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Seasonal Patterns of Carbohydrates in Mandarin cvs. 'Fremont', 'Nova' and 'Robinson' on Different Rootstocks

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Abstract

The study was conducted at the experimental farm of Mustafa Kemal University, Dörtyol, Turkey during the 2010 and 2011 growing seasons. The aim of this study was to investigate the effect of 'Troyer' and 'Carrizo' citranges (*Poncirus trifoliata* Raf. × *Citrus sinensis* Osb. var. 'Troyer' and 'Carrizo'), and common sour orange (*Citrus aurantium* L. var. *common*), rootstocks on the seasonal variation of carbohydrate content in the leaves of cvs. 'Fremont', 'Nova', and 'Robinson' mandarin. The seasonal variation of carbohydrate content of the three cultivars budded on different rootstocks was nearly same. Soluble carbohydrate concentration showed a continuous decrease from January to mid or late-summer, and then slowly began to increase after early autumn till winter. The sucrose was the dominant soluble carbohydrate in leaves. The seasonal evolution of starch content in leaves increased initially during January to March, and then decreased in April. The starch concentration showed a continuous decrease slowly until the mid-autumn, and then accumulation began during late-autumn and winter. The total carbohydrate content differences among the rootstocks were significant, but the content was changed among the cultivars and according to the season. The change in the total carbohydrate content of leaf tissues showed a strong similarity in cultivars budded on different rootstocks throughout the year. The total carbohydrate content reached their lowest levels in July for cv. 'Robinson', in August for cv. 'Fremont' and cv. 'Nova'. The total carbohydrate content in leaves increased from the mid- or late-summer to winter. It is suggested that the seasonal variation of carbohydrate content in plant tissues can be considered during fertilization program in mandarin trees.

Keywords: carbohydrate, cultivar, mandarin, rootstock, seasonal variation

Introduction

Turkey is one of the major citrus-producing countries with suitable climate and other ecological conditions. Over the last decade, citrus production in Turkey was about 3.572.376 tons and exhibited a 2.5 times higher than in the world citrus production. Mandarin has the second largest share for citrus production with a total of 858.699 tons in Turkey (FAO, 2010).

In the Mediterranean regions of Turkey, the most commonly grown mandarin cultivars are 'Owari' Satsuma, 'Clementine', 'Fremont', 'Nova' and 'Robinson' (Demirkeser *et al.,* 2009). 'Nova' and 'Robinson' mandarins, hybrids between 'Clementine' and 'Orlando' tangelo, are preferred in the European market because of its large size and good appearance with suitability for transportation and storage. These cultivars are commonly grown in Mediterranean countries such as Spain and Israel. 'Fremont' is a hybrid of the 'Clementine' × 'Ponkan' mandarin, has a high yield per tree, and is self- compatibility (Saunt, 1990; Tuzcu, 1990).

The rootstock utilization is mandatory in citrus productions because of the benefits in solving the problems that are caused by soil, climate, pests and diseases. They also supply additional benefits for achieving higher productivity and quality, earlier and later fruit production. Rootstocks may be having different characteristics depending on the climatic and soil conditions and reflect these effects to the scion. Thus, rootstock selection specific to a region is as important as cultivar selection (Davies and Albrigo, 1994). Common sour orange is the main rootstock in Turkey, but 'Trifoliate', 'Troyer' and 'Carrizo' citrange rootstocks are also used to a lesser extent. However, 'Carrizo' citrange has become more frequently used in the last couple of years (Toplu *et al.,* 2012).

It is known that rootstock and scion, which are indispensable compenents in fruit cultivation, affect each other in terms of activities for physiological events, such as carbohydrate, plant nutrient and hormone in plant metabolism. Rootstocks have an indirect effect of reducing sink size and increasing the amount of photosynthates available to fruits and other active meristems above the grafting point (Richer, 2007). Many studies concerning the effect on citrus tree physiology of rootstock and scion interaction were conducted and the events occurring as a result of this interaction have been tried to explain by the researchers (Calatayud *et al.,* 2006; Gonzalez-Mas *et al.,* 2009; Vu *et al.,* 2002), but there is no sufficient study about the effect of rootstocks on accumulation of carbohydrate changes in citrus plant tissues.

