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Seasonal Carbohydrate Changes of the Bark Tissues of Hazelnut Cultivars Grown in the East and West Black Sea Region

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Abstract: The seasonal changes in total carbohydrate, fructose, glucose and sucrose levels of bark tissues of the Tombul, Palaz, Kalınkara, Çakıldak and Sivri cultivars grown in the East and West Black Sea regions were determined by high performance liquid chromatography (HPLC). As with other fruit species, carbohydrate levels decreased from the end of spring to summer, showed steady changes with low values in summer and increased starting in the middle of fall until winter. Despite a general tendency of decline during spring, the carbohydrate and soluble sugar contents of Sivri increased in the Düzce region in April. Annual changes in carbohydrates from different regions and cultivars did not show significant differences. The differences between regions and cultivars were prominent in fall and winter. Sucrose levels were higher in December and January in Düzce, which has lower winter temperatures than Giresun. The opposite results were obtained for other sugar content levels except for the total carbohydrate and glucose content of Kalınkara in December and the total carbohydrate content of Palaz in January. Differences between regions during winter mostly occurred in the Palaz, Çakıldak and Sivri cultivars. Sucrose levels were also higher in those cultivars in January. The Çakıldak cultivar had more total carbohydrates in December and January than other cultivars in both regions.

Key Words: hazelnut, fructose, glucose, sucrose, total carbohydrate, HPLC

Doğu ve Batı Karadeniz Bölgelerinde Yetiştirilen Bazı Fındık Çeşitlerinin Kabuk Dokularındaki Karbonhidratların Yıllık Değişimleri

Özet: Araştırmada Doğu ve Batı Karadeniz bölgelerinde yetiştirilen Tombul, Palaz, Kalınkara, Çakıldak ve Sivri çeşitlerinin kabuk dokularındaki fruktoz, glukoz, sakaroz ve toplam karbonhidrat miktarlarının yıllık değişimleri, HPLC yöntemi kullanılarak saptanmıştır. Diğer meyve türleri ile benzer olarak, karbonhidrat miktarları ilkbahar sonlarından yaz aylarına doğru azalmakta, yaz aylarında daha düşük ve stabil sayılabilecek bir değişim göstermekte, sonbahar ortalarından itibaren kış aylarına doğru artmaya başlamaktadır. İlkbahar aylarında görülen genel azalma eğiliminden farklı olarak, Nisan ayında Düzce'deki Sivri çeşidinde karbonhidrat ve şeker miktarları artmıştır. Farklı bölgelerde ve fındık çeşitlerinde yıllık karbonhidrat seyri önemli bir değişiklik göstermemektedir. Bölgeler ve çeşitler arasındaki farklılıklar sonbahar ve kış aylarında daha belirgindir. Kış ayları daha soğuk geçen Düzce'de, Aralık, Ocak aylarındaki sakaroz miktarları Giresun'dan daha yüksektir. Aralık ayında Kalınkara çeşidindeki toplam karbonhidrat ve glukoz ile Ocak ayında Palaz çeşidindeki toplam karbonhidrat dışında, diğer şekerlerde tersi bir durum saptanmıştır. Kış aylarındaki bölgeler arası farklılıklar daha çok Palaz, Çakıldak, Sivri çeşitlerinde görülmüştür. Bu çeşitlerde Ocak ayındaki sakaroz miktarları da diğer çeşitlerden yüksektir. Özellikle Çakıldak çeşidinde Ocak ayındaki toplam karbonhidrat miktarları her iki bölgede de diğer çeşitlerden daha yüksek bulunmuştur.

Anahtar Sözcükler: fındık, fruktoz, glukoz, sakaroz, toplam karbonhidrat, HPLC

Introduction

Many researchers state that the amount and variety of carbohydrates found in plants differ in various plant organs and conditions all throughout the growing season. As a result, they react differently in terms of growth and development (Bianco et al., 1999), yield (Caruso et al., 1999), quality (Wang and Camp, 2000), bud and root formation (Davies, 1988; Maust et al., 2000), foliage (Niinemets, 1999), periodicity (Goldschmidt and Golomb, 1982; Nzima et al., 1999), dormancy (Salisbury and Ross, 1991), and cold resistance (Palonen, 1999) in perennials and fruit trees. Although storage polysaccharides have significance in plant physiology, mono and disaccharides are the most important carbohydrates in plant metabolism (Salisbury and Ross, 1991). In order to obtain useful results and determine the mechanism of carbohydrates in different phenomena,

it is necessary to estimate the changes in carbohydrates in different organs. Studies on carbohydrates have mostly been focused on nutritional value and the content inside the fruit. No study has been found on seasonal changes of carbohydrates in hazelnut plant tissues.

The aim of this research was to compare the seasonal changes in bark tissue carbohydrate content of the hazelnut cultivars grown in East and West Black Sea regions of Turkey.

