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Some parameters of hydroponic and soil Rhubarb cultivated in the Ararat Valley of Armenia

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ABSTRACT

