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A simple approach to bolting tendency in purple carrot: Correlation and path analysis between some morphological and biochemical traits

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Abstract

In this study, five purple carrot accessions were used to investigate interactions between some agronomic and biochemical factors affecting the bolting tendency by applying correlation and path analysis. Only non-inflorescences individuals were evaluated for morphological measurements and biochemical analyzes in each accession. Leaves amount, root length, root weight, root diameter, and leaves length were recorded as morphological traits. Also, after the harvest, fructose, sucrose, glucose, total sugar, total soluble solids and C vitamin contents of roots were determined as biochemical characters. Bolting ratios of accessions were ranked between 17-45%.Correlation coefficient analysis revealed that the all biochemical characters had a negative correlation with bolting tendency. Path coefficient analysis showed that the only four traits: lengths of leaves, leaves amount, length of root, and total sugar content exhibited a direct effect on bolting tendency. In addition to these results, maximum positive indirect effect on bolting tendency was the leaves amount through the total sugar content. At the end of the study, it was being concluded that the selection of these traits can be contributed to efficiency for the breeding of the purple carrot varieties.

Keywords: Bolting, purple carrot, path analysis

Introduction

Carrot (*Daucus carota* L. var. *sativus* Hoffm., 2n = 18) is one of the major vegetables with an annual production quantity of 569.533 tons annually in Turkey. This vegetable is significant nutritionally providing a majority of both β-carotene and a-carotene (Arscott and Tanumihardjo, 2010). There are different prominent market classes of carrot based on processing and consumer use. Even though the majority of cultivars are orange-rooted in color, there are also red, yellow, purple and white-rooted carrots that robustly contain a kind of secondary compounds, notably carotenoids and anthocyanin. Despite phenotypic differences among market class and root color, several studies have proposed that Western/European carrot germplasm forms an unstructured population, meaning that there is not a significant genetic division among groups (Iorizzo, 2013; Baranski, 2012;Clotault, 2010;Bradeen, 2002).Also, orange colored carrots compose a sister group with all other cultivated carrots, proposing that orange colored was selected from other colors of cultivated carrots (Iorizzo, 2013).

The bolting is one of the most evident undesired characteristic in cultivated carrot. (Ritz et al., 2010).It is assumed that there are two periods in flowering induction and evocation. The first period of flowering induction is photoinduction (5 leaves in rosette). Metabolites of photomorphogenetic system are carried to apical meristems, where they can unblock the genes of inflorescence axis creation. After this stage, the evocation period first starts which ends with the formation of the inflorescence axis. The second period of flowering induction of carrot is thermo induction (vernalization; 9 leaves in rosette); its metabolites specify the formation of inflorescence axis structures. These transactions recompense in flower initiation and differentiation (Duchovskis and Samuoliene 2004).

In almost all biennials crop species, early flowering is usually found. These crops include turnip, carrot, cabbage beet, sugar beet, and clover. The existence of bolting causes significant economic loss to the producer. Carrot which normally classified in biennial species is required vernalization to induce flowering. During the first year, it produces a basal rosette of leaves and stores carbohydrates in its hypertrophic root (Whitaker et al., 1970). The stage of growth when carrot seedlings are not responsive to low-temperature vernalization is known as juvenility. This status generally finishes when carrot plants have initiated 8 to 12 leaves, and storage roots are larger than 4 to 8 mm in diameter (Galmarini and Della Gaspera, 1996; Galmarini et al., 1992). Floral stem elongation and flowering are induced after a vernalization period. At this time, generally, the temperature is between 0-10 and long days are experienced (Atherton and Basher, 1984).

Carrot roots rapidly become very lignified after vernalization, even before the floral stalk elongates so that the initiation of flowering results in a complete loss of commercial value (Rubatzky et al., 1999). The genetic mechanism of vernalization response and flowering habit have been studied in several biennial species, such as the Brassica species, *B. napus* L., *B. rapa*, and *B. oleracea* (Ferreira et al., 1995). In *B. oleracea* the annual habit is clearly dominant and seems to be controlled by several factors, and the inheritance pattern for flowering behavior depends on the specific parents used (Bagget and Kean, 1989). There are several attempts research of the physiological bases of vernalization response in carrot (e.g., Atherton et al., 1990).