For bud burst and early spring growth, deciduous trees are totally dependent upon carbohydrate reserves stored in perennial, woody tree organs. The uninterrupted presence of leaves, which may be old, but still functional photosynthetically, in evergreens, eases the dependence upon carbohydrate reserves. Nevertheless, the spring flush, floral development, anthesis, and fruit set demand more energy that cannot be furnished by current photosynthesis and must be obtained from tree reserves. These reserves are used up in shoot formation during the spring flush of growth (Bustan and Goldschmidt, 1998; Goldschmidt, 1999). Guardiola (1997) reported that "the developing leaves initially draw carbohydrates from other tree parts, but at flower opening they have completed the transition from sink to source and become net carbohydrate exporters, and the developing flowers and fruitlets draw both carbohydrates and mineral elements from other tree parts throughout their development". The management of internal resources in citrus species is not yet completely clarified. In addition, no detailed study had found the effect of rootstocks on seasonal carbohydrate variations in citrus tissues. The objective of the present research was to examine the influence of the three citrus rootstocks 'common sour orange', 'Carrizo' citrange and 'Troyer' citrange on seasonal variability, and the content of non-structural carbohydrate in leaves of mandarin cv. 'Fremont', 'Nova' and 'Robinson' in Hatay, in the Eastern Mediterranean region of Turkey.

Materials and methods

Plant material

The study was conducted at the experimental farm of Mustafa Kemal University, in Dörtyol, Hatay, Turkey during the 2010 and 2011 growing seasons. Investigations included cvs. 'Fremont', 'Nova' and 'Robinson' cultivar on common sour orange (*Citrus aurantium* L. var. *common*), 'Troyer' and 'Carrizo' citranges (*Poncirus trifoliata* Raf. × *Citrus sinensis* Osb. var. 'Troyer' and 'Carrizo') rootstocks. Plant materials were planted with the space of 7 × 7 m in November 1998 and February 1999. The experimental design was a completely randomized one with five replicates and a single-tree per plot.

Sampling

Leaf samples were collected from the fruitless shoots every month throughout the growing season and included: about 5-6 month-old in January, from the summer flush of the previous season (from January to June), and about 3-4 months-old in July, from the spring flush of the current season (from July to December). Leaf samples were decontaminated by washing with a detergent solution, tap water and rinsing with distilled water. Then, samples were dried at 70°C till constant weight and homogenized by particle size reduction to < 0.5 mm, then stored at 4°C until extraction.

Carbohydrate analyses

Soluble carbohydrate (fructose, glucose, and sucrose) content was analyzed by high-performance liquid chromatography (HPLC) (Kafkas *et al.* (2007). One-gram sample was added to 40 mL of 80% (v/v) ethanol and mixed for 20 s using a vortex. The extraction was placed in an ultrasonic bath for 2 hour at 80°C, and then was filtered through the regular filter paper. The extracts were evaporated to dryness on boiling water bath. The residue was dissolved in 5 ml of distilled water and filtered (Whatman nylon syringe filters, 0.45 μm, 13 mm, dia) before HPLC analysis.

HPLC analyses were performed on LC-10A equipment consisting of LC-10AD pumps, in-line degasser, a CTO-10A column oven, a SCL-10A system controller, and a refractive index detector, and operated by LC solution software (Shimadzu, Japan). Reducing sugars were separated on EC (250 × 4 mm) Nucleosil Carbohydrate columns (Macherey-Nagel, Düren, Germany) at 25°C. The mobile phase was acetonitrile: water (80:20, v/v) at a flow rate of 2 ml min^{-1}. The sugars were detected using a refractive index detector and quantified by the external standard method.

The total sugar and starch contents were determined with spectrofotometric assey, according to the procedure described by Kaplankiran (1984). The concentrations of total sugar and starch were summed to give an estimate of total non-structural carbohydrate. All carbohydrate results were expressed as a dried weight basis (%).

Data analysis

Data were subjected to the analysis of variance using GLM procedure of SAS software (SAS Institute Inc., North Carolina, USA). Mean separations were carried out by a Tukey test and assessed at 5% significance level.

