Current Journal of Applied Science and Technology

35(3): 1-9, 2019; Article no.CJAST.48205
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Correlation and Path Coefficient Analysis for Morphological and Biochemical Traits in Diverse Pomegranate (*Punica granatum* L.) Genotypes

Nusrat Perveen[1], Sarvamangala S. Cholin[1*], Kulapati Hipparagi[1], G. Prabhuling[1], B. N. S. Murthy[2] and Dadapeer Peerjade[1]

[1]University of Horticultural Sciences, Bagalkot, Karnataka, India.
[2]Indian Council of Agriculture Research, New Delhi, India.

Authors' contributions

This work was carried out in collaboration among all authors. Authors NP, SSC and KH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors GP, BNSM and DP managed the analyses of the study and revised the final draft. Author NP managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2019/v35i330185
Editor(s):
(1) Dr. Aleksey Aleksandrovich Hlopitskiy, Professor, Department of Technology Inorganic Substances, Ukrainian State University of Chemical Technology, Ukraine.
Reviewers:
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(2) A. A. Gulumbe, Usmanu Danfodiyo University, Nigeria.
Complete Peer review History: http://www.sdiarticle3.com/review-history/48205

Original Research Article

Received 05 February 2019
Accepted 13 April 2019
Published 20 May 2019

ABSTRACT

The present experiment was conducted to study the correlation and path coefficient analyses among some morphological and biochemical traits of twenty-three pomegranate genotypes. Results of correlation analysis showed a high, positive and statistically significant (at 0.1% P) correlation between fruit weight and fruit length (r= 0.897), peel weight (r=0.931), fruit volume (r= 0.67), fruit diameter (r=0.554) and total number of arils per fruit (r=0.428). Peel weight exerted direct positive effect as well indirect positive effect on fruit weight through characters like fruit volume, fruit length, total no. of arils per fruit, aril weight and fruit diameter while among the biochemical traits, fruit juiciness exerted maximum positive direct effect on TSS (0.298). The results suggested that these traits could be used for indirect selection of genotypes for higher yield and fruit quality traits will be suitable for cultivation as well as for use in breeding programme.

Keywords: Pomegranate; correlation; path coefficient.

**Corresponding author: E-mail: sarugpb@gmail.com;*

1. INTRODUCTION

Pomegranate (*Punica granatum* L.), one of the oldest cultivated species of fruit crops, is a predominant member of family Lythraceae (earlier Punicaceae) [1]. Pomegranate is highly prized for its juicy arils and has been deeply embedded in human history and was lauded in the old testament of the Bible, Koran, the Jewish Torah, and the Babylonian Talmud as a sacred fruit which confers the power of fertility, abundance, and good luck. The pomegranate is widely considered to be the native of region circumventing Iran and Northern India based on the wild pomegranate plants found in many forests of these areas. While others are of opinion that it is native to the smaller area of Iran and vicinity, and has stretched to a much broader area in prehistoric times mostly by human movement.

The edible part of fruit is aril which contains acids, sugars, vitamins, polysaccharides, polyphenols and minerals [2,3]. Howsoever, several factors including cultivar, environmental conditions; ripening can exert an influence on the chemical compositions of the fruit, affecting fruit quality and health beneficial components. Pomegranate is very well adapted to the Mediterranean climate [4]. However, the agro-climatic conditions of the Deccan Plateau of India are highly suitable for production of fruit throughout the year [5]. In India, pomegranate is one of the major crops in states of Maharashtra, Karnataka, Gujarat, Andhra Pradesh, Uttar Pradesh and Tamil Nadu. However, the improvement in this crop through systematic breeding programme is still meagre basically because this crop has till date been considered as a minor fruit crop in India. Nevertheless, since the establishment of National Research Centre (NRC) for pomegranate, the efforts in this direction have increased significantly.