Materials and Methods

The study was carried out in the Giresun and Düzce districts of the West and East Black Sea regions respectively, with the Tombul, Palaz, Kalınkara, Çakıldak and Sivri cultivars.

Yields and tendencies to periodicity of the investigated cultivars are high except for Kalınkara (low), and low except for Palaz (medium), respectively. The adaptation abilities of the Kalınkara, Çakıldak and Sivri cvs. are high. The Kalınkara and Sivri cvs. are resistant to spring frosts (Ayfer et al., 1986).

The study was performed in three replicates and 10 trees in each replicate for each cultivar in both ecologies were used. Sample collection started in March 1996 and continued for two years at monthly intervals, except for in February 1997 and 1998 due to severe weather conditions. Bark tissues were taken from the main branches approximately 10 cm above the soil surface from the shrubs at the same growth stage of each cultivar.

Bark tissues were dried at 60-70 ºC for 48 h and ground. Then 2 g of the sample was put in 10 ml high performance liquid chromatography (HPLC) grade water and extracted in an 80 ºC water bath for 4 h, filtered, and analyzed. A Shimadzu Shim-Pack CLCNH$_2$ (M) 250 x 4.6 mm, ID analytical column was used for HPLC analyses with 1 ml/ml flow velocity, 40 ºC column temperature and 75% acetonitrile + 25% deionized water as mobile phase (McBee and Maness, 1983). Glucose, fructose and sucrose values were taken into account to calculate the content of total carbohydrates. Since all the data obtained from different cultivars in both regions for two years showed similar trends, the mean values of the experiment years were used to compare any change. A three-factor experiment with repeated measures on a one-factor design were used to evaluate the results of the mean values over two years (Winer, 1971).

Results

As a mean of the two experiment years, the lowest monthly temperatures in Giresun and Düzce districts were 12.90-9.85 ºC in November, 11.05-7.95 ºC in December, 7.30-4.95 ºC in January, 6.43-5.30 ºC in March and 9.85-5.30 ºC in April. Temperatures between May and October were 16.15-23.20 ºC in Giresun and 13.35-22.70 0C in Düzce.

When all parameters of the study were considered, three-way interactions among the regions, cultivars and months were found to be significant (Tables 1-4).

Considering the regions and cultivars, the total carbohydrate, fructose, glucose and sucrose contents of bark tissues were 0.4584-6.9030 mg/g, 0.0310-2.9603 mg/g, 0.1030-4.1860 mg/g and 0.0225-3.0220 mg/g respectively. In general, the highest total carbohydrate, fructose, glucose and sucrose values of the cultivars were obtained between the end of fall and winter while the values were lowest in late spring and throughout summer. Total carbohydrate and sugar contents obtained in late spring and summer were similar. The differences among the months and almost all cultivars were not significant (Tables 1-4).

Differences among the regions and cultivars were generally significant for fall and winter, but were not significant for spring and summer. Significant differences were obtained in total carbohydrate contents among the regions during September to January, except in April and June for the Tombul cv., in August for the Çakıldak cv., and in March and April for the Sivri cv. (Table 1). Significant differences for fructose contents were determined between the regions in July for the Tombul cv., in December and January for the Palaz cv., in December for the Çakıldak cv., and in March, September and January for the Sivri cv. There was no significant difference between the regions for the Kalınkara cv. (Table 2). Except in April and March for the Tombul and Sivri cvs. respectively, significant differences were found between the regions during September, October, December and January in glucose contents. No significant differences in the glucose content of the Palaz cv. were found (Table 3). While there was no significant differences between the regions in terms of the sucrose content of the Kalınkara cv., significant differences for other cultivars were found between September and January (Table 4). In almost all months in which

Table 1. The amounts of total carbohydrates obtained at different months in the bark tissues of some hazelnut cultivars grown in the East and West Black Sea regions (mg/g).