The aim of this study was to investigate the interaction of some morphological and biochemical traits in bolting tendency of purple carrot genotypes.

Materials and Methods

The field trials and analysis were carried out in Ataturk Central Horticultural Research Institute, Yalova, Turkey in 2016/2017. The climate of this region is temperate. The minimum and maximum air temperatures during the cropping periods (Apr. to Sept.) were 11,2°/21,3°; 14,0°/29,0°; 18,3°/22,9°; 19,9°/30,8°; 25,6°/30,3°; 16,8°/26,3°C, respectively. Five accessions maintained in the purple carrot gene pool were used as plant material. These accessions were preferred due to different bolting tendency identified in previous studies. The seeds were sown in field in late summer. All accessions were each planted in 0,3×1.6 m plot that consisted of at least fifty plants in Randomized Complete Block Design with three replications. All cultural practices were performed during vegetation period. In all morphological measurements and biochemical analysis, only non-inflorescences individuals were evaluated for each accession. Data on different agronomic characters were recorded on individual plant basis from ten plants randomly selected in each plot (Table 1).After measurements, six root-crops were used for biochemical analysis in three replications according to Cemeroglu (2007)at the laboratory of Food Technology.

Numbers of fourteen traits for accessions were transformed into standardized units. The correlation and path coefficient was calculated according to Singh and Choudhary (1985), and Dewey and Lu (1959) respectively. The concept behind path analysis is that, Y: bolting tendency (%) is the function of various components like X1, X2, X3 … X13. A path diagram is constructed using simple correlation coefficient among various characters under study. The direct path coefficient was obtained by regression analysis. The indirect effect of a particular character through other character was obtained by multiplication of direct effect and their correlation coefficient. Regression and correlation analysis were held using Microsoft Office Excel program. The PAST3 software was used the principal component analysis.

Results and Discussion

Analysis of variance revealed significant variation among the accessions for some traits indicating a wide variability in the accessions. Descriptive statistics for traits are showed in Table 1. According to results, considerable variability was detected in total sugar, root weight and sucrose content.

Table 1. Descriptive statistics for fourteen traits.

	Traits	Mean	SE	SD	Variance (%)	Minimum	Maximum
Y	Boltingtendency (%)	27,134	4,854	10,853	117,794	17,000	45,000
x1	Lenght of leaves (cm)	58,172	1,407	3,147	9,901	54,660	61,670
x2	Rootweight (g)	202,856	9,362	20,934	438,225	178,710	229,270
x3	Lenght of root (cm)	26,760	1,723	3,853	14,845	20,330	30,200
x4	Diameter of root (cm)	3,868	0,195	0,436	0,190	3,360	4,440
x5	Ratio of rootlenght/diamter	6,906	0,241	0,540	0,291	6,050	7,500
x6	Leavesamount	11,538	0,631	1,411	1,990	9,870	13,600
x7	Fructose (g/l)	13,608	2,003	4,478	20,053	5,800	16,490
x8	Glucose (g/l)	20,736	4,624	10,340	106,926	3,700	31,810
x9	Sucrose (g/l)	38,922	4,905	10,967	120,280	29,500	56,470
x10	Total sugar (g/l)	73,266	10,455	23,377	546,495	39,820	104,770
x11	Ph	5,790	0,105	0,236	0,056	5,440	6,070
x12	Solublesolidcontent (%)	7,708	0,985	2,202	4,849	4,570	10,430
x13	C vitamin (mg/100 g)	9,162	2,294	5,129	26,311	3,260	17,040

The results of morphological and biochemical analysis were showed in Table 2. The evaluation of purple carrotroot- biochemical composition and agronomic traits showed that variation was wide although the core-collection evaluated is quite small. 45% percent of the individuals of “MH/2” were flowered before the root development. The lowest bolting tendency was observed in individual plants of “MH/4”. Theaccessions accumulated3,70 to 31,81g/l ofglucose. Roots of the accession ‘MH/4’ in the yearsof study had the largest content of total sugar (104,77 g/l), while thetotal sugar content in number “MH/2”roots was low (39.82 g/l).