Results and discussion

The variation of investigated soluble carbohydrate (fructose, glucose and sucrose) concentration was determined by different rootstocks and cultivars, and plant development stages (Fig. 1-3). As a mean of the two experiment years, the seasonal variations of soluble carbohydrate contents of the three cultivars grafted on different rootstocks were nearly same. These carbohydrate fractions showed a continuous decrease from January to mid- or late-summer. The sucrose was the dominant soluble carbohydrate in mandarin leaves (1.91%) in entire year mean, while the concentrations of glucose and fructose were in 0.69% and 0.93%, respectively. The sucrose content in leaves showed more clear change than fructose and glucose contents. There was the sharp decline in the sucrose content of leaves in almost all the cultivars in May. The sucrose content was reduced by 43.5% in 'Fremont', 54.8% in 'Nova' and 60% in 'Robinson', in this period compared with the previous months (data not shown). The sucrose concentration of leaves reached the lowest values in July for 'Fremont', in August for 'Nova' and 'Robinson' cultivars during the annual growth cycle. The soluble carbohydrate contents slowly began to increase after early autumn and, the same continued during autumn and winter. The seasonal variation trend of soluble carbohydrate contents of three rootstocks in all the cultivars were similar. During the season, the mean concentration of sucrose in the leaves was the lowest level on common sour orange rootstock (1.72% and 1.84%), the highest level on 'Troyer' citrange (2.09% and 1.89%) in 'Fremont' and 'Nova' cultivars, respectively. On the contrary, the lowest content was trees grafted on 'Troyer' citrange (1.87%), and the highest content was those on common sour orange (2.00%) in 'Robinson' cultivar.

Most studies have evaluated seasonal variations in carbohydrates of citrus tree (Garcia-Luis *et al.,* 1995; Goldschmidt, 1999; Mataa *et al.,* 1996; Monerri *et al.,* 2011; Ruiz and Guardiola, 1994; Sugiyama *et al.,* 2006), but have not measured the differences between individual soluble sugars, except for 'Washington Navel' orange leaf (Sanz *et al.,* 1987) and 'Ponkan' mandarin bark and xylem (Mataa *et al.,* 1998). In this study, the sucrose was the dominant soluble carbohydrate in leaves. It is known that sucrose is the major translocated sugar in most of the plants (Ho and Baker, 1982).

The soluble carbohydrate content of the leaves in investigated all mandarin cultivars grown on three rootstocks continuously decreased from January to mid- or late-summer, then gradually began to rise during autumn and winter (Fig. 1-3). The concentration of soluble carbohydrate in leaves declined sharply in May, this may suggest that these carbohydrates were transported from the leaves to support active growth such as bud break, primary root growth, shoot expansion, leaf emergence and enlargement, flowering and fruit and seed set (Goodman *et al.,* 1990; Gregory and Wargo, 1986). The soluble sugar content in different organs of the trees had reached a maximum level in the winter due to the hydrolysis of polysaccharides (Kaplankiran, 1984; Keller and Loescher, 1989; Seyyednejad *et al.,* 2000). The increase in soluble carbohydrate levels during early winter facilitates the cold resistance of the plants (Salisbury and Ross, 1991; Yastioka *et al.,* 1988). Sugars, especially sucrose, have an important role in the cold resistance of plants by increasing the cell protoplasm density (Sakai, 1966). In addition, Mehouachi *et al.* (1995) mentioned that sucrose levels correlated positively with fruit growth and negatively with fruit abscission.

The synthesis of total sugar in the cultivars on different rootstocks and plant development stages occurred differently (Tab. 1-3). The total sugar content of all cultivars budded on three rootstocks decreased from January to mid- or late summer. The total sugar content of leaves attained a minumum value in July for 'Nova' and 'Robinson' cultivars, in August for 'Fremont' cultivar through the entire growing season. The total sugar concentration in leaves showed accumulation from late summer to winter. This trend of total sugar content was similar in all cultivars on different rootstocks. The annual mean highest concentration of total sugar was found in 'Fremont' and 'Nova' cultivars grafted on 'Carrizo' citrange (5.91% and 5.59%), in 'Robinson' grafted on sour orange (5.80%). The growing season mean showed that the total sugar content was higher in 'Fremont' (5.66%) than both 'Robinson' and 'Nova' cultivars (5.51% and 5.52%, respectively).