	TOMBUL		PALAZ		KALINKARA		ÇAKILDAK		SİVRİ	
	GİRESUN	DÜZCE	GİRESUN	DÜZCE	GİRESUN	DÜZCE	GİRESUN	DÜZCE	GİRESUN	DÜZCE
MARCH	1.4490	1.0710	0.9375	1.0850	2.5190	1.5840	1.7150	1.5690	4.3955	1.4180
	D bc *A*	BC a *A*	E c *A*	B a *A*	AB b *A*	CD a *A*	CD bc *A*	C a *A*	B a *A*	C a *B*
APRIL	3.4940	0.5770	1.6400	0.6220	1.5950	0.6900	2.2650	1.4045	1.6760	3.4845
	BC a *A*	C b *B*	DE b *A*	B b *A*	BC b *A*	D b *A*	CD b *A*	C b *A*	DE b *B*	A a *A*
MAY	1.3355	1.3285	2.2265	0.8420	1.7040	0.7786	1.7260	1.1240	1.2070	1.7625
	D a *A*	BC a *A*	BCDE a *A*	B a *A*	BC a *A*	CD a *A*	CD a *A*	C a *A*	E a *A*	BC a *A*
JUNE	2.4680	0.7785	1.3285	0.8505	1.2245	0.7640	1.2255	1.1560	0.8460	0.7700
	CD a *A*	BC a *B*	E ab *A*	B a *A*	BC ab *A*	CD a *A*	D ab *A*	C a *A*	E b *A*	C a *A*
JULY	1.7705	0.5505	1.4050	1.6610	1.3860	0.8550	1.7910	1.0200	0.8985	1.3510
	D a *A*	C a *A*	E a *A*	B a *A*	BC a *A*	CD a *A*	CD a *A*	C a *A*	E a *A*	C a *A*
AUGUST	2.4615	1.6790	1.9235	0.4585	0.6090	0.9500	2.9490	1.1820	1.8530	0.9640
	CD a *A*	BC a *A*	CDE a *A*	B a *A*	C b *A*	CD a *A*	C a *A*	C a *B*	DE a *A*	C a *A*
SEPTEMBER	1.3670	0.5175	1.1470	1.1415	0.6455	1.3285	5.4330	2.1195	3.5355	1.2740
	D c *A*	C b *A*	E c *A*	B ab *A*	C c *A*	CD ab *A*	B a *A*	C a *B*	BC b *A*	C ab *B*
OCTOBER	4.0635	2.0045	3.1759	1.1780	3.3705	2.1210	4.7170	3.5190	3.6460	2.9740
	AB ab *A*	B bc *B*	ABC b *A*	B c *B*	A b *A*	C bc *A*	B a *A*	B a *A*	BC ab *A*	AB ab *A*
NOVEMBER	3.4410	3.8020	3.5490	1.6755	2.5250	1.6035	2.8825	4.2950	1.4995	1.3610
	BC a *A*	A a *A*	AB a *A*	B b *B*	AB ab *A*	CD b *A*	C a *A*	B a *A*	DE b *A*	C b *A*
DECEMBER	3.4805	4.0610	4.4315	3.7610	3.2375	5.1650	4.9365	4.7200	2.6590	1.3940
	BC bc *A*	A ab *A*	A ab *A*	A b *A*	A bc *B*	A a *A*	B a *A*	AB ab *A*	CD c *A*	C c *A*
JANUARY	4.8995	3.4000	2.8530	4.5150	3.4225	3.6390	6.9050	5.6330	6.3840	3.2240
	A b *A*	A b *B*	BCD c *B*	A ab *A*	A c *A*	B b *A*	A a *A*	A a *B*	A a *A*	A b *B*

Capital letters, letters and italic capital letters indicate differences among the months (in the same region and cultivar), cultivars (in the same region and month) and regions (in the same cultivar and month) respectively. The differences among the means that have different capital letters, letters, and italic capital letters are significantly different from each other at $p < 0.05$ level.

Table 2. The amounts of fructose obtained in different months in the bark tissues of some hazelnut cultivars grown in the East and West Black Sea regions (mg/g).

