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Yield and Quality of Celeriac (*Apium graveolens var. gapaceum* M.) As Affected by Harvesting Dates and Cultivars

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Abstract: Two celeriac cultivars (*Apium graveolens var rapaceum* M.) [CV Brilliant, "BC" and CV Giant Smooth Prague, "GSPC"] were assessed for yield and quality characteristics at the Experimental Farm, Faculty of Agriculture, Al-Azhar University during two successive winter seasons of 2008/2009 and 2009/2010 years. In order to investigate the effect of three harvesting dates "HD1", "HD2" and "HD3" at 120, 135 and 150 days after transplantation respectively on Celeriac "Shoots and swollen root" yield and quality. Physical characteristics of plant length, leaves number per plant, leaf length and swollen root diameter were measured. Pigment content analysis of Chlorophyll a, Chlorophyll b, total Chlorophyll and Carotenoids were also determined. Nutritional composition of Titratable acidity (TA), Ascorbic acid (AA), total soluble solids (TSS), total sugar (TS) and dry weight in leaves and swollen roots of two celeriac cultivars were determined. Yield of leaves and swollen roots weight were also recorded. There were high significant differences among harvesting dates for all studied characters in both growing seasons. As well as high significant differences between two cultivars were detected, for all studied characters in both seasons. HD3 gave the highest value for leaf pigment content, nutritional composition of leaf and swollen root (TA, AA, TSS), total sugar and dry weight in both cultivars in both growing seasons. However, HD3 improved the nutrceutical value, leaf and swollen root yield in cultivar GSPC more than BC in both seasons. The results of this investigation proved that the most suitable consumption of celeriac leaves and/or swollen roots are at the delayed harvesting to 150 days after transplanting "HD3". In general, the interaction between HD3 and GSPC cultivar produced higher values for most investigated characteristics. So that it's recommended under such conditions to grow CV Giant Smooth Prague, "GSPC" and to be harvested after 150 days from transplanting.

Key words: Celeriac % Harvesting dates % Pigments % Vitamin C % Total sugars

INTRODUCTION

Even celeriac (*Apium graveolens* var *rapaceum* M.) is not well known vegetables crop in Egypt, it is one of the most important root vegetable crops in Europe as a flavoring in soups and stews. It can also be used on its own, usually mashed, or used in casseroles, gratins and baked dishes. It can be roasted like a potato, giving it a crispy edge. Moreover, Celeriac leaves and root are rich in N, P, K, vitamin C, vitamin K and minerals [1-4]. Celeriac also contains 1.55% of proteins. 33% fat, 2.25% (FW) of total sugars and 4.23% total dietary fiber [2]. Beside the minerals, vitamins and dietary fiber content, celeriac is in use because of its characteristic aroma and health benefits which include positive effects on lipid levels [5] and the potential anticarcinogenic properties [6-7]. Celeriac is not as widely used as some other root vegetables, perhaps because it is harder to prepare and clean. Like other root vegetables celeriac is pretty good at taking on the flavors of the dishes in which it is used as an ingredient. Several investigators pointed to many factors towards enhancement of celeriac production and quality [4, 8-11]. One of the most important factors is the genotype and harvesting dates. Dambrauskiene *et al*. [12] and Guerra *et al*. [13] showed that celeriac cultivars differed significantly in their yields and qualities. Increasing celeriac yield and quality is one of the main research purposes and it can be attained through the

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adjustment of the crop management for the given genotypes. Harvesting dates also is one of the important factors which affected crop growth and yield by its impact on the efficiency of plant absorbing nutrients and utilizing the environmental factors. The Celery nutritional value, texture and flavor may change with plant age and different zones of the plant. Harvest date plays an important role on yield and quality, therefore the late harvest of celery plants improved the nutraceutical value [13]. The leaves of celeriac or celery may be dried quickly in a warm oven or microwave to make celery flakes Snakeroot Organic Farm (SOF). Many authors studied the effect of harvesting dates on growth, yield and quality of celeriac [13-16]. Celeriac crop is newly grown in Egypt and we have a little bit knowledge about how to grow and which developmental stages are suitable for harvest. So, the aim of this work was to know the effect of three harvest dates on yield and quality of two introduced celeriac cultivars leaves and swollenroots.