Yield is a complex trait which not only is influenced by environment but is also dependent on various yield components like number of fruits per plant, fruit weight, fruit diameter etc. [6] which exerts positive or negative effects on this trait. Thus, an increase in yield through breeding necessitates the studies on the correlations as well as the direct and indirect effects of yield components to understand the relative contribution of each of these components that ultimately impacts the final yield and hence provides a criterion for the selection of desirable genotypes [6]. Correlation coefficient measures the mutual relationships between any two traits, which is helpful for understanding the association of these traits with yield as well as between other traits. This eventually enables a breeder to devise an efficient strategy for indirect selection for yield using component character association along with simultaneous selection of multiple traits. However, the use of correlation analysis alone is not sufficient to explain completely the relationships among different characters and hence, the path coefficient analysis is used for complete determination of the impact of each independent variable on the dependent one. The path coefficient analysis helps the breeders to identify the direct and indirect effects of each component trait on yield and provides a comprehensive insight into the inter-relationship between various characters. The objective of this experiment was to study the nature and degree of direct and indirect effects of various yield contributing characters in pomegranate.

2. MATERIALS AND METHODS

Twenty-three pomegranate genotypes (Table 1) having distinct diversity for various morphological and biochemical traits were taken in a randomized block design with three replications at the experimental orchard, University of Horticultural Sciences, Bagalkot, during Hasth bahar (Sept-Oct) season of 2016-2017 . Plants were maintained using standard cultural management practices till the fruits were ready for harvesting.

Three plants from each genotype (each plant serving as one replication) were randomly selected for recording data on different morphological and biochemical traits (Table 2). Analysis of variance was done using replicated phenotypic data and was used for the estimation of correlations. The correlation coefficients (phenotypic) were computed to determine the degree of association between various morphological as well as biochemical character using the formula given by Webber and Moorthy [7]. Further, the phenotypic correlation coefficients were compared against Table value at (n-2) degrees of freedom at the probability levels of 0.05 and 0.01 to test their significance [8]. Path coefficient analysis was carried out separately for morphological and biochemical characters by using the correlation coefficients to determine the direct and indirect effects of all the components on fruit weight or total fruit yield/plant as suggested by Wright [9] and illustrated by Dewey and Lu [10].

Table 1. List and source of collection of different pomegranate genotypes utilized in the present study

Sl. no.	Cultivar	Source of collection
1	Amlidana	Indian Institute of Horticultural Research, Bengaluru
2	Bhagwa	University of Horticultural Sciences, Bagalkot
3	CO-1	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)
4	Dholka	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)
5	Early Bhagwa	University of Horticultural Sciences, Bagalkot
6	G-137	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)
7	Ganesh	University of Horticultural Sciences, Bagalkot
8	Kabul Yellow	Indian Institute of Horticultural Research, Bengaluru
9	Kaladagi Local	University of Horticultural Sciences, Bagalkot
10	KRS	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)
11	Mridula	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)
12	P-23	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)
13	P-26	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)
14	PhuleArakta	University of Horticultural Sciences, Bagalkot
15	Ruby	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)
16	Super Bhagwa	University of Horticultural Sciences, Bagalkot
17	Tobesto	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)
18	UHSP 23	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)
19	UHSP 57	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)
20	UHSP 81	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)
21	UHSP 125	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)
22	Wonderful	University of Horticultural Sciences, Bagalkot
23	Yercaud	University of Horticultural Sciences, Bagalkot (HRES, Tidagundi)

Table 2. List of observations recorded for morphological and biochemical characters in different pomegranate genotypes