	TOMBUL		PALAZ		KALINKARA		ÇAKILDAK		SİVRİ	
	GİRESUN	DÜZCE	GİRESUN	DÜZCE	GİRESUN	DÜZCE	GİRESUN	DÜZCE	GİRESUN	DÜZCE
MARCH	0.8250	0.4870	0.0735	0.5430	1.1015	0.4320	0.4525	0.7870	1.5030	0.3835
	BCDE ab *A*	CDE a *A*	C c *A*	BC a *A*	AB ab *A*	AB a *A*	CD bc *A*	BC a *A*	BC a *A*	AB a *B*
APRIL	0.3070	0.2690	0.4860	0.2025	0.6285	0.5085	0.7795	0.6020	0.1730	1.0345
	E a *A*	DE b *A*	BC a *A*	C b *A*	BC a *A*	AB ab *A*	BCD a *A*	C ab *A*	D a *A*	A a *A*
MAY	0.4690	0.7855	0.9145	0.0930	0.3760	0.2495	0.2120	0.5865	0.8100	0.7875
	DE a *A*	CDE a *A*	B a *A*	C a *A*	BC a *A*	AB a *A*	D a *A*	C a *A*	CD a *A*	AB a *A*
JUNE	1.0790	0.4780	0.2860	0.0670	0.3325	0.3160	0.2020	0.2825	0.3370	0.2255
	BCDE a *A*	CDE a *A*	BC b *A*	C a *A*	BC b *A*	AB a *A*	D b *A*	C a *A*	D ab *A*	AB a *A*
JULY	1.0565	0.0625	0.2545	0.6485	0.7090	0.2870	0.9295	0.1510	0.3985	0.5025
	CDE a *A*	E a *B*	BC b *A*	ABC a *A*	BC ab *A*	AB a *A*	BCD ab *A*	C a *A*	D ab *A*	AB a *A*
AUGUST	1.4100	0.7690	0.4790	0.1505	0.0985	0.1870	0.9205	0.3160	0.7290	0.3815
	B a *A*	CDE a *A*	BC bc *A*	C a *A*	C c *A*	AB a *A*	BCD ab *A*	C a *A*	CD abc *A*	AB a *A*
SEPTEMBER	0.5995	0.0405	0.6565	0.1925	0.4095	0.1350	1.0630	0.4355	1.9925	0.4115
	CDE b *A*	E a *A*	BC b *A*	C a *A*	BC b *A*	B a *A*	BC b *A*	C a *A*	B a *A*	AB a *B*
OCTOBER	0.5330	1.1850	0.4495	0.7375	0.4160	0.7900	1.4370	0.9090	1.3345	0.5815
	DE b *A*	BC a *A*	BC b *A*	ABC a *A*	BC b *A*	AB a *A*	B a *A*	BC a *A*	BC a *A*	AB a *A*
NOVEMBER	1.3485	1.6000	1.7130	1.4065	0.4260	0.1895	1.0025	0.6350	0.7800	0.5090
	BC ab *A*	B a *A*	A a *A*	A a *A*	BC c *A*	AB b *A*	BCD abc *A*	C b *A*	CD bc *A*	AB b *A*
DECEMBER	1.2400	0..9850	2.3510	1.0420	0.7515	0.9170	2.6640	1.8710	0.8365	0.2180
	BCD b *A*	BCD b *A*	A a *A*	AB b *B*	BC b *A*	AB bc *A*	A a *A*	A a *B*	CD b *A*	AB c *A*
JANUARY	2.2640	2.8820	2.3190	1.1580	1.5165	0.9900	1.4115	1.4920	2.9630	0.0310
	A a *A*	A a *A*	A a *A*	AB b *B*	A b *A*	A b *A*	B b *A*	AB b *A*	A a *A*	B c *B*

Capital letters, letters and italic capital letters indicate differences among the months (in the same region and cultivar), cultivars (in the same region and month) and regions (in the same cultivar and month) respectively. The differences among the means that have different capital letters, letters, and italic capital letters are significantly different from each other at $p < 0.05$ level.

Table 3. The amounts of glucose obtaned in different months in the bark tissues of some hazelnut cultivars grown in the East and West Black Sea regions (mg/g).

	TOMBUL		PALAZ		KALINKARA		ÇAKILDAK		SİVRİ	
	GİRESUN	DÜZCE	GİRESUN	DÜZCE	GİRESUN	DÜZCE	GİRESUN	DÜZCE	GİRESUN	DÜZCE
MARCH	0.4515	0.4720	0.3690	0.3250	1.3760	0.5275	0.4670	0.3560	2.0205	0.3915
	CDE b *A*	A a *A*	B b *A*	AB a *A*	AB ab *A*	B a *A*	D b *A*	C a *A*	A a *A*	B a *B*
APRIL	2.5750	0.1735	0.8485	0.2805	0.2790	0.1030	0.8165	0.4535	1.2430	1.5635
	CDE a *A*	A b *B*	B b *A*	AB b *A*	C b *A*	B b *A*	D b *A*	C b *A*	ABC b *A*	A a *A*
MAY	0.2935	0.2290	0.7420	0.3865	0.3815	0.3750	1.2895	0.2555	0.2680	0.6740
	DE a *A*	A a *A*	B a *A*	AB a *A*	BC a *A*	B a *A*	CD a *A*	C a *A*	C a *A*	AB a *A*
JUNE	1.3045	0.1340	0.7240	0.5825	0.5470	0.2235	0.8495	0.4120	0.4865	0.3070
	CD a *A*	A a *A*	B a *A*	AB a *A*	BC a *A*	B a *A*	D a *A*	C a *A*	BC a *A*	B a *A*
JULY	0.4230	0.3170	0.5490	0.7180	0.5665	0.1095	0.6100	0.7275	0.2125	0.1275
	CDE a *A*	A a *A*	B a *A*	AB a *A*	BC a *A*	B a *A*	D a *A*	BC a *A*	C a *A*	B a *A*
AUGUST	0.9995	0.7435	1.0720	0.1775	0.4300	0.4845	1.1660	0.3690	0.6300	0.1165
	CDE a *A*	A a *A*	AB a *A*	B a *A*	BC a *A*	B a *A*	CD a *A*	C a *A*	BC a *A*	B a *A*
SEPTEMBER	0.1435	0.3820	0.2890	0.2560	0.1175	0.7915	1.9905	0.3815	1.4135	0.1965
	E b *A*	A a *A*	B b *A*	B a *A*	C b *A*	B a *A*	BC a *A*	C a *B*	AB a *A*	B a *B*
OCTOBER	2.6660	0.5390	0.9994	0.3315	1.8360	0.7480	2.8830	0.5780	1.7605	1.0160
	A ab *A*	A a *B*	AB c *A*	AB a *A*	A bc *A*	B a *A*	B a *A*	BC a *B*	A bc *A*	AB a *A*
NOVEMBER	1.4625	0.5280	1.2920	0.4260	1.7365	0.5850	1.1920	0.6380	0.5420	0.3925
	BC ab *A*	A a *A*	AB ab *A*	AB a *A*	A a *A*	B a *A*	CD ab *A*	BC a *A*	BC b *A*	B a *A*
DECEMBER	0.6675	0.2750	1.8770	1.3520	1.8825	2.9910	2.1615	1.7280	1.5015	1.0850
	CDE b *A*	A c *A*	A a *A*	A b *A*	A a *B*	A a *A*	BC a *A*	A b *A*	AB ab *A*	AB bc *A*
JANUARY	2.4000	0.1830	0.4170	1.2320	1.7490	2.3370	4.1860	1.5450	2.2155	0.7330
	AB b *A*	A c *B*	B c *A*	AB b *A*	A b *A*	A a *A*	A a *A*	AB ab *B*	A b *A*	AB bc *B*