The total sugar content clearly decreased from the first months of year to mid- or late- summer and then accumulation of the total sugar content began from late summer to winter (Tab. 1-3). This finding was in agreement with oth-

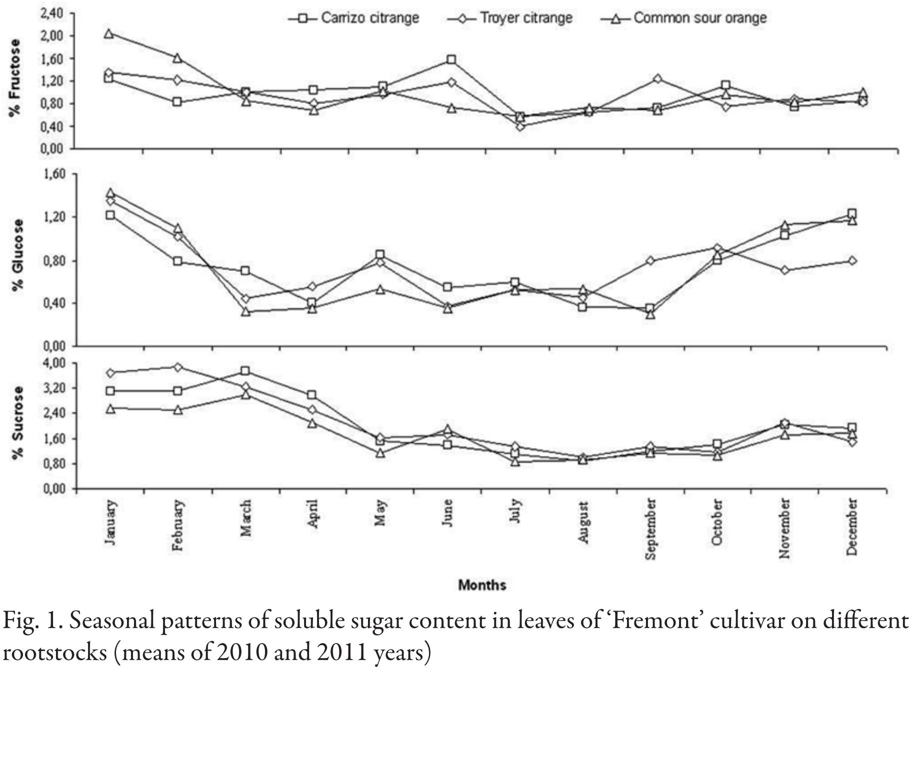

Fig. 1. Seasonal patterns of soluble sugar content in leaves of 'Fremont' cultivar on different rootstocks (means of 2010 and 2011 years)

ers reporting the seasonal variations of this carbohydrate fraction in mandarin (Mataa *et al.,* 1996; Mataa and Tominaga, 1998; Yahata *et al.,* 1995), orange (Yildirim, 2003) and grapefruit trees (Acikalin *et al.,* 2009). However, Kim and Wetzstein (2005) reported that immature leaves are only partially self-supporting and depend on reserves stored in the previous season. Citrus bud break occurred at early spring as from the second half of March and then vegetative and reproductive growth began under Eastern Mediterranean conditions. Carbohydrate reserves were used-up during all plant development stage as from the second half of March to late-summer or early- autumn.

Rootstocks had no significant effect on starch pattern in leaves of 'Fremont' (Tab. 1). The starch differences among the rootstocks in 'Robinson' and 'Nova' cultivars were not also significant, except for leaves at the April and May sampling date, respectively (Tab. 2-3). The seasonal evolution of starch content in leaves first increased in January to March, and then clearly decreased in April. During the period, the amounts of starch in leaves declined for 'Fremont' in 35.0% ratio, for 'Nova' in 37.2% ratio and for 'Robinson' in 41.0% ratio. The starch concentration decreased continously until the mid-autumn, and then accumulation began during late-autumn and winter. Throughout the year, the mean content of starch in the leaves was

