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DETERMINATION OF RELATIONSHIPS AMONG KERNEL PERCENTAGE AND YIELD CHARACTERISTICS IN SOME TURKISH WALNUT GENOTYPES BY CORRELATION AND PATH ANALYSIS

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ABSTRACT

Experiments were conducted to determine correlations among important fruit and plant characteristics using 12 walnut genotypes (Bilecik, Malatya 1, Şebin, Tokat 1, Kaplan 86, Yalova 1, Yalova 3, Yalova 4, Şen 1, 65/4, 77H1, KR 2). Twelve traits viz., fruit weight, fruit diameter, fruit length, fruit height, shell thickness, kernel weight, shell weight, kernel percentage, shoot length, trunk diameter, tree canopy volume, total number of fruits per tree, and yield per tree were evaluated for correlation and path analysis. Results depicted that kernel percentage and yield were influenced by direct and indirect effects of different characters. Fruit weight and shell weight of walnut were the most important properties that directly reduced the kernel percentage whereas kernel percentage increased as the kernel weight increased. Kernel percentage increased as shell thickness decreased. Total fruit number per tree, fruit height, and kernel percentage were determined as the most important characters that directly affected the yield per tree. Kernel percentage and yield per tree were the most important characters for walnut breeding researches and were positively associated. Fruit and shell weight had negative effect on both the kernel percentage and the yield per tree whereas fruit weight and tree canopy volume had the positive effect on both of kernel percentage and yield per tree. It is suggested that these properties can be used as a criterion for selection in walnut breeding research studies.

Key words: walnut, kernel percentage, yield, correlation, path analysis.

INTRODUCTION

Walnut is one of the oldest species cultured both in Turkey and in the world (Şen, 1986). Though there are as many as eighteen different walnut species exploited on natural basis in several countries around the world, the most important one commercially cultivated is the *Juglans regia*, which is native to Turkey among other places.

Compared with other countries, Turkey has a prominent place on account of walnut population (Ozkan and Koyuncu, 2005). There is wide range of diversity in quality traits within this population. On account of selecting a particular feature in breeding work to create a new product, correlation studies, conducted on diverse physiological and vegetative properties of plants, are used as selection tool (Singh, 1992). Determining the relation between the fruit quality and productivity under similar conditions ensures an efficient breeding program and facilitates a more appropriate selection made to target. However, the possibility that the correlation between two traits might be affected by another trait prevents the correlation coefficients from being used alone for selection work (Okut and Orhan, 1993). Path analysis is a method which facilitates multiple regression applications. This method distinguishes the direct and/or indirect effects on the evaluated traits under analysis and clarifies the proportional significance of them (Moghaddam and DeEll, 2009). The method is aimed at finding out where the relations between the variables are rooted (Olsen, 1999). It is widely used in determining the significance of the components acting upon the productivity (Sukhchain and Sidhu, 1992; Ofori, 1996), as well as in detecting any direct and/or indirect impacts among morphological features of certain product (Tiwari *et al*., 1988; Mokhtassi *et al.,* 2006).

There is limited information on the relations between the traits affecting kernel percentage and productivity of walnut and evaluation with path analysis.

MATERIALS AND METHODS

Twelve genotypes of walnuts were used in this study including Bilecik, Malatya 1, Şebin, Tokat 1, Kaplan 86, Yalova 1, Yalova 3, Yalova 4, Şen 1, 65/4, 77H1 and KR 2. These genotypes were planted in Yayladağı (Hatay, Turkey) in 1999 with 7x7 m density in five replications each having one tree. Data obtained in 2008 and 2009 were used in the study. Data were recorded on fruit weight (g), fruit width (suture width; mm), fruit length (mm), fruit height (cheek diameter; mm), shell thickness (mm), kernel weight (g), shell weight (g), kernel percentage (%), shoot length (cm), trunk diameter (cm), tree canopy volume (m^3), total number of fruits per tree, and the yield per tree (kg/tree). Fruit width, fruit length, fruit height, and shell thickness were measured by a digital caliper (Mitutoyo, 0–150 mm). Shoot length, trunk diameter, and tree canopy volume per walnut tree were measured beginning of the first week in December. Shoot length was evaluated in the five trees for each genotype and four shoot from a different direction on each tree.

To determine the relationships between these traits correlation and direct-indirect path analysis were conducted (Singh and Chaudhary, 1979) using SPSS. 11. 0 computer software.

RESULTS AND DISCUSSION

For all the fruit and plant characters, mean squares with their significance levels were displayed on the ANOVA (Table 1). According to results of variance analysis, the fruit and plant traits were highly significant ($p<0.01$) except for trunk diameter and total number of fruits per tree ($p<0.05$).