Capital letters, letters and italic capital letters indicate differences among the months (in the same region and cultivar), cultivars (in the same region and month) and regions (in the same cultivar and month) respectively. The differences among the means that have different capital letters, letters, and italic capital letters are significantly different from each other at $p < 0.05$ level.

Table 4. The amounts of sucrose obtained in different months in the bark tissues of some hazelnut cultivars grown in the East and West Black Sea regions (mg/g).

	TOMBUL		PALAZ		KALINKARA		ÇAKILDAK		SİVRİ	
	GİRESUN	DÜZCE	GİRESUN	DÜZCE	GİRESUN	DÜZCE	GİRESUN	DÜZCE	GİRESUN	DÜZCE
MARCH	0.1725	0.1120	0.4950	0.2120	0.0415	0.6245	0.7955	0.4260	0.8720	0.6430
	BC ab *A*	C a *A*	B ab *A*	C a *A*	B b *A*	AB a *A*	BC a *A*	DE a *A*	AB a *A*	BC a *A*
APRIL	0.6120	0.1345	0.3055	0.1390	0.6875	0.0785	0.6690	0.3490	0.2600	0.8865
	BC a *A*	C b *A*	B a *A*	C b *A*	AB a *A*	B b *A*	BC a *A*	E ab *A*	BC a *A*	BC a *A*
MAY	0.5555	0.3140	0.5700	0.3625	0.9465	0.1530	0.2245	0.2820	0.1290	0.3010
	BC ab *A*	C a *A*	B ab *A*	C a *A*	A a *A*	B a *A*	C ab *A*	E a *A*	BC b *A*	C a *A*
JUNE	0.0845	0.1665	0.3185	0.2010	0.3450	0.2245	0.1740	0.4615	0.0225	0.2375
	BC a *A*	C a *A*	B a *A*	C a *A*	AB a *A*	B a *A*	C a *A*	DE a *A*	C a *A*	C a *A*
JULY	0.2910	0.1710	0.6015	0.2945	0.1105	0.4585	0.2515	0.1415	0.2875	0.7210
	BC a *A*	C a *A*	B a *A*	C a *A*	B a *A*	B a *A*	C a *A*	E a *A*	BC a *A*	BC a *A*
AUGUST	0.0520	0.1395	0.3725	0.1305	0.0805	0.2785	0.8625	0.4970	0.4940	0.4660
	C b *A*	C a *A*	B ab *A*	C a *A*	B b *A*	B a *A*	BC a *A*	DE a *A*	ABC ab *A*	C a *A*
SEPTEMBER	0.6240	0.0950	0.2015	0.6930	0.1185	0.4020	2.3795	1.3025	0.1295	0.6690
	BC b *A*	C b *A*	B b *A*	BC ab *A*	B b *A*	B b *A*	A a *A*	C a *B*	BC b *A*	BC ab *A*
OCTOBER	0.8645	0.2805	1.7270	0.1090	1.1185	0.5830	0.3970	2.0320	0.5510	1.3765
	B b *A*	C b *A*	A a *A*	C b *B*	A ab *A*	AB b *A*	C b *B*	B a *A*	ABC b *A*	B a *A*
NOVEMBER	0.6300	1.6740	0.5440	0.3430	0.3625	0.8290	0.6880	3.0220	0.1775	0.4595
	BC a *B*	B a *A*	B a *A*	C b *A*	AB a *A*	AB b *A*	BC a *B*	*A* a *A*	BC a *A*	C b *A*
DECEMBER	1.5730	2.8010	0.2035	1.3670	0.6035	1.3020	0.1110	1.1210	0.3210	0.0910
	A a *B*	A a *A*	B b *B*	B b *A*	AB b *A*	A b *A*	C b *B*	CD b *A*	BC b *A*	C c *A*
JANUARY	0.2355	0.3350	0.1700	2.1250	0.1570	0.3120	1.3075	2.5960	1.2055	2.4600
	BC b *A*	C b *A*	B b *B*	A a *A*	B b *A*	B b *A*	B a *B*	AB a *A*	A a *B*	A a *A*