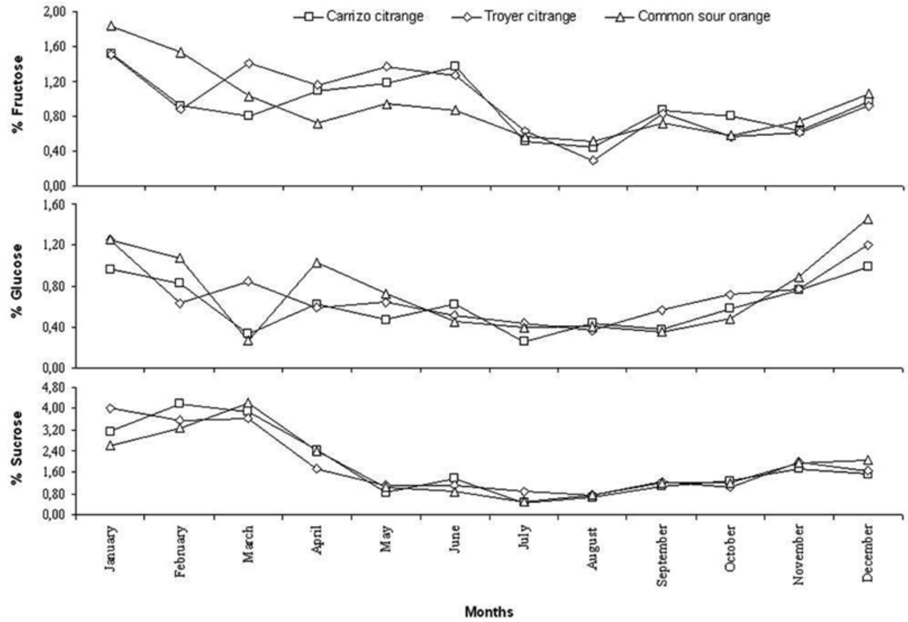

Fig. 2. Seasonal patterns of soluble sugar content in leaves of 'Nova' cultivar on different rootstocks (means of 2010 an 2011 years)

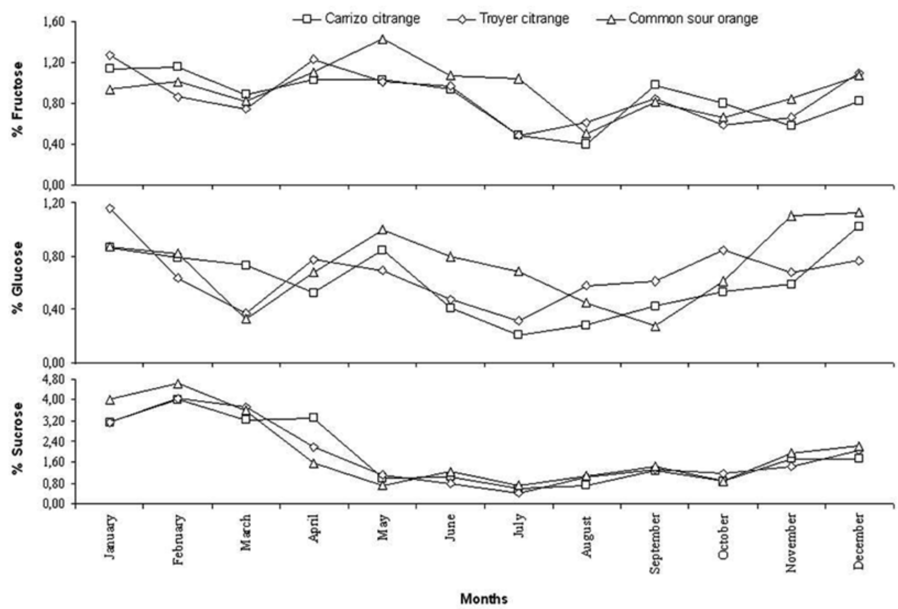

Fig. 3. Seasonal patterns of soluble sugar content in leaves of 'Robinson' cultivar on different rootstocks (means of 2010 and 2011 years)