Correlation coefficients between the fruit and plant traits of the walnut genotypes included in the study are given in Table 2. Significant correlations ($p<0.01$) were found between fruit weight, fruit width, fruit length and fruit height which compose the fruit size. However, no correlation ($r=0.10$; $p>0.05$) was found between the fruit weight and shell thickness. Similar studies in hazelnut by Bostan and Islam (1999), in almonds by Oguz *et al*. (1997) and in walnut by Amiri *et al*. (2010) showed no correlations between the fruit weight and the shell thickness.

Fruit weight had significant positive correlation with kernel weight ($r=0.69$; $p<0.01$), skin weight ($r=0.95$; $p<0.01$) and the shoot length ($r=0.33$; $p<0.01$), a negative correlation was determined between the fruit weight and the kernel percentage ($r=-0.66$; $p<0.01$). These findings are in harmony with the results obtained on walnuts by Sharma and Sharma (2001), Eskandari *et al*. (2006) and Amiri *et al*. (2010).

A negative correlation was observed between the trunk diameter ($r=-0.25$; $p<0.05$), total number of fruits per the tree ($r=-0.38$; $p<0.01$) and fruit weight. While the kernel weight, shell weight, and fruit size showed positive correlations with each other ($p<0.01$). Kernel weight and total number of fruits per tree had a negative correlation ($r=-0.27$; $p<0.05$) (Table 2).

Kernel percentage had negative correlation with fruit weight, fruit width, fruit length, fruit height, shell thickness, kernel weight, and shoot length while the tree canopy volume and the number of fruits per tree positively affected the kernel percentage (Table 1). Sen (1985), Eskandari *et al*. (2006) and Amiri *et al*. (2010) reported that there was a negative correlation between the kernel percentage of walnuts and the shell thickness. Our findings are in accordance with these researchers. On the other hand, Li *et al*. (2009) reported that the strongest affect on walnut shell thickness was imposed by the genotype characteristics.

No correlations were found between kernel weight, yield per tree ($r= 0.01$; $p>0.05$) and the kernel percentage ($r=-0.03$; $p>0.05$) (Table 2). However, contrary to our findings, Amiri *et al*. (2010) reported correlations between the kernel weight and the yield per tree of walnut.

It was also observed that as the shoot length increased, shell thickness and skin weight increased and the kernel percentage decreased. Therefore, it seems that genotypes with relatively slow shoot growth rate should be preferred in breeding work. The parameters of shell thickness ($r=0.23$; $p<0.05$), trunk diameter ($r=0.40$; $p<0.01$), total number of fruits per tree ($r=0.25$; $p<0.05$) and yield per tree ($r=0.68$; $p<0.01$) for the genotypes having larger tree canopy volume registered relatively higher figures. A negative correlation was found between total number of fruits per tree and fruit dimensions (width, length, height), shell thickness, and weight while there was a positive correlation between total number of fruits per tree and the kernel percentage, trunk diameter, tree canopy volume, and yield per tree. Atefi (1990) also reported that there was a positive correlation between the walnut yield and trunk diameter as well as tree height.

Both direct factor and indirect ones acting upon the kernel percentage based on path analysis are given in Table 3. Though no correlation was observed between the kernel weight and the kernel percentage the kernel percentage affected kernel weight in the path analysis. The path analysis showed a negative effect between the kernel percentage and shell weight as well as fruit weight, which were -0.77 and -0.62 respectively, but a positive effect (0.42) with the kernel weight. These results were in accord with those of Bostan *et al*. (1999) and Islam *et al*. (2005) in hazelnut as well as with those of Amiri *et al*. (2010) in walnuts. The direct effect of shell thickness on kernel percentage was relatively low (-0.12), it was found to affect kernel percentage indirectly through fruit weight, shell weight and fruit height. As a result, the decreases in shell thickness increased the kernel percentage. Amiri *et al.* (2010) also mentioned shell thickness as one of the major factors acting upon walnut kernel percentage.

Among the traits under study, fruit weight was found to have the most significant indirect affect (4.90) on kernel percentage and it was followed by shell weight (2.66), yield per tree (1.18), fruit width (1.16) and the tree canopy volume. Total number of fruits per tree indirectly affected the kernel percentage through tree canopy volume and yield per tree significantly. Fruit height indirectly affected kernel percentage through fruit weight, fruit width, shell thickness and shell weight. The direct effects of tree canopy volume and yield per tree on kernel percentage were low, but the tree canopy volume and yield per tree had significant indirect effects on the kernel percentage, indicating that the tree canopy volume and yield per tree were influenced by some other factors.