MATERIALS AND METHODS

Two field experiments were carried out at the Experimental Farm, Faculty of Agriculture, Al-Azhar University during winter growing seasons of 2008/2009 and 2009/2010. Two introduced cultivars of celeriac purchased from Reimer seeds company (www.reimerseeds.com), USA were used (Brilliant Celeriac, BC and Giant Smooth Prague Celeriac, GSPC). The initial seeds were sowing in the first of September in greenhouse in both seasons. After 60 days seedlings were transplanted outdoors to the field which had 3-4 true healthy leaves. Recommended culture procedures for commercial production of celeriac were applied. Celeriac plants "shoots and swollen roots" yield were harvested at three harvesting stages, after 120-150 days of their transplanting. The harvesting dates were in March 1st "HD1", March 15th "HD2" and April 1st "HD3". The experiment was conducted in split-plot design with four replications. The harvesting dates were arranged in the main plot and cultivars were assigned to sub plots. Each experimental plot was 10.5 m^2 (five ridges 60 cm wide and 3.5 m long.

At the harvest time, ten guarded plants were taken at random from the inner ridges and data of plant length (cm) number of leaves per plant, Leaf length (cm) swollen root diameter (cm) and total dry matter content, % (determined by drying100g fresh weight of leaf and root at 105°C to constant weight, in accordance with AOAC [17]. Chlorophyll a (Chl. a), Chlorophyll b (Chl. b), total Chlorophyll and Carotenoids were determined in according to AOAC [18]. Titratable acidity (TA mg/ 100g), Ascorbic acid content (AA mg/100g), total soluble solids (TSS %) were measured in leaves and roots by commonly approved methods according to AOAC [18]. Total sugars % (g/100g dry weight) was determined colorimetrically according to the method of Smith *et al*. [19]. Celeriac leaf and root yield per plot were also recorded.

All obtained data were statistically analyzed and the least significant difference (LSD) test was used to compare means at the level of 5% of probability according to Senedcor and Cochran [20].

RESULTS AND DISCUSSION

Data presented in our study clearly show that harvesting dates significantly affect on vegetative, quality and yield traits in both seasons. Moreover, the highest values were obtained by HD3 as compared to other two harvest dates in the two experimental seasons.

The two studied celeriac cultivars significantly differed in their vegetative, quality and yield traits in both seasons. GSPC cultivar gave higher values for all vegetative studied traits (Table 1), some pigment content traits (carotenoids character, Table 2), chemical content traits (titratable acidity and total sugars in leaves, Table 3 and ascorbic acid content, total soluble solids and total sugars in roots, Table 4), leaf/root dry weight traits and leaf/root yield traits (Table 5) in both seasons. While, BC cultivar produced higher values for some pigment content in leaf (Chlorophyll b, total Chlorophyll, Table 2), some chemical content traits (ascorbic acid content and total soluble solids in leaves, Table 3 and titratable acidity in roots, Table 4) in both seasons.

The interaction between harvesting dates and the two studied cultivars gradually increased vegetative growth traits (Table 1), leaf/root chemical contents traits (Table 3), leaves/roots dry matter and leaves/roots yield (Table 5) in both seasons. These increments failed to be a significant from the statistical point of view. On the other hand the interaction between harvesting dates and cultivars significantly improved leaf pigment content characters (Table 2) in both seasons. The combination between HD3 and GSPC produced the higher value for Chlorophyll a, total Chlorophyll and Carotenoids (Table 2). This suggests a differential response of cultivars to harvest dates.