Tab. 1. Seasonal variation of non-structural carbohydrate content in leaves of 'Fremont' cultivar on different rootstocks (means of 2010 and 2011 years)

Carbohydrate	Rootstocks	Months											
		1	2	3	4	5	6	7	8	9	10	11	12
Total sugar	Carrizo cit.	7.67	6.91	6.52	6.99	5.56	5.16	3.72	3.52	4.36	5.97	6.78	7.78
	Troyer cit.	8.78	8.00	6.59	6.12	4.89	4.81	4.14	3.82	5.47	4.56	6.08	6.19
	Sour orange	8.55	6.21	6.10	5.45	4.24	4.14	3.20	3.66	3.77	4.66	6.39	7.11
	HSD (5%)	NS[1]	0.56	NS	1.29	0.47	0.37	NS	NS	0.80	0.93	0.40	0.62
	Mean	8.33	7.04	6.40	6.19	4.90	4.70	3.69	3.67	4.53	5.06	6.42	7.02
Starch	Carrizo cit.	4.61	5.40	5.85	4.04	2.65	2.60	2.18	1.97	1.91	1.79	3.17	4.43
	Troyer cit.	5.16	5.88	5.70	3.48	2.44	1.97	2.02	1.95	1.90	1.92	3.11	4.32
	Sour orange	5.19	5.15	5.24	3.39	2.47	2.43	2.14	1.63	2.13	2.11	2.87	4.00
	HSD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Mean	4.99	5.48	5.59	3.64	2.52	2.33	2.11	1.85	1.98	1.94	3.05	4.25
Total Carbohydrate	Carrizo cit.	12.28	12.31	12.37	11.03	8.21	7.76	5.90	5.49	6.27	7.76	9.94	12.20
	Troyer cit.	13.93	13.88	12.29	9.60	7.33	6.79	6.16	5.77	7.38	6.47	9.20	10.51
	Sour orange	13.75	11.36	11.34	8.84	6.71	6.56	5.34	5.30	5.90	6.78	9.27	11.10
	HSD (5%)	1.13	1.30	NS	0.75	0.96	0.93	NS	NS	1.28	0.41	NS	0.92
	Mean	13.32	12.52	12.00	9.82	7.42	7.04	5.80	5.52	6.52	7.00	9.47	11.27

[1] NS: Non-significant

the highest level on 'Carrizo' citrange rootstock (3.38% and 3.74%, respectively) in 'Fremont' and 'Nova' cultivars, on common sour orange rootstock (3.44%) in 'Robinson' cultivar. Also, the mean starch concentration in 'Nova' were considerably higher than in 'Fremont' (3.31%) and 'Robinson' (3.39%) with 3.55%.

The seasonal evolution of starch content in leaves increased during January to March, and then obviously decreased in April. This starch disappearance can be explained with conversion of starch into sugar to support the beginning of new shoot growth. The starch content of the leaves remained low levels during summer and mid-autumn, and then accumulation began until the end of year (Tab. 1-3).

Similar results regarding the seasonal variation of starch were registered in evergreen species, such as mandarin (Mataa *et al.,* 1996; Mataa and Tominaga, 1998), avocado (Castillo-González *et al.,* 1998) and mango (Tahir *et al.,* 2003). In evergreens, the continuous existence of leaves partly lessens the dependence on storaged carbohydrate. However, current photosynthesis is not enough to support active growth, such as bud break, primary root growth, shoot expansion, leaf emergence and enlargement, flowering and fruit and seed set, and it must be used from tree reserves (Bustan and Goldschmidt, 1998; Goldschmidt, 1999). The concentration and localisation of starch in

Tab. 2. Seasonal variation of non-structural carbohydrate content in leaves of 'Nova' cultivar on different rootstocks (means of 2010 and 2011 years)

