.89	V3	-0.73	0.23	0.40	-0.66

Table 5
Canonical loadings of the original variables with their canonical variables.

	X-variable set										Y-variable set			
	Day.Fl	Day.FR	Day.H	N.S.F	TH.S.W	S.L	S.W	P.L	F.R		F.WE	F.L	F.WI	NFP
U1	-0.09	-0.34	0.24	0.22	-0.80	-0.06	-0.06	0.45	-0.14	V1	0.44	-0.27	0.93	-0.01
U2	-0.36	-0.12	0.02	0.42	0.16	-0.52	0.52	0.43	0.28	V2	-0.48	0.34	0.32	0.85
U3	0.41	0.13	0.21	-0.42	-0.18	0.32	0.19	-0.26	0.80	V3	-0.69	0.45	0.10	-0.50

Day.Fl-number of days to flowering; Day.FR- number of days to fruit forming; Day.H- number of Days to harvest; N.S.F- number of seed per fruit; TH.S.W- thousands seed weight; S.L-seed length; S.W- seed weight; P.L- plant length; D.F.R- number of days to fruit ripening; F.WE-fruit weight; F.L-fruit length; F.WI- fruit width-N.F.P-number of fruits per plant.

According to the cross loadings, thousand seed weight and fruit width contributed the most to canonical variables U1 and V1, respectively (Table 6). This finding indicated that plant length and thousand seed weight should be used with the aim of increasing the yield of melon populations. In the present study, it was found that 29% of total variation in the yield components set was explained by all canonical variables V1, while the redundancy measure of 0.17 for the first canonical variable suggests that about 17% of the ratio was explained by canonical variable U1 (Table 7). It was found that 13% of total variation in the x- set was explained by the first canonical variable U1, while the redundancy measure of 0.08 for the first canonical variable suggests that about 8% of the ratio was explained by canonical variable V1. The Kaiser-Meyer-Olkin (KMO) value, which measures the sampling adequacy, should be more than 0.5 and this value was obtained 0.51 and thus satisfactory to proceed with factor analysis (results are presented in Table 8). The analysis identified six factors, of which only four were extracted and together explained more than 60% of the variance among the entries. The first factor accounted for only 20.85% of the variance and was primarily related to number of fruits per plant and plant length, The second factor accounted for 15.19 % of the total variance, and was mainly loaded by thousand seed weight and fruit width, but with opposite signs, The third factor accounted for 14.57 % of the total variance, and was primarily related to number days to flowering and number days to harvest. The communality values ranged from 0.64 for plant length to 90.4 for days number to fruit forming.

Table 6
Cross loading of the original variables with opposite canonical variables.

	X-variable set										Y-variable set			
	Day.Fl	Day.FR	Day.H	N.S.F	TH.S.W	S.L	S.W	P.L	F.R		F.WE	F.L	F.WI	NFP
U1	0.05	0.07	0.03	0.03	0.40	0.02	0.02	0.12	0.01	V1	0.12	0.04	0.53	0.02
U2	0.06	0.08	0.03	0.10	0.41	0.11	0.11	0.20	0.04	V2	0.22	0.09	0.58	0.30
U3	0.10	0.08	0.04	0.15	0.42	0.14	0.12	0.22	0.20	V3	0.34	0.14	0.58	0.36

Table 7
The explained total variation ratio by canonical variables for the variable sets.

	X-variable set				Y-variable set		
	Variance extracted		Redundancy		Variance extracted		Redundancy
U1	0.13	V1	0.08	V1	0.29	U1	0.17

4. Discussion

It is important to determine the relationship between two or more characters of special crop to use in breeding program to gain more yield (Akbas and Takma, 2005; Cankaya and Kayaalp, 2007) so early selection regarding to effective traits on plant yield, is one of the useful vegetable breeding methods. If there is a relationship between plant characters and yield components, multivariate analysis such as canonical correlation analysis (CCA) is a good technique for describing the relationship between two variable sets simultaneously and for producing both structural and spatial meanings (Thompson, 1984). Based on correlation analysis, fruit length had a negative effect on fruit weight, the findings not supported those of Naroui Rad et al. (2010). At a glance in correlation analysis, fruit length and fruit width had a negative association with fruit weight, the main reason of this result could be due to selection of round shape of fruits, fruits with more length or width size had less fruit weight than round types. Cankaya et al. (2010) were reported the highest correlations between fruit weight and fruit number per plant also they reported that the fruit length and stem thickness of genotypes are important factors, as they are the primary determinant for fruit numbers per plant. Solanki et al. (1986) and Basavaraj (1997) have reported that fruit length, fruit width, number of fruits per plant and total fruit weight have strong positive correlations with yield. In this study total variation which explained by first pair of canonical variable was 13% but Balkaya et al. (2011) were reported that 20.4% of total variation in the plant characters set was explained by the first canonical variable U1, while the redundancy measure of 0.167 for first canonical variable suggests that about 16.7% of the ratio was explained by canonical variable V1. Ramos (1997) and Bezerra Neto et al. (2006) have reported that fruit diameter and length, number of days for flowering first female flower and total fruit weight have strong positive correlations with yield so variables with larger canonical loadings contributed more to the multivariate relationships between yield components and plant characters and based on these results value for days number to flowering in firs canonical variables is negative and negligible. Based on factor analysis in this research, 4 factors explained 62% of variation among characters, Naroui Rad et al. (2009;2010) were reported that three first factors explained 77% and 60% of variation among studied traits in melon respectively, low variation for measured traits in this research could be due to using of one specific population (Ghandak), also the first factor in their report which accounted for the highest proportion (31.24%) was mostly correlated with characters such as fruit weight, fruit length, fruit width and flesh.

Table 8
Total variance explained for each factor based on 13 different characters of 41 melon populations.

	Rotated Component Matrix						Communality
	1	2	3	4	5	6	
Day.Fl	-.141	-.084	.791	.227	.024	-.081	.712
Day.FR	-.103	-.039	.050	.058	.940	.049	.904
Day.H	.237	.198	.716	-.003	.421	.086	.793
N.S.F	.132	.234	.145	.003	.123	.311	.684
TH.S.W	.046	-.903	.096	.077	-.173	.194	.900
S.L	-.386	-.179	.656	-.146	-.244	.018	.693
S.W	-.028	.027	.058	.128	.045	.879	.795
P.L	.674	.344	-.135	-.182	.084	.120	.646
F.R	-.011	.151	.287	.771	.234	.017	.754
F.WE	.132	.147	.112	-.693	-.180	-.387	.714
F.L	.065	-.234	-.008	.744	-.273	-.042	.689
F.WI	.267	.834	.048	-.088	-.238	.207	.877
NFP	.571	-.083	-.297	-.024	-.008	.517	.689
Comulative Variance%	20.85	36.043	50.614	60.784	69.078	76.785	

Therefore factor analysis helps breeders to improve traits such as yield that has low heritability specifically in early generations via indirect selection (Khan et al., 2013). This paper proposes a strategy to select the traits to be used in breeding programs. The above analyses led us to suggest that in this population, fruits with more width but with low thousands seed weight, days number to fruit forming and days number to fruit ripening could be used to gain more yield for regions like Sistan, eventually early maturity is a good trait for breeders to find melon with favorite traits. The results obtained from this study could be useful for melon breeders. It should be taken into consideration that all the investigated traits are quantitative characters and are affected by environmental conditions to a great extent; therefore, the result may be changed from environment to environment.

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