Sl. no.	Characters	Particulars
	Morphological parameters	
1	Fruit weight (g)	Precision balance
2	Fruit length (mm)	Digital Vernier calipers with 0.001mm accuracy
3	Fruit diameter (mm)	Digital Vernier calipers with 0.001mm accuracy
4	Fruit length/width	Ratio calculated
5	Fruit volume (cm^3)	Liquid displacement methods
6	Fresh wt. of 100 arils (g)	Precision balance
7	Dry wt. of 100 arils (g)	Precision balance
8	Moisture %	Oven drying arils at 60°C until constant weight
9	Crown length (mm)	Digital Vernier calipers with 0.001mm accuracy
10	Peel weight (g)	Precision balance
11	Aril weight (g)	Precision balance
12	Seed %	Percent ratio calculated
13	Skin %	Percent ratio calculated
14	Total No. of Arils/fruit	Manual counting
15	Aril length (mm)	Digital Vernier calipers with 0.001mm accuracy
16	Aril width (mm)	Digital Vernier calipers with 0.001mm accuracy
17	Seed length (mm)	Digital Vernier calipers with 0.001mm accuracy
18	Seed width (mm)	Digital Vernier calipers with 0.001mm accuracy
19	Rind thickness (mm)	Digital Vernier calipers with 0.001mm accuracy
20	Red coverage of Peel (%)	Visual observation
	Biochemical parameters	
21	Anthocyanin content (mg/L)	pH differential method
22	Ascorbic Acid (mg/100gm)	Dye (dichlorophenol indophenol) binding method
23	Titratable Acidity (%)	Titration method with 0.1 N NaOH (pH 8.1)
24	pH of the Juice	pH-meter
25	Fruit Juiciness % (per 100gm aril wt.)	Extracted juice from 100 arils and measured as weight/weight with aril wt.
26	TSS (°Brix)	Digital Refractometer

3. RESULTS AND DISCUSSION

Correlation coefficient measures the mutual relationships between the various traits, which is helpful for understanding the association among various traits. This eventually enables a breeder to devise efficient strategies for indirect selection using component character along with simultaneous selection of multiple traits. Fruit weight is an important economic trait for pomegranate which has the most important bearing on the total yield of the crop. Thus, in order to increase the yield and make efficient selection for higher yield, it is highly important that the associations of different quantitative traits with fruit weight should be known.

The results of the correlation analysis among the different morphological and biochemical traits is shown in Table 3 (a&b).With regard to the 26 morphological traits, fruit weight was found to have significantly high positive correlation (at P 0.1%) with traits like fruit length (r= 0.897), peel weight (r=0.931), fruit volume (r= 0.67), fruit diameter (r=0.554) and total number of arils per fruit (r=0.428). However, no significant negative correlations were found between fruit weight and other studied traits. This result is in harmony with earlier report by Mir et al. [11], where they found a significant positive correlation between fruit weight and fruit diameter, fruit volume, juice content, fruit set and number of fruits/plant and gross fruit yield. Verma et al. [12] has reported positive correlations of fruit weight with fruit diameter and fruit volume in case of strawberry.

Fruit length was also found to have significant positive correlation with fruit volume (r=0.668), aril and seed parameters like fresh and dry weights of 100 arils (r=0.677; 0.397), aril length (r=0.475), aril width (0.428) and total number of arils (r=0.428). Fruit length by width ratio, which determines the fruit shape was found to be significantly and positively correlated with fruit length (r=0.823) and crown length (r=0.925). Fruit volume had a significant positive correlation with different fruit and aril parameters like peel weight (r=0.683), fresh weight of 100 arils (r=0.865), total no. of arils per fruit (r=0.631), aril length (r=0.693) and crown length (r=0.699). No significant negative correlations were found between fruit volume and other studied traits.

The significantly high correlation observed between fruit volume and weight (r = 0.976) indicates that weight can be interchangeably used to indicate size. Also, aril number per fruit exhibited a strong linear relationship with fruit size. Thus, any of the characteristics loading high on the factor analysis fruit index (fruit volume, fruit weight, aril weight per fruit, skin and pericarp weight, and aril number) could serve as a measure for grading pomegranate fruit for different purposes (*e.g.*, fresh fruit versus extracted arils) where fruit weight, diameter, or volume could be used as the index of size. Understanding that, number of arils dictates final fruit size can have important implications on cultural practices since each aril is the product of fertilization, obtaining large fruit and high yields will depend upon careful crop management during the early stages of pollination and fertilization and subsequent fruit set and development. An interest in understanding fruit attributes and how fruit size relates to the percent of edible aril weight is pertinent, especially with the onset of mechanical extraction methods [13] for marketing of pomegranate arils in a ready-to-eat form.