Carbohydrate	Rootstocks	Months											
		1	2	3	4	5	6	7	8	9	10	11	12
Total sugar	Carrizo cit.	7.44	7.85	7.20	6.83	4.93	5.07	2.19	2.97	4.64	4.62	6.27	7.10
	Troyer cit.	8.10	7.49	7.49	5.55	4.88	4.90	3.17	2.18	4.74	4.04	5.65	7.54
	Sour orange	8.32	7.91	7.34	6.77	5.58	3.19	2.42	2.79	4.28	4.22	5.71	7.54
	HSD (5%)	0.76	0.26	NS[1]	1.19	0.48	NS	0.78	0.49	NS	NS	NS	NS
	Mean	7.95	7.75	7.34	6.39	5.13	4.38	2.59	2.64	4.55	4.29	5.88	7.39
Starch	Carrizo cit.	4.92	5.84	6.82	4.23	3.07	2.99	2.11	2.05	2.27	2.32	3.35	4.95
	Troyer cit.	4.70	5.17	5.75	3.51	3.13	2.61	2.21	2.29	1.97	1.79	3.06	5.05
	Sour orange	4.90	5.64	5.78	3.77	3.32	2.20	2.42	1.98	2.22	2.14	2.85	4.49
	HSD (5%)	NS	NS	NS	NS	NS	0.60	NS	NS	NS	NS	NS	NS
	Mean	4.84	5.55	6.12	3.84	3.17	2.60	2.25	2.11	2.15	2.08	3.09	4.83
Total Carbohydrate	Carrizo cit.	12.37	13.69	14.02	11.06	8.00	8.06	4.29	5.02	6.91	6.93	9.61	12.05
	Troyer cit.	12.80	12.66	13.24	9.06	8.01	7.50	5.38	4.46	6.71	5.82	8.70	12.59
	Sour orange	13.22	13.55	13.12	10.55	8.90	5.39	4.84	4.77	6.49	6.36	8.56	12.03
	HSD (5%)	0.76	NS	NS	1.83	NS	2.08	0.48	NS	NS	0.84	0.89	NS
	Mean	12.79	13.30	13.46	10.22	8.30	6.98	4.84	4.75	6.71	6.37	8.96	12.22

[1] NS: Non-significant

plant tissues are affected by many factors, such as temperature, moisture, light, pruning and time of planting.

The total carbohydrate differences among the rootstocks were generally significant, but these changed according to season and cultivars (Tab. 1-3). Changes in the total carbohydrate content of leaf tissues showed a strong similarity throughout the year in cultivars budded on different rootstocks. Generally, the amounts of total carbohydrate remained almost at stable levels from January to March, then began to decline from the end of spring, because carbohydrates actively moves from leaves to buds. Total carbohydrate content reached their lowest levels in July for 'Robinson', in August for 'Fremont' and 'Nova'. In this period, the total carbohydrate concentration of levaes declined for 'Fremont', 'Nova' and 'Robinson' cultivars 54.0%, 64.7% and 63.7%, respectively, to data in March. The total carbohydrate contents in leaves increased from the mid- or late-summer to winter. The annual mean total carbohydrate concentration of leaves was ranged in 'Fremont' between 8.52% (common sour orange) and 9.29% ('Carrizo' citrange), in 'Nova' between 8.91% ('Troyer' citrange) and 9.34% ('Carrizo' citrange) and in 'Robinson' between 8.69% ('Carrizo' citrange) and 9.25% (common sour orange). These contents in leaves of 'Robinson', 'Fremont' and 'Nova' cultivars were almost similar with 8.90%, 8.97% and 9.08%, respectively. There was a significant difference in leaf total carbohydrate concentration between 'Nova' trees on 'Carrizo' sitrange (9.34%), the most vigorous rootstock, and 'Nova' trees on sour orange and 'Troyer' citrange (8.98% and 8.91%, respectively), the least vigorous rootstocks. Similar status weren't found in 'Fremont' and 'Robinson' cultivars.

The total carbohydrate results (Tab. 1-3) agreed with those reported by Mataa *et al.* (1996), Acikalin (1998) and Yildirim (2003), who found that the total carbohydrate content decreased from early spring to mid- or late-summer, then increased to winter. Mehouachi *et al.* (1995) and Goldschmidt and Koch (1996) reported that young leaves not transport the carbohydrates to the other plant tissues until it has completed development, and compete with the developing fruits.