Capital letters, letters and italic capital letters indicate differences among the months (in the same region and cultivar), cultivars (in the same region and month) and regions (in the same cultivar and month) respectively. The differences among the means that have different capital letters, letters, and italic capital letters are significantly different from each other at $p < 0.05$ level.

differences were significant between the regions, values were higher in Giresun than in Düzce. The difference was more obvious for fructose (Table 2). However, total carbohydrate contents in the Palaz, Kalınkara and Sivri cvs. in January, December and April respectively (Table 1), and glucose content in the Kalınkara cv. in December (Table 3) were higher in Düzce than in Giresun. Higher sucrose values were obtained in the Düzce district during the months in which the differences between the regions were significant, while only the Palaz and Çakıldak cvs. showed higher values in Giresun in October and September, respectively (Table 4).

Total carbohydrate contents of the Çakıldak and Sivri cvs. in Giresun and the Çakıldak cv. in Düzce (Table 1); fructose contents of the Tombul, Palaz, Sivri cvs. in Giresun and the Tombul cv. in Düzce (Table 2); glucose contents of the Çakıldak cv. in Giresun and the Kalınkara cv. in Düzce (Table 3); and sucrose contents of the Çakıldak and Sivri cvs. in Giresun; and the Palaz, Çakıldak, Sivri cvs. in Düzce (Table 4) were significantly higher than the other cultivars in January, which is the coolest month of the year in both regions.

Changes in the total carbohydrate, fructose, glucose and sucrose contents of investigated cultivars bark tissues showed a strong similarity throughout the year in both regions. As a general tendency, the amounts of total carbohydrate, fructose, glucose and sucrose began to decline starting from the end of spring and reached their lowest levels in summer, remaining at minimum and almost stable levels during summer and before rising from mid-fall until winter (Figures 1-4). Despite a general tendency of decline during spring, total carbohydrate and glucose in the Tombul, Palaz and Çakıldak cvs. (Figures 1 and 3), fructose in the Palaz and Çakıldak cvs. (Figure 2), and sucrose in the Tombul and Kalınkara cvs. (Figure 4) showed an increase in April in the Giresun district. Total carbohydrate, fructose, glucose and sucrose contents of the Sivri cv. increased in the Düzce region in the same period.

Discussion

Total carbohydrate, fructose, glucose and sucrose contents of bark tissues in all cultivars in both regions investigated in this research increased from summer to winter and during the dormancy period, and their highest levels were found at the end of fall and during winter. Amounts of the mentioned substances were at lower and similar levels during spring and summer. The results of