Fresh weight of 100 arils was having strong positive correlation with other aril parameters *viz*., peel weight (r=0.626), total no. of arils (r=0.596), aril length (r=0.668) and aril width (r= 0.337 at P 1%). However, dry weight of 100 arils was found to be significantly and positively correlated with moisture per cent (r=0.265 at 5% P), in addition to its strong positive correlation with rind thickness (r=0.438) and aril width (r=0.420).

Moisture per cent of the fruit was found to be significantly negatively correlated with rind thickness (r=-0.412). Peel weight was significantly and positively correlated with total no. of arils per fruit (r=0.415) and aril length(r=0.446). Further, it was also found to be significantly and positively correlated with Fruit weight, fruit length, aril weight, total no. of arils per fruit, aril length and width and seed length as well as rind thickness. This finding agrees with the results of Zamani et al. [14] and Karimi and Mirdehghan [15].

Zamani et al. [14] found peel weight to be significantly correlated with fruit weight (r = 0.86), aril weight (r = 0.73) and aril length (r = 0.51) and Karimi and Mirdehghan [15] reported a significant correlation between peel weight and fruit diameters (r = +0.94), and fruit length (r = +0.93) however in contrast to the findings of this study, they observed a negative correlation of peel weight with number of arils in fruit (r = –0.78). Moreover, they reported a positive correlation

Table 3(a).Pearson's correlation coefficient among morphological traits in different genotypes of pomegranate

Traits	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26
X1	**1.00**																									
X2	0.897***	**1.00**																								
X3	0.554***	0.143	**1.00**																							
X4	0.92***	0.823***	0.494**	**1.00**																						
X5	0.67***	0.668***	0.224	0.717**	**1.00**																					
X6	0.633***	0.677***	0.113	0.631***	0.865**	**1.00**																				
X7	0.276*	0.397***	0.168	0.203	0.225	0.666**	**1.00**																			
X8	-0.045	0.155	-0.388***	-0.057	0.01	0.15	0.265*	**1.00**																		
X9	0.888***	0.822***	0.427***	0.925***	0.699***	0.637***	0.252*	-0.062	**1.00**																	
X10	0.931***	0.854***	0.462***	0.955***	0.683***	0.626***	0.256*	-0.075	0.862**	**1.00**																
X11	0.135	0.143	0.034	0.14	0.052	0.065	0.07	0.055	-0.157	0.319**	**1.00**															
X12	-0.135	-0.143	-0.034	-0.14	-0.052	-0.065	-0.07	-0.55	0.157	-0.319**	0	**1.00**														
X13	0.841***	0.822***	0.307*	0.826***	0.497***	0.520***	0.347**	0.072	0.868***	0.835***	0.012	-0.012	**1.00**													
X14	0.428***	0.484***	0.046	0.473***	0.631***	0.596***	0.244*	0.269*	0.421***	0.415***	0.098	-0.098	0.399**	**1.00**												
X15	0.468***	0.475***	0.17	.510***	0.693***	0.668***	0.270*	0.207	0.437***	0.446***	0.125	-0.125	0.352**	0.841**	**1.00**											
X16	0.384**	0.428***	0.017	0.409***	0.191	0.337**	0.420***	0.296*	0.464***	0.344**	0.149	0.149	0.528***	0.237*	0.2	**1.00**										
X17	0.053	-0.03	0.226	-0.008	0.138	0.154	0.059	-0.128	0.038	-0.037	-0.269*	0.269*	-0.127	0.198	0.153	0.055	**1.00**									
X18	0.212	0.285*	-0.074	0.239*	0.1	0.112	0.147	0.095	0.363**	0.147	-0.282*	0.282*	0.276*	0.076	0.096	0.417	-0.062	**1.00**								
X19	0.024	-0.134	0.338**	-0.03	-0.128	-0.342	0.438***	-0.412***	0.05	-0.039	-0.261*	0.261*	0.014	0.237*	-0.216	-0.006	0.208	-0.053	**1.00**							
X20	-0.007	0.055	-0.105	0.057	0.019	0.172	0.328**	0.013	-0.002	0.034	0.087	-0.087	0.038	0.194	0.241*	0.121	0.042	0.146	0.420**	**1.00**						
X21	0.194	0.013	0.416***	0.173	0.116	-0.124	-0.447***	-0.328**	0.19	0.137	-0.13	0.13	-0.008	-0.155	-0.075	-0.07	0.163	-0.039	0.521***	0.577**	**1.00**					
X22	0.079	0.115	-0.038	0.157	-0.103	0.028	0.259*	-0.059	0.157	0.152	0.035	-0.135	0.174	0.036	0.094	0.089	-0.094	0.272*	-0.161	0.648**	0.265*	**1.00**				
X23	-0.132	0.01	-0.359**	-0.047	-0.215	0.061	0.500***	0.244*	-0.044	-0.165	0.067	-0.067	0.092	0.046	0.03	0.311	-0.245	0.304*	0.398***	0.524**	0.456***	0.676**	**1.00**			
X24	-0.008	0.023	-0.06	-0.016	0.037	0.075	0.066	0.042	0.042	-0.036	-0.147	0.147	0.007	0.074	0.118	-0.004	0.166	-0.034	0.017	-0.191	0.167	0.089	-0.017	**1.00**		
X25	-0.08	0.001	-0.2	-0.012	-0.381	-0.181	0.284	0.146	0	-0.02	0.047	-0.047	0.155	-0.123	-0.153	0.236	0.276*	0.3001 *	-0.133	0.411***	0.2855 *	0.7373 **	0.8975 ***	0.045	**1.00**	
X26	0.946	0.871	0.464	0.976	0.711	0.651	0.263	0.072	0.941	0.932	0.154	-0.154	0.875	0.431	0.458	0.4	-0.011	0.232	-0.007	0.022	0.161	0.159	-0.06	0.009	-0.014	**1.00**