Table 2. Evaluation of the biochemical and morphological parameters of purple carrot accessions

Geno types	Traits													
	Y	**x1**	**x2**	**x3**	**x4**	**x5**	**x6**	**x7**	**x8**	**x9**	**x10**	**x11**	**x12**	**x13**
MH/1	20,67	55,33	229,27	30,2	4,44	6,80	10,73	16,35	21,62	36,89	74,86	5,86	8,8	9,9
MH/2	45,00	58,4	214,64	28,93	4,09	7,07	13,60	5,80	3,70	30,32	39,82	5,44	6,77	6,37
MH/3	24,67	61,67	185,0	27,93	3,93	7,11	9,87	13,98	24,04	41,43	79,45	5,88	7,97	17,04
MH/4	17,00	60,8	178,71	26,41	3,52	7,50	12,05	16,49	31,81	56,47	104,77	5,70	10,43	9,24
MH/5	28,33	54,66	206,66	20,33	3,36	6,05	11,44	15,42	22,51	29,50	67,43	6,07	4,57	3,26

-Abbreviations: As in Table 1.

The correlation coefficients were showed in Table 3. In general, positive correlation coefficients were detected between biochemical traits. Negative correlation was observed only between PH (x11) and soluble solid content (x12) and between ph (x11) and sucrose (x9).The highest correlation coefficient was found between glucose (x8) and total sugar content (x10) (0,962). Also, the interrelationship of total sugar(x10) was significantly positive with the fructose content (x7) (0,831) and sucrose content (x8) (0,885). Another high positive correlation was observed between fructose (x7) and glucose (x8) content. The highest negative correlation coefficient was observed for bolting tendency with the fructose content (x7) and total sugar (x10). Little relationship was being detected between length of root (x3) and leaves amount (x6).

Similar results have been reported by Natarajan and Arumugam (1980) and Pariariet al.(1992). Increased root weight is known to be an important character as regards increased total carrot yield (Krarup and Mosnaim, 980). Total dissolved solids was not only negatively correlated with root weight but also with all other vegetative characters evaluated in the study of Santos et al. (2005). Randhiretal. (1992) reported that a negativecorrelation between total dissolved solids and leaf length, root weight and root yield involving 40 carrot populations. High levels of total dissolved solids is one of the important selection criteria's for many carrot breeding programs because selection for this trait can be effective in improving sweetness and flavor (Stommel and Simon, 1989). Singh et al.,(2004) evaluated carrot germplasm for TSS and reported that TSS varied from 3.83% – 8.04%. Since, diversity between the parents is an important factor in determining extent of improvement. Amin et al. (2010) investiaged the variability of carrot germplasm using agronomic and molecular data. They reported high variation for root lenght (19,57/24,92 cm), total soluble solids (6,25/8,78 %). In this study, purple carrots genotypes contain an average of 9,162 mg/100 g of vitamin C. This data higher than those reported in food composition tables (Souici et. al. 2000; McErlain et. al. 2001)

Table 3. Correlation coefficients of different characters of purple carrot accessions