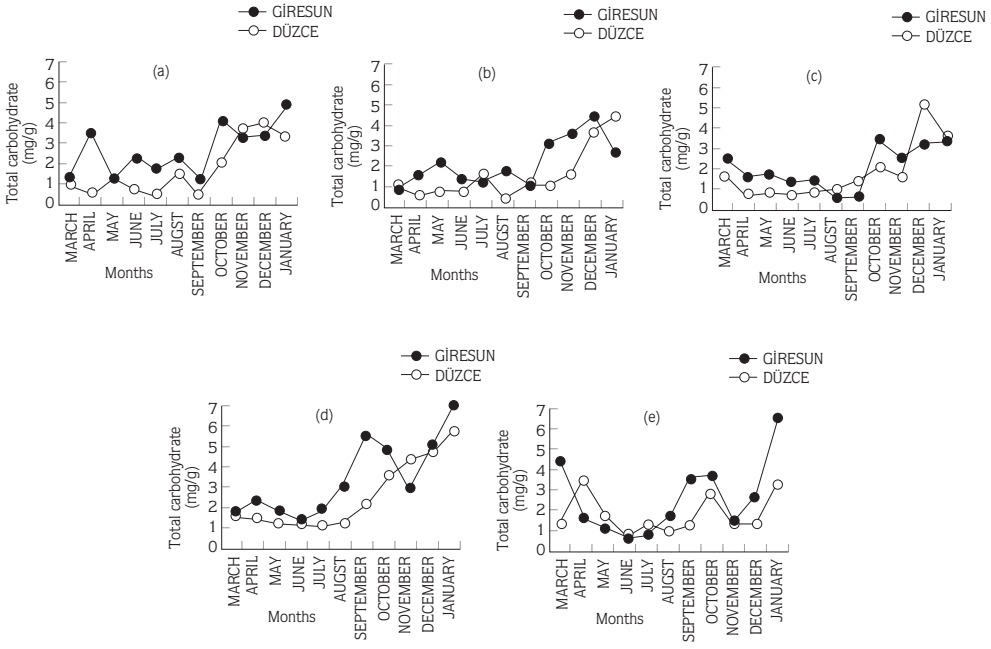

Figure 1. Seasonal changes of total carbohydrate amounts in the bark tissues of some hazelnut cultivars grown in the East and West Black Sea regions (mg/g).
(a): Tombul cv., (b): Palaz cv., (c): Kalınkara cv., (d): Cakıldak cv., (e): Sivri cv.

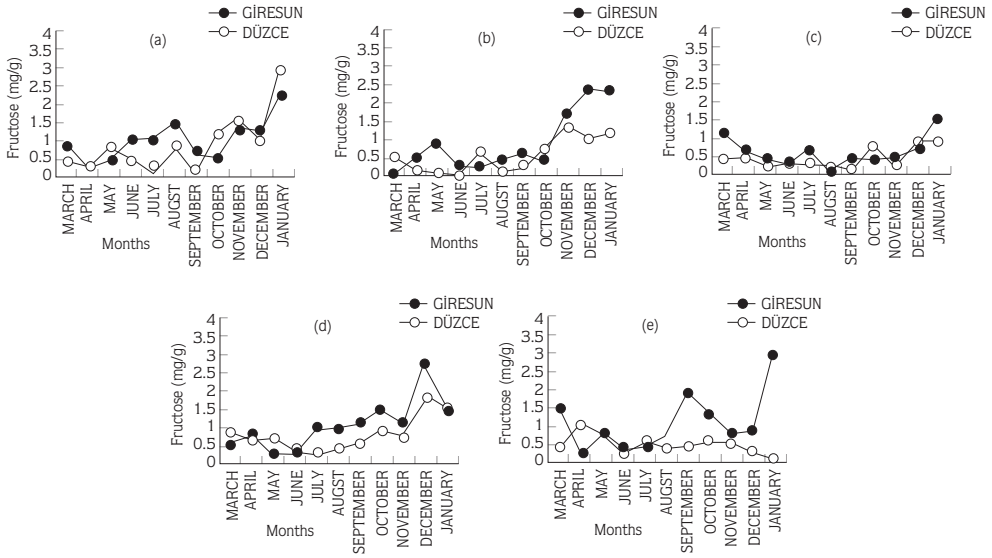

Figure 2. Seasonal changes of fructose amounts in the bark tissues of some hazelnut cultivars grown in the East and West Black Sea regions (mg/g). (a): Tombul cv., (b): Palaz cv., (c): Kalınkara cv., (d): Cakıldak cv., (e): Sivri cv.

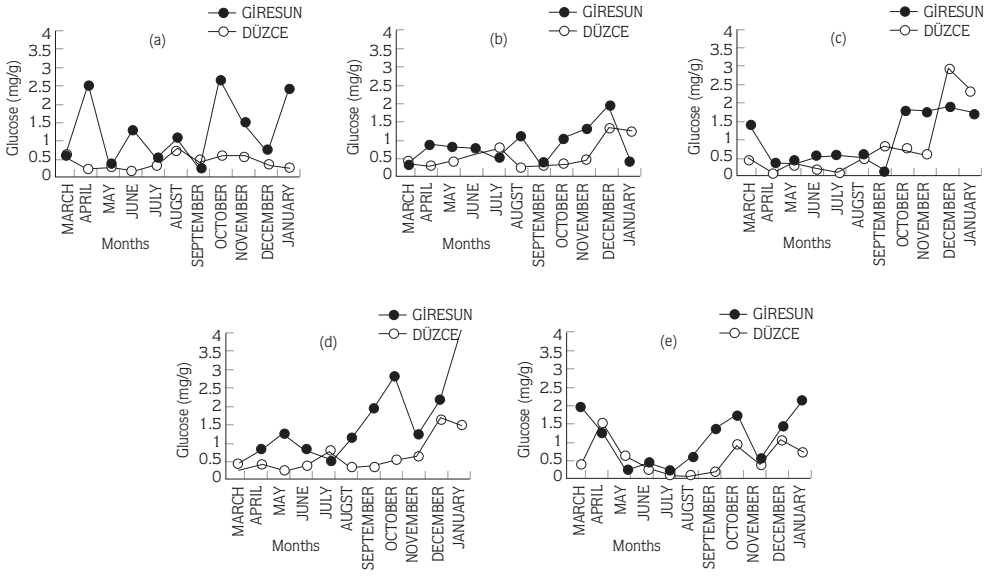

Figure 3. Seasonal changes of glucose amounts in the bark tissues of some hazelnut cultivars grown in the East and West Black Sea regions (mg/g). (a): Tombul cv., (b): Palaz cv., (c): Kalınkara cv., (d): Cakıldak cv., (e): Sivri cv.