-Significance at 5% Probability, **-Significance at 1% Probability, *-Significance at 0.1% Probability*

X1- Fruit weight
X2- Fruit length
X3- Fruit diameter
X4- Fruit length/width
X5- Fruit volume
X6- Fresh wt. of 100 arils
X7- Dry wt. of 100 arils
X8- Moisture %
X9- Crown length
X10- Peel weight
X11- Aril weight
X12- Seed %
X13- Skin %
X14- Total No. of Arils/fruit
X15- Aril length;
X16- Aril width
X17- Seed length
X18- Seed width
X19- Rind thickness
X20- Red coverage of Peel
X21- Anthocyanin content
X22- Ascorbic Acid
X23- Titratable Acidity
X24- pH of the Juice
X25- Fruit Juiciness %
X26- TSS (°Brix)

Table 3(b). Pearson's correlation coefficient among quantitative biochemical traits indifferent genotypes of pomegranate

Traits	X1	X2	X3	X4	X5	X6
X1	1.000					
X2	-0.315**	1.000				
X3	0.405***	0.350**	1.000			
X4	-0.070	-0.647***	-0.510***	1.000		
X5	-0.399***	-0.068	-0.325**	0.353**	1.000	
X6	-0.261	0.190	0.029	-0.044	0.298	1.000

-Significance at 5% Probability, **-Significance at 1% Probability, *-Significance at 0.1% Probability*
X1-Anthocyanin (mg/L); X2- Ascorbic acid (mg/100g); X3-Titratable Acidity (%); X4- pH of the juice; X5- Fruit juiciness (%); X6-TSS (° Brix)

between number of arils in fruit and fruit length (r = 0.74), and a similar trend has been observed in this study for the aforementioned trait. Khadivi-Khub et al. [16] also found that fruit weight, fruit diameter and fruit length were positively correlated with each other and emphasized that these characters can be used to predict each other.