	Y	***x1***	***x2***	***x3***	***x4***	***x5***	***x6***	***x7***	***x8***	***x9***	***x10***	***x11***	***x12***	***x13***
Y	1													
x1	-0,125	1												
x2	0,366	-0,803	1											
x3	0,057	0,340	0,247	1										
x4	0,160	-0,089	0,633	**0,880**	1									
x5	-0,168	**0,827**	-0,489	0,664	0,230	1								
x6	0,667	-0,078	0,169	**0,009**	-0,096	0,155	1							
x7	**-0,953**	-0,125	-0,237	-0,286	-0,265	-0,138	-0,698	1						
x8	-0,954	0,215	-0,574	-0,285	-0,434	0,127	-0,615	**0,928**	1					
x9	-0,705	0,665	-0,718	0,188	-0,222	0,752	-0,168	0,489	0,729	1				
x10	**-0,935**	0,383	-0,636	-0,093	-0,347	0,383	-0,484	**0,831**	**0,962**	**0,885**	1			
x11	-0,555	-0,399	**-0,033**	-0,601	-0,348	-0,668	-0,754	0,760	0,597	-0,109	0,359	1		
x12	-0,584	0,569	-0,350	0,626	0,281	**0,860**	-0,125	0,319	0,465	**0,868**	0,674	-0,335	1	
x13	-0,368	0,709	-0,415	0,552	0,365	0,557	-0,652	0,177	0,305	0,441	0,376	0,016	0,536	1

-Abbreviations: As in Table 1

Path coefficient analysis of thirteen traits indicated that lengths of leaves (x1) and leaves amount (x6) had the positive direct effect; length of root(x3) and total sugar content (x10) had negative direct effect on bolting tendency (Y) (Table 4). No direct effect of any other traits was observed. While the highest positive direct effect was observed for the lengths of leaves (x1) highest negative direct effect was observed for the total sugar content (x10) (Table 4).

Table 4. Partitioning of direct and indirect effects of morphological traits of bolting by path coefficient analysis

Traits	Effect	Traits	Effect	Traits	Effect	Traits	Effect
x1>Bolting	0,306	x3>Bolting	-0,137	x6>Bolting	0,231	**x10>Bolting**	**-0,954**
x1>x1>Bolting	0,306	x3>x1>Bolting	0,104	x6>x1>Bolting	-0,024	x10>x1>Bolting	0,117
x1>x3>Bolting	-0,047	x3>x3>Bolting	-0,137	x6>x3>Bolting	0,231	x10>x3>Bolting	0,013
x1>x6>Bolting	-0,018	x3>x6>Bolting	0,002	x6>x6>Bolting	0,231	x10>x6>Bolting	-0,112
x1>x10>Bolting	-0,365	x3>x10>Bolting	0,088	**x6>x10>Bolting**	**0,462**	x10>x10>Bolting	-0,954

-Abbreviations: As in Table 1

Principal component analysis (PCA) of some biochemical and morphological traits of purple carrot was performed using PAST3 Software. Biplot graphic of two main principal components were showed in Figure 1.