Table 1: Effect of harvesting dates on vegetative growth of two Celeriac cultivars during 2008/2009 and 2009/2010 seasons

		Plant Length (cm)		Number of Leaves/Plant		Leaf Length (cm)		Root Diameter (cm)	
Harvesting dates	Cultivars	First season	Second season	First season	Second season	First season	Second season	First season	Second season
HD1	BC	38.000	36.810	14.020	14.030	30.580	29.560	6.400	6.570
	GSPC	39.500	38.800	24.580	20.100	29.710	30.050	7.440	6.960
	Mean	38.750	37.805	19.300	17.065	30.145	29.805	6.920	6.765
HD2	BC	39.590	39.180	17.690	17.370	32.920	31.950	7.140	6.920
	GSPC	43.620	43.970	26.740	25.390	32.120	32.110	7.950	7.890
	Mean	41.605	41.575	22.215	21.380	32.520	32.030	7.545	7.405
HD3	BC	41.380	41.190	19.110	20.380	35.830	33.670	8.580	7.440
	GSPC	46.330	45.990	29.880	27.150	34.880	33.190	8.940	8.490
	Mean	43.855	43.590	32.720	33.185	41.080	39.830	27.455	26.715
Means									
Cultivars	BC	118.970	117.180	50.820	51.780	99.330	95.180	22.120	20.930
	GSPC	129.450	128.760	97.650	91.480	108.160	108.150	61.720	60.840
LSD 0.05	A	1.755	2.139	1.191	1.304	1.794	0.902	0.409	0.444
	B	1.433	1.747	0.973	1.065	N.S	N.S	0.334	0.362
	AB	N.S.	N.S.	N.S.	N.S.	N.S	N.S	N.S	N.S

A= Harvesting dates, B= Cultivars, N.S. = Non significant

Table 2: Effect of harvesting dates on leaf pigment content (Chlorophyll a, Chlorophyll b, Total Chlorophyll and Carotenoids) in the two Celeriac cultivars during 2008/2009 and 2009/2010 seasons

		Chlorophyll a (mg/L)		Chlorophyll b (mg/L)		Total Chlorophyll (mg/L)		Carotenoids (mg/L)	
Harvesting dates	Cultivars	First season	Second season	First season	Second season	First season	Second season	First season	Second season
HD1	BC	6.590	6.080	3.280	2.710	9.860	8.79	1.310	1.160
	GSPC	6.010	6.000	1.450	2.350	8.680	8.35	1.450	1.390
	Mean	6.300	6.040	2.365	2.530	9.270	8.57	1.380	1.275
HD2	BC	7.950	7.810	3.780	3.070	11.740	10.88	1.360	1.700
	GSPC	7.460	7.590	1.750	1.410	9.210	9.00	1.570	1.930
	Mean	7.705	7.700	2.765	2.240	10.475	9.94	1.465	1.815
HD3	BC	9.220	6.940	4.260	3.510	13.480	10.46	2.280	2.950
	GSPC	10.160	8.890	3.690	3.540	13.850	12.44	3.850	3.520
	Mean	9.690	7.915	3.975	3.525	13.665	11.45	3.065	3.235
Means									
Cultivars	BC	23.760	20.830	11.320	9.290	35.080	30.13	4.950	5.810
	GSPC	23.630	22.480	6.890	7.300	31.740	29.79	6.870	6.840
LSD 0.05	A	0.370	0.230	0.610	0.730	0.680	0.84	0.260	0.390
	B	N.S.	0.190	0.490	0.600	0.550	N.S.	0.210	0.320
	AB	0.530	0.320	0.850	N.S.	0.960	1.19	0.36	N.S.

A= Harvesting dates, B= Cultivars, N. S. = Non significant

Table 3: Effect of harvesting dates on chemical contents in leaves of two Celeriac cultivars during 2008/2009 and 2009/2010 seasons

		Titratable Acidity (mg /100 g FW)		Ascorbic Acid (mg /100 g FW)		Total Soluble Solids (%)		Total Sugars (%)	
Harvesting dates	Cultivars	First season	Second season	First season	Second season	First season	Second season	First season	Second season
HD1	BC	51.000	54.670	17.040	15.780	3.500	2.780	11.910	10.690
	GSPC	79.330	84.330	10.060	7.770	3.310	2.460	12.850	11.690
	Mean	65.165	69.500	13.550	11.775	3.405	2.620	12.380	11.190
HD2	BC	65.000	62.670	18.630	16.190	4.010	3.380	12.730	11.890
	GSPC	87.660	102.000	11.220	8.030	3.750	3.110	13.880	12.190
	Mean	76.330	82.335	14.925	12.110	3.880	3.245	13.305	12.040
HD3	BC	82.660	72.670	20.420	17.780	4.500	3.710	13.430	12.290
	GSPC	97.000	114.330	13.420	9.370	4.000	3.490	14.690	13.300
	Mean	89.830	93.500	16.920	13.575	4.250	3.600	14.060	12.795
Means									
Cultivars.	BC	198.660	190.010	56.090	49.750	12.010	9.870	38.070	34.870
	GSPC	263.990	300.660	34.700	25.170	11.060	9.060	41.420	37.180
LSD 0.05	A	12.840	15.500	1.740	0.899	0.322	0.300	0.801	0.605
	B	10.480	12.650	1.420	0.734	0.263	0.245	0.654	0.494
	AB	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