Among the biochemical parameters, anthocyanin content showed a significant positive correlation with titratable acidity (r=0.405) and a strong negative correlation with fruit juiciness percentage and ascorbic acid content (-0.315 at P=1%). On the other hand, ascorbic acid was found to be positively correlated with titratable acidity (r=0.350, at P=1%) while a strong negative correlation existed between this parameter and pH of the juice (r=-0.647 at P=0.1%). Titratable acidity was significantly and negatively correlated with pH (r=-0.510 at P=0.1%). Titratable acidity (TA) was found to be significantly and negatively correlated with pH, which in turn was showing negative correlation with TSS which agrees with findings of Khadivi-Khub et al. [16] Zamani et al. [14] reported titratable acidity (TA) to be negatively correlated with TSS (r = -0.56) and pH (r = -0.86) and similar reports are available from the investigations of Zamani et al. [17] and Mir et al. [18].

Path coefficient analysis provides a comprehensive insight into the inter-relationship between various characters. In pomegranate fruit yield is influenced by a number of inter-dependent traits. This inter-dependence between the component traits influences the direct relationships of traits with each other, making the correlation coefficient derived information less dependable. Under such circumstances, path coefficient analysis provides a better selection index by separating the correlation coefficients of yield and its components into direct and indirect effects [19].

The traits selected for correlation studies were also analysed for phenotypic path coefficient analyses the results of which are summarised in the Table 4 (a & b). Fruit weight is an important trait which has bearing on total fruit yield. Since, our focus was to select for genotypes bearing big size fruits which are suitable for export as well as preferred in the domestic market, fruit weight was selected as the dependent character for the morphological traits studied, to find out the direct and indirect effects of rest characters taken as independent characters. Direct positive effect of fruit weight on yield has been reported in pomegranate and ber [19,20]. Direct effects (positive or negative) on fruit weight was found to be exerted by traits like peel weight, aril weight and seed percentage. Out of these, peel weight (0.62) and seed percentage (0.99) had a positive direct effect on fruit weight. On the other hand, aril weight (-0.10) had exerted a negative direct effect on fruit weight. Similar trends were observed for indirect effect where also only the aforementioned traits were found to have indirect effect on fruit weight through various others traits under investigation.

Among these, peel weight was observed to exert positive indirect effect on fruit weight through characters like fruit volume, fruit length, total no. of arils per fruit, aril weight and fruit diameter. A negative indirect effect of peel weight, although of lesser magnitude, was also found, on fruit weight through seed percentage.

Aril weight also exerted indirect positive effect on fruit weight through fruit length, fruit diameter, fruit volume, peel weight and total no. of arils, with its highest indirect effect through fruit volume followed by fruit length. Unlike peel weight, aril weight exerted a negative indirect effect on fruit weight through skin percentage. Although, seed percentage was found to have direct negative effect on fruit weight, it exhibited an indirect positive effect on the fruit weight through skin percentage, while an exact opposite

Table 4(a). Path coefficient analysis of morphological traits on fruit weight among different pomegranate genotypes

Traits	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X25	Fr.wt
X1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95
X2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87
X3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46
X4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.98
X5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71
X6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65
X7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26
X8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.07
X9	0.33	0.30	0.16	0.34	0.26	0.24	0.09	-0.02	0.37	0.32	-0.06	0.06	0.06	0.32	0.16	0.16	0.17	0.01	0.13	0.02	0.00	0.07	0.06	-0.02	0.02	0.00	0.94
X10	0.62	0.57	0.31	0.64	0.45	0.42	0.17	-0.05	0.57	0.66	0.21	-0.21	-0.21	0.56	0.28	0.30	0.23	-0.03	0.10	-0.03	0.02	0.09	0.10	-0.04	-0.02	-0.01	0.98
X11	-0.10	-0.10	-0.03	-0.10	-0.04	-0.05	-0.05	-0.04	0.11	-0.23	-0.73	0.73	0.73	-0.01	-0.07	-0.09	0.11	0.20	0.21	0.19	-0.06	0.09	-0.03	-0.05	0.11	-0.03	0.15
X12	0.99	0.10	0.03	0.10	0.04	0.05	0.05	0.04	-0.11	0.23	0.73	-0.73	-0.73	0.01	0.07	0.09	-0.11	-0.20	-0.21	-0.19	0.06	-0.09	0.03	0.05	-0.11	0.03	-0.15
X13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88
X14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
X15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46
X16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40
X17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
X18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23
X19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
X20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
X21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16
X22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16
X23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.06
X24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
X25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01