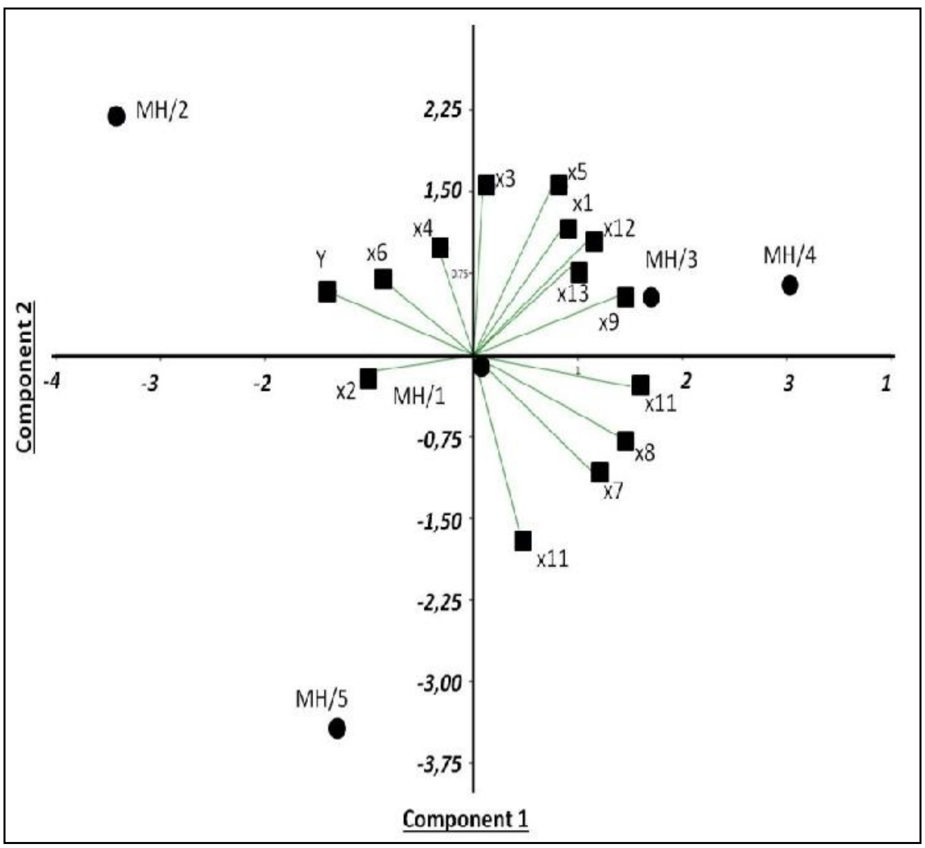

Figure 1. Distribution of observed characters and accessions based on the first and second principal component. Abbreviations: As in Table 1.

Out of the total thirteen PCs, four principal components (PC1 to PC4) with eigen values >1 accounted with individual variance values of 45,17, 30,46, 15,80, and 8,57%, respectively, and contributed 100% of the cumulative variation of accessions. The coefficients defining the four principal components of these data are given in Table 5. In each principal component, coefficients equal or greater than |0.3| was chosen to determine the cut off limit for the coefficients of the proper vectors (Raji, 2002).

Table 5: Eigen valuesof eachmorphological and biochemicalcharacters

Traits	PC1	PC2	PC3	PC4
Y	**-0,355**	0,149	-0,165	-0,203
x1	0,221	**0,304**	-0,231	**-0,386**
x2	-0,278	-0,043	**0,417**	**0,316**
x3	0,023	**0,406**	**0,361**	0,072
x4	-0,091	0,264	**0,541**	0,058
x5	0,199	**0,411**	-0,102	0,077
x6	-0,228	0,181	**-0,385**	**0,411**
x7	0,296	-0,280	0,174	0,191
x8	**0,362**	-0,194	-0,012	0,097
x9	**0,357**	0,141	-0,158	0,212
x10	**0,384**	-0,073	-0,046	0,179
x11	0,117	**-0,432**	0,182	-0,194
x12	0,289	0,278	0,094	**0,319**
x13	0,237	0,207	0,254	**-0,514**

-Abbreviations: As in Table 1.

The first principal component (PC1) has high positive component value for total sugar content (x10), sucrose content (x9), glucose content (x8). PC1 has negative component value for bolting tendency (Y). The second principal component had high positive component value for length of leaves (x1), length of root (x3), ratio of root length/diameter (x5); and high negative component value for ph (x11). These traits having high positive or negative component value reveal more genetic diversity. Principal component analysis simplifies the complex data by transforming the number of correlated variables into a smaller number of variables called principal components. The first principal component accounts for maximum variability in the data with respect to succeeding components (Leilah and Al-Khateeb, 2005).

Conclusion

In this study, it has been determined that characters lengths of leaves, leaves amount, length of root, and total sugar content had positive or negative direct effect on bolting tendency. Also, the results of the path analysis indicated that the maximum positive indirect effect on bolting tendency was the leaves amount through the total sugar content.

Path coefficient analysis can be used to determine the direct and indirect effect of variables on the dependent trait and is an effective tool for meritorious characters to be used in selection programs to get maximum yield (Chattoo et. al., 2015). Thus, these traits could be prioritized when studies to develop non-bolting tendence purple carrot lines in a breeding program.

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Competing interests

The authors declare that there are no competing interests.

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