As can be seen in Table 4, total number of fruits per tree (0.73) showed the highest direct effects on yield per tree followed by fruit height (0.44) kernel weight (0.27). Shoot length, tree canopy volume, and trunk diameter. Fruit length showed negative affect on the yield (-0.15 and -0.12 respectively). The most significant factor having an indirect affect on the yield was found to be the fruit weight (6.26). Although it had a negative direct effect on the yield however, it had a positive indirect effect through kernel weight, shell weight and shell thickness. Other factors having an indirect affect on the yield via trunk diamater, tree canopy volume, and fruit weight were found to be the tree canopy volume (1.22), fruit width (0.86), and kernel weight (0.67). Amiri *et al*. (2010) pointed that kernel percentage was mostly affected by kernel weight, fruit weight, and shell thickness. Findings obtained from this study are in accord with those cited by Amiri *et al*. (2010).

Table 1. Analysis of variance for the mean squares of fruit weight (FW), fruit width (FW), fruit length (FL), fruit height (FH), shell thickness (ST), kernel weight (KW), shell weight (SW), kernel percentage (KP), shoot length (SL), trunk diameter (TD), tree canopy volume (TCV), total number of fruits per tree (FN), and the yield per tree (Y) of some Turkish walnut genotypes.

Source	df	FW	FD	FL	FH	ST	KW	SW	KP	SL	TD	TCV	FN	Y
Genotpye	11	40.2**	49.8**	91.6**	65.7**	0.1**	3.5**	26.1**	147.1**	365.9**	2.1*	2133.6**	21294.4*	1.8**
Error	24	1.9	1.5	7.0	0.5	0.0	0.5	1.5	10.7	70.3	0.6	200.1	4982.4	0.2
CV (%)		8.7	3.4	6.1	1.7	4.1	9.1	14.9	6.5	13.7	12.0	24.1	57.1	23.6

**: Significant at p<0.01, *: Significant at p<0.05, CV: Coefficient of variation

Table 2. Correlation coefficienties between important fruit quality traits, and plant traits in some Turkish walnut genotypes

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Fruit weight	1.00	0.78**	0.72**	0.89**	0.10	0.69**	0.95**	-0.66**	-0.25*	0.33**	-0.07	-0.38**	-0.07
2. Fruit width		1.00	0.62**	0.83**	0.02	0.62**	0.71**	-0.51**	-0.14	0.21*	0.23	-0.36**	0.00
3. Fruit length			1.00	0.68**	0.14	0.28**	0.78**	-0.73**	-0.29**	0.35**	-0.01	-0.28**	-0.06
4. Fruit height				1.00	-0.05	0.65**	0.83**	-0.60**	-0.27*	0.21*	0.02	-0.38**	-0.02
5. Shell thickness					1.00	-0.17	0.20*	-0.29**	0.15	0.22*	0.23*	0.11	0.20*
6. Kernel weight						1.00	0.43**	-0.03	-0.11	0.11	0.08	-0.27*	0.01
7. Shell weight							1.00	-0.81**	-0.26*	0.36**	-0.21	-0.35**	-0.09
8. Kernel percentage								1.00	0.29**	-0.29**	0.15	0.32**	0.18
9. Tree trunk diameter									1.00	0.03	0.40**	0.44**	0.29*
10. Shoot length										1.00	0.09	-0.01	0.12
11. Tree canopy volume											1.00	0.25*	0.31**
12. Total number of fruit												1.00	0.68**
13. Yield per tree													1.00

*, **: Significant at 0.05 and 0.01, respectively.

Table 3. Path coefficients of direct and indirect effects on kernel percentage in some Turkish walnut genotypes