X1- Fruit weight
X2- Fruit length
X3- Fruit diameter
X4- Fruit length/width
X5- Fruit volume
X6- Fresh wt. of 100 arils
X7- Dry wt. of 100 arils
X8- Moisture %
X9- Crown length
X10- Peel weight
X11- Aril weight
X12- Seed %
X13- Skin %
X14- Total No. of Arils/fruit
X15- Aril length
X16- Aril width
X17- Seed length
X18- Seed width
X19- Rind thickness
X20- Red coverage of Peel
X21- Anthocyanin content
X22- Ascorbic Acid
X23- Titratable Acidity
X24- pH of the Juice
X25- Fruit Juiciness %
X26- TSS (°Brix)

Table 4(b). Path coefficient analysis of biochemical traits on TSS among different pomegranate genotypes

Traits	X1	X2	X3	X4	X5	TSS (°Brix)
X1	-0.268	0.084	-0.108	0.018	0.107	-0.261
X2	-0.006	0.019	0.006	-0.012	-0.001	0.190
X3	0.162	0.140	0.401	-0.204	-0.130	0.029
X4	-0.009	-0.086	-0.068	0.133	0.047	-0.044
X5	-0.092	-0.015	-0.075	0.082	0.232	0.298

Residual value=0.8692
X1-Anthocyanin (mg/L)
X2- Ascorbic acid (mg/100g)
X3-Titratable Acidity (%)
X4- pH of the juice
X5- Fruit juiciness (%)
X6- TSS (° Brix)

trend was observed for indirect effect of skin percentage on fruit weight through seed percentage (Table 4a). Mir et al. [19], also reported that number of fruit/plants, fruit weight, fruit volume and fruit set exerts maximum positive direct effect towards gross fruit yield (kg/ plant) suggesting that both the number of fruits/plant and fruit weight could form a selection criterion for yield improvement in pomegranate. Number of fruits per plant has been found to have positive and significant association with maturity duration, dormancy duration and yield per plant and selection based on these characters is suggested to be effective for increasing number of fruits and yield per plant in pomegranate [21].

Furthermore, for the six biochemical parameters analysed, TSS was selected as a dependent character to find out the direct and indirect effects of other five characters selected as independent characters. Considering rates of direct effect on TSS, the highest value was obtained from Fruit juiciness (0.298). Positive and negative indirect effects also existed of the independent traits on TSS. Titratable acidity was found to exert a negative indirect influence on TSS through pH (-0.204) while pH was showed to have a negative indirect effect on TSS through ascorbic acid (-0.086) (Table 4b).

4. CONCLUSION

Comparing correlation coefficient values of different morphological and biochemical traits, significant differences were observed. Fruit weight is an important trait with direct bearing on total crop yield, in the present study a significant association was obtained between fruit weight and traits like fruit length, peel weight, fruit volume, fruit diameter and total number of arils per fruit. Based on these results these traits could be an effective selection criterion for selecting cultivars with high yield potential. The results of path coefficient analysis, demonstrates that Peel weight exerts positive indirect effect on fruit weight through characters like fruit volume, fruit length, total no. of arils per fruit, aril weight and fruit diameter, suggesting that these traits could be used for indirect selection of genotypes for higher yield and genotypes with these traits should be used for cultivation as well as in breeding programme.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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