this study reveal that annual carbohydrate variations of in hazelnut cultivars are similar to those of other fruits. The findings observed in this study are in agreement with the findings of other studies on different fruits. On the other hand, İdem and Gezerel (1995) determined higher reducing sugar content in the spring in pistacia seedlings. They stated that increases in soluble carbohydrate levels during early winter facilitate the cold resistance of the plants (Sakai, 1966; Yastioka et al., 1988; Salisbury and Ross, 1991). High glucose levels were also obtained in some cultivars during April in our study similar to Drossopoulos and Niavis (1988) probably due to the hydrolysis of polysaccharides (Niinemets, 1999). They stated that glucose had a tendency to rise from spring to

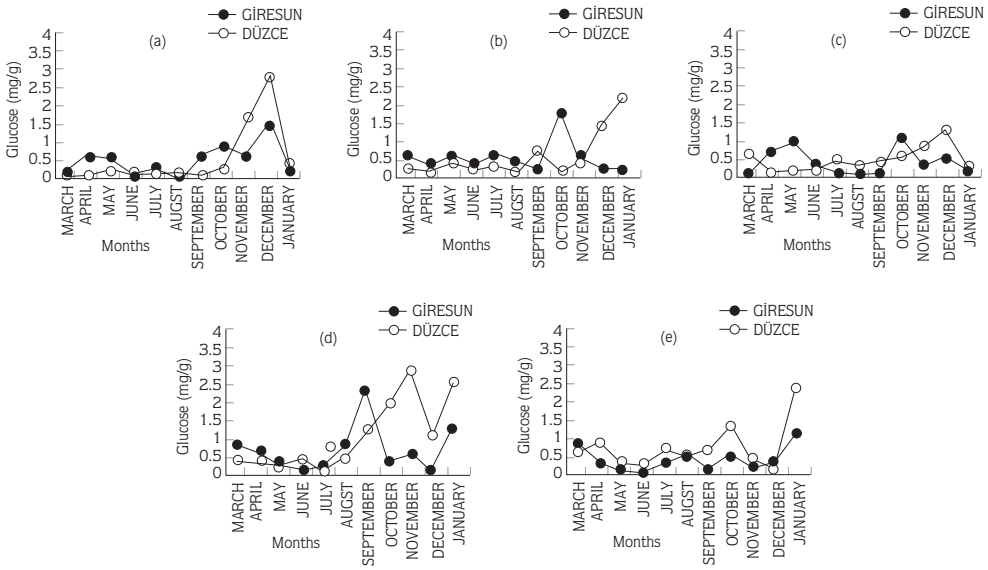

Figure 4. Seasonal changes of sucrose amounts in the bark tissues of some hazelnut cultivars grown in the East and West Black Sea regions (mg/g). (a) : Tombul cv., (b): Palaz cv., (c): Kalınkara cv., (d): Cakıldak cv., (e): Sivri cv.

the beginning of summer and remained stable during a hot summer, fall and winter in the bark tissues of olive trees. In this study, it was determined that in hazelnut shrubs with active growth in spring, there was a decreasing tendency in the content of fructose, sucrose and total carbohydrates. However, sugars in the bark tissues increased during the period of newly formed shoot growth.

Sugars, especially sucrose, have an important role in the cold resistance of plants by increasing the cell protoplasm density (Sakai, 1966). Differences among regions and cultivars mainly occurred between September and January in our experiments. This is especially noticable for sucrose levels. Differences in total carbohydrates, fructose, glucose and sucrose were probably a result of temperature change.

The sugar content of cold resistant cultivars during December, January and March, which are the coldest months were determined to be higher than others. Those differences were especially clear for total carbohydrate, glucose and sucrose levels in January. Likewise, Bonhevi and Coll (1993) and Savage and McNeill (1998) indicated that levels of sucrose in typical mountainous hazelnut cultivars are higher than in other cultivars. Although high sucrose levels were determined in cold regions and periods, differences between cultivars were influenced by sugar type. While there were no significant differences between resistant and susceptable cultivars, in some cases cold resistant cultivars showed high levels. Results show both the importance of sugars, especially sucrose, and the existence of different mechanisms other than carbohydrates for cold resistance. Detailed research on the correlation between levels of carbohydrates and fruitfulness, cold resistance and the like would be useful.

It was determined that hazelnut cultivars demonstrate a similarity with other fruit species in carbohydrate content seasonal variations. This conclusion is also true for cultivars grown in various regions. Only a few differences were seen probably due to ecological conditions in the periods in which increases and decreases in carbohydrate content were initiated.

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