Characters	1	2	3	4	5	6	7	8	9	10	11	12	Total indirect effect
1. Fruit weight	**-0.77**	0.20	0.71	0.70	1.19	1.06	1.25	0.21	0.70	-0.97	0.20	-0.34	4.90
2. Fruit width	0.08	**-0.12**	0.18	0.27	-0.07	0.13	0.10	0.14	-0.10	0.58	-0.24	0.09	1.16
3. Fruit length	0.19	0.12	**-0.18**	0.05	-0.04	-0.41	0.24	-0.30	0.25	0.14	0.07	-0.05	0.26
4. Fruit height	0.52	0.48	0.12	**-0.13**	-0.75	-0.19	0.65	-0.21	-0.44	0.22	-0.26	0.42	0.56
5. Shell thickness	0.17	-0.02	-0.02	-0.15	**-0.12**	-0.27	0.21	0.04	0.01	0.27	-0.11	0.19	0.32
6. Kernel weight	0.30	0.16	-0.17	0.17	-0.11	**0.42**	-0.06	0.03	0.11	-0.04	-0.04	0.04	0.39
7. Shell weight	0.80	0.16	0.57	0.56	0.95	-0.20	**-0.62**	0.17	0.56	-0.78	0.16	-0.29	2.66
8. Tree trunk diameter	0.03	0.05	-0.16	-0.04	0.04	-0.03	0.04	**0.05**	0.08	0.26	0.21	-0.06	0.42
9. Shoot length	0.09	-0.03	0.11	-0.07	0.01	-0.06	0.11	0.07	**0.01**	0.08	-0.05	0.10	0.36
10. Tree canopy volume	-0.17	0.24	0.09	0.05	0.32	0.18	-0.21	0.31	0.12	**0.04**	0.06	0.05	1.04
11. Total number of fruit	0.05	-0.15	0.06	-0.10	-0.20	-0.11	0.06	0.38	-0.11	0.10	**-0.03**	0.75	0.73
12. Yield per tree	-0.08	0.05	-0.04	0.13	0.29	0.13	-0.11	-0.10	0.19	0.08	0.64	**0.12**	1.18

Table 4. Path coefficients of direct and indirect effects on yield per tree in some Turkish walnut genotypes

Characters	1	2	3	4	5	6	7	8	9	10	11	12	Total indirect effect
1. Fruit weight	**-0.15**	0.06	0.42	0.64	0.81	2.86	1.25	-0.11	0.37	0.73	-0.88	0.11	6.26
2. Fruit width	0.02	**0.12**	0.13	0.29	-0.09	0.15	0.12	-0.11	0.15	-0.07	0.60	-0.33	0.86
3. Fruit length	0.09	0.09	**0.00**	0.03	-0.12	-0.10	0.43	-0.18	-0.27	0.26	0.16	0.11	0.50
4. Fruit height	0.34	0.48	0.07	**0.44**	-0.67	-0.01	0.11	-0.08	-0.24	-0.36	0.27	0.04	-0.05
5. Shell thickness	0.09	-0.03	-0.06	-0.14	**0.21**	-0.06	0.12	-0.10	0.04	0.05	0.30	0.04	0.25
6. Kernel weight	0.44	0.21	-0.03	0.21	0.05	**-0.07**	-0.44	0.42	-0.04	0.08	-0.10	-0.13	0.67
7. Shell weight	0.80	0.05	0.34	0.51	0.65	-2.29	**-0.12**	-0.65	0.29	0.58	-0.70	0.08	-0.34
8. Kernel percentage	-0.32	-0.14	-0.33	-0.06	-0.36	0.68	-0.40	**0.27**	0.15	0.10	0.15	0.22	-0.31
9. Tree trunk diameter	0.04	0.05	-0.13	-0.05	0.04	-0.05	0.05	0.04	**-0.07**	0.07	0.25	0.31	0.62
10. Shoot length	0.07	-0.02	0.11	-0.06	0.04	-0.04	0.08	0.02	0.05	**0.09**	0.09	0.02	0.36
11. Tree canopy volume	-0.12	0.24	0.09	0.07	0.36	0.07	-0.14	0.05	0.30	0.12	**0.04**	0.18	1.22
12. Total number of fruit	0.01	-0.11	0.05	0.01	0.04	-0.04	0.01	0.06	0.30	0.03	0.14	**0.74**	0.50

Conclusion: Breeding work aims to develop new walnut genotypes with such fruit qualities as high kernel percentage, thin shell and medium or big size reaching a high yield. It is known that kernel percentage and the yield are queered by other fruit and vegetative traits in walnuts and other nut species. Indeed, correlation and path analyses carried out in this study showed that these two fundamental criteria were directly and/or indirectly affected by several other factors. Yet, it was noticed that other studies in general were focused on mostly kernel percentage. This is the first detail report in the literature to the best of our knowledge to have determined both path analysis and correlation methods for the first time together with kernel percentage and yield traits, which are both determining criteria in walnut breeding. Thus, correlation and path analyses involving these traits were conducted. Accordingly, the fruit size and shell weight were found to directly decrease the kernel percentage, while the kernel weight proved to increase the kernel percentage. Moreover, relatively smaller shell thickness resulted in increases in the kernel percentage. The most important features directly affecting the yield were found to be the total number of fruit per tree, fruit height, and the kernel percentage. It was established that the kernel percentage and the yield had a positive interaction. Therefore, genotypes with both high kernel percentage and yield ratio can qualify for selection criteria in the future breeding strategies. Furthermore, kernel weight and tree canopy volume were found to have positive impact on both kernel percentage and the yield.

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