A= Harvesting dates, B= Cultivars, N.S. = Non significant

Table 4: Effect of harvesting dates on chemical contents in roots of two Celeriac cultivars during 2008/2009 and 2009/2010 seasons

		Titratable Acidity (mg /100 g FW)		Ascorbic Acid (mg /100 g FW)		Total Soluble Solids (%)		Total sugars %	
Harvesting dates	Cultivars	First season	Second season	First season	Second season	First season	Second season	First season	Second season
HD1	BC	50.67	62	4.21	4.08	2.27	2.24	18.09	17.27
	GSPC	40.33	48.33	4.5	4.15	2.640	2.39	18.30	18.17
	Mean	45.50	55.165	4.355	4.115	2.455	2.315	18.195	17.72
HD2	BC	62.33	68.67	4.62	4.31	2.38	2.27	18.4	17.46
	GSPC	48.00	55.67	5.95	5.77	2.93	2.52	20.73	20.03
	Mean	55.165	62.17	5.285	5.04	2.655	2.395	19.565	18.745
HD3	BC	68.67	76.33	5.00	4.57	2.97	2.54	21.02	19.99
	GSPC	52.33	60.67	6.25	6.13	3.33	3.02	23.5	21.7
	Mean	60.50	68.5	5.625	5.35	3.15	2.78	22.26	20.845
Means									
Cultivars	BC	181.67	207	13.83	12.96	7.62	7.05	57.51	54.72
	GSPC	140.66	164.67	16.7	16.05	8.90	7.93	62.53	59.9
LSD 0.05	A	7.638	10.035	0.694	0.321	0.441	0.311	1.08	0.862
	B	6.236	8.193	0.567	0.262	0.36	0.254	0.88	0.704
	AB	N.S.	N.S.	N.S.	4.08	N.S.	N.S.	N.S.	N.S.

A= Harvesting dates, B= Cultivars, N.S. = Non significant

Table 5: Effect of harvesting dates on leaves and roots dry matter and yield in the two Celeriac cultivars during 2008/2009 and 2009/2010 seasons

		Leaves Dry weight (%)		Roots Dry weight (%)		Leaves Yield (kg/plot)		Roots Yield (kg/plot)	
Harvesting dates	Cultivars	First season	Second season	First season	Second season	First season	Second season	First season	Second season
HD1	BC	14.85	12.68	9.33	9	20.41	15.54	14.81	14.68
	GSPC	16.23	14.25	10.23	9.85	20.72	21.81	18.51	17.84
	Mean	15.54	13.465	9.78	9.425	20.565	18.675	16.66	16.26
HD2	BC	17.5	14.77	10.03	9.47	22.58	22.64	15.41	14.88
	GSPC	18.37	16.13	10.95	10.72	24.53	26.13	21.23	20.3
	Mean	17.935	15.45	10.49	10.095	23.555	24.385	18.32	17.59
HD3	BC	18.82	17	11.15	10.17	24.87	27.36	17.65	17.64
	GSPC	19.32	18.85	11.67	11.4	26.5	26.63	23.12	22.3
	Mean	19.07	17.925	11.41	10.785	25.685	26.995	20.385	19.97
Means									
Cultivars.	BC	51.17	44.45	30.51	28.64	67.86	65.54	47.87	47.2
	GSPC	53.92	49.23	32.85	31.97	71.75	74.57	62.86	60.44
LSD 0.05	A	1.975	2.508	0.9	0.564	2.48	3.755	2.466	1.714
	B	N.S.	N.S.	0.735	0.461	N.S.	N.S.	2.014	1.399
	AB	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