The earlier studies showed that different rootstocks affect citrus tree physiology, especially net photosynthetic rates (Calatayud *et al.,* 2006; González-Mas *et al.,* 2009; Sheng *et al.,* 2009; Vu *et al.,* 2002). These investigations have not sufficiently presented that the effect of rootstocks on accumulation of carbohydrate changes in citrus tissues. Carbohydrates react differently in terms of growth and development, yield, quality, bud and root formation, foliage, periodicity, dormancy, and cold resistance in fruit trees (Okay *et al.,* 2002; Sabajeviene *et al.,* 2007).

The results of the study reveal that annual carbohydrate variations in mandarin cultivars are similar to those of all citrus species. Generally, the carbohydrates were used as energy source during vegetative and generative development in spring, therefore these reduced until the summer. Non-structural carbohydrate accumulation began from autumn because photoassimilates continued at the evergreen species and, the translocation of reserves to fruit decreased depend on low temperatures. Declines in content of soluble sugar and starch of leaves during fruit development indicate that fruiting is a stress period, and that fruit is a strong sink for carbohydrates. It is well known that the fruit is a major and priority sink in citrus, and that a heavy fruit load reduces both the diversion of carbohydrates towards the root system (García-Luis *et al.,* 1995) and the accumulation of carbohydrate reserves (Goldschmidt and Koch, 1996).

Tab. 3. Seasonal variation of non-structural carbohydrate content in leaves of 'Robinson' cultivar on different rootstocks (means of 2010 and 2011 years)

Carbohydrate	Rootstocks	Months											
		1	2	3	4	5	6	7	8	9	10	11	12
Total sugar	Carrizo cit.	8.01	7.62	7.14	5.88	4.34	4.03	2.18	2.58	5.23	4.21	5.48	7.12
	Troyer cit.	8.30	7.83	7.47	5.93	4.70	3.56	2.04	3.91	5.03	4.86	5.02	6.20
	Sour orange	8.59	8.29	6.08	6.00	5.12	4.38	4.12	3.69	4.71	4.15	7.06	7.44
	HSD (5%)	NS[1]	0.23	1.09	NS	0.38	0.63	1.17	0.45	NS	NS	0.37	0.84
	Mean	8.30	7.92	6.90	5.94	4.72	3.99	2.78	3.40	4.99	4.41	5.86	6.92
Starch	Carrizo cit.	4.91	5.78	6.08	3.21	2.57	2.43	1.90	1.91	2.33	1.82	2.94	4.61
	Troyer cit.	5.04	5.36	5.90	3.57	2.98	2.24	1.91	2.02	2.11	1.98	2.67	4.58
	Sour orange	4.97	5.93	5.75	3.69	3.30	2.40	1.82	2.29	1.92	2.04	2.75	4.45
	HSD (5%)	NS	NS	NS	NS	0.59	NS	NS	NS	NS	NS	NS	NS
	Mean	4.97	5.69	5.91	3.49	2.95	2.36	1.88	2.07	2.12	1.95	2.79	4.55
Total Carbohydrate	Carrizo cit.	12.92	13.41	13.22	9.09	6.91	6.46	4.08	4.49	7.55	6.03	8.42	11.73
	Troyer cit.	13.34	13.18	13.36	9.50	7.68	5.80	3.95	5.93	7.13	6.84	7.69	10.77
	Sour orange	13.56	14.22	11.84	9.69	8.42	6.79	5.94	5.98	6.63	6.20	9.81	11.89
	HSD (5%)	NS	NS	1.08	0.53	0.79	0.62	0.87	0.50	0.87	NS	0.97	NS
	Mean	13.27	13.60	12.81	9.43	7.67	6.35	4.65	5.47	7.11	6.36	8.64	11.47

[1] NS: Non-significant

Conclusions

It is determined that the seasonal variations of non-structural carbohydrate contents of the three cultivars budded on different rootstocks were nearly same, and that the carbohydrate concentrations showed a continuous decrease from January to mid- or late-summer, and then slowly began to increase after early autumn. During the period, the most carbohydrate loss occurred in the vegetative and generative development phases. The carbohydrate accumulation in mandarin trees should be increased at the previous year for using next spring. In addition, mandarin trees should be supported with fertilization program especially in spring so that they are able to photosynthesis at high levels.

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