A= Harvesting dates, B= Cultivars, N. S. = Non significant

Our results indicated that the vegetative growth (plant length, number of leaves/plant, leaf length and swollen root diameter) were increased and differ significantly in HD3 compared with the other two harvesting dates (HD1 and HD2). Significant effect of HD3 on vegetative growth traits has also been reported by Yadav and Khurana [21]. GSPC cultivar exceeded BC cultivar by (64.16 and 65.60%) in the first and second seasons respectively. The decrease in plant height with early harvest (HD1) could be attributed to shorter period of vegetative growth and lower temperature at early growth stages which might have slowed down the vegetative growth of crop plants [22].

Pigment content (chlorophyll a, chlorophyll b, total chlorophyll and carotenoids content) were significantly elevated in both cultivars with HD3 (Table 2) during the two seasons. This is may be due to celeriac plants were harvested at pre and/or mature stage. At HD3 plants are in full mature with green leaves and contents high amount of pigment. The pigment content increased gradually at plant growth and developmental stage with no degradation [23]. These results can be attributed the increment induced in pigments content at HD3 achieved by plant vegetative growth and high temperature may be affected the photosynthesis [24]. During developmental stage of plants, photosynthetic pigment content increased and at the onset of aging, pigment contents start to decrease. Photosynthetic pigment content of the plants increased gradually till 96 days and started to decline there after [25].

The content of titratable acidity (TA), ascorbic acid (AA), total soluble solids (TSS) and total sugars (TS) were gradually increased in both leaves and roots but these increments failed to be significant from the

statistical point of view (Table 3 and 4). These results are consistent with those reported by several authors [12-14]. Gomez and Artes [26-27] and Kresic *et al.* [28] revealed that there were significant differences in titratable acidity (TA) between harvesting dates and cultivars. Moreover, Kader *et al*. [24] reported that the titratable acidity and ascorbic acid increased in tomato fruit when grown at 26-35°C compared with that those grown at lower temperature. TSS contents in root were less than in leaves, but were higher in GSPC root than in BC with record of 3.17% and 2.75% respectively. This increase may be related to organic reserves transformation by which energy is made available for the catabolism uses, but it might be also associated with an aging product and with structural changes of carbohydrates and indicate that harvest delay improved the nutraceutical value as a result of the development of pithiness [13, 26-27]. However, the total sugar content was found more higher and increased in swollen root of cultivars GSPC and BC in the HD3 (Table 3 and 4). The average total sugar content in both seasons was high significant in cultivar GSPC than in cultivar BC (22.6 % and 20.5 % respectively). In contrast, there are not different significant was found between harvesting dates and cultivars.

These results can be attributed the increments induced depending on growth, development and physiological status of the plant were reported by several investigators [10, 29-30]. According to the data of the other countries which agreement with our results, celery root-crops accumulate more sugars, but this occurs in southern European countries, where climatic conditions are more favorable for the synthesis of organic matter in plants [28, 31-32].

Our results also indicated that both celeriac cultivars can grow well under Egypt condition, however the significant differences between the cultivars may be related their inheritance and climatic conditions [11-12, 32]. Plant growth and productivity dependent on their tolerance and response to field temperature largely determined the geographic distribution of vegetables and the seasons of their production at harvest and their response to post-harvest environment [24].

CONCLUSIONS

From the data presented in this study it is clear that the quality characterization in two cultivar Celeriac plants (BC and GSPC) by harvesting dates recognized differences in growth parameter as physical characteristics such as: Plant length, leaf number, leaf length and swollen root diameter. The highest productivity and quality was recorded in HD3 than other harvesting dates. Harvesting dates modify pigments, TA, AA, TSS, total sugar content leaf and root yield. Nutrceutical value was enhanced by a late harvest and more mature plants showed high productivity and quality. This study provides basic information about the physical, chemicals and nutritional quality of the Celeriac plant associated with harvest maturity stage. Future research including blanching with more different stages of Celeriac development will elucidate the changes associated with plant maturity. These findings are essential to determine the optimum maturity stage at harvest with which the highest quality of the product is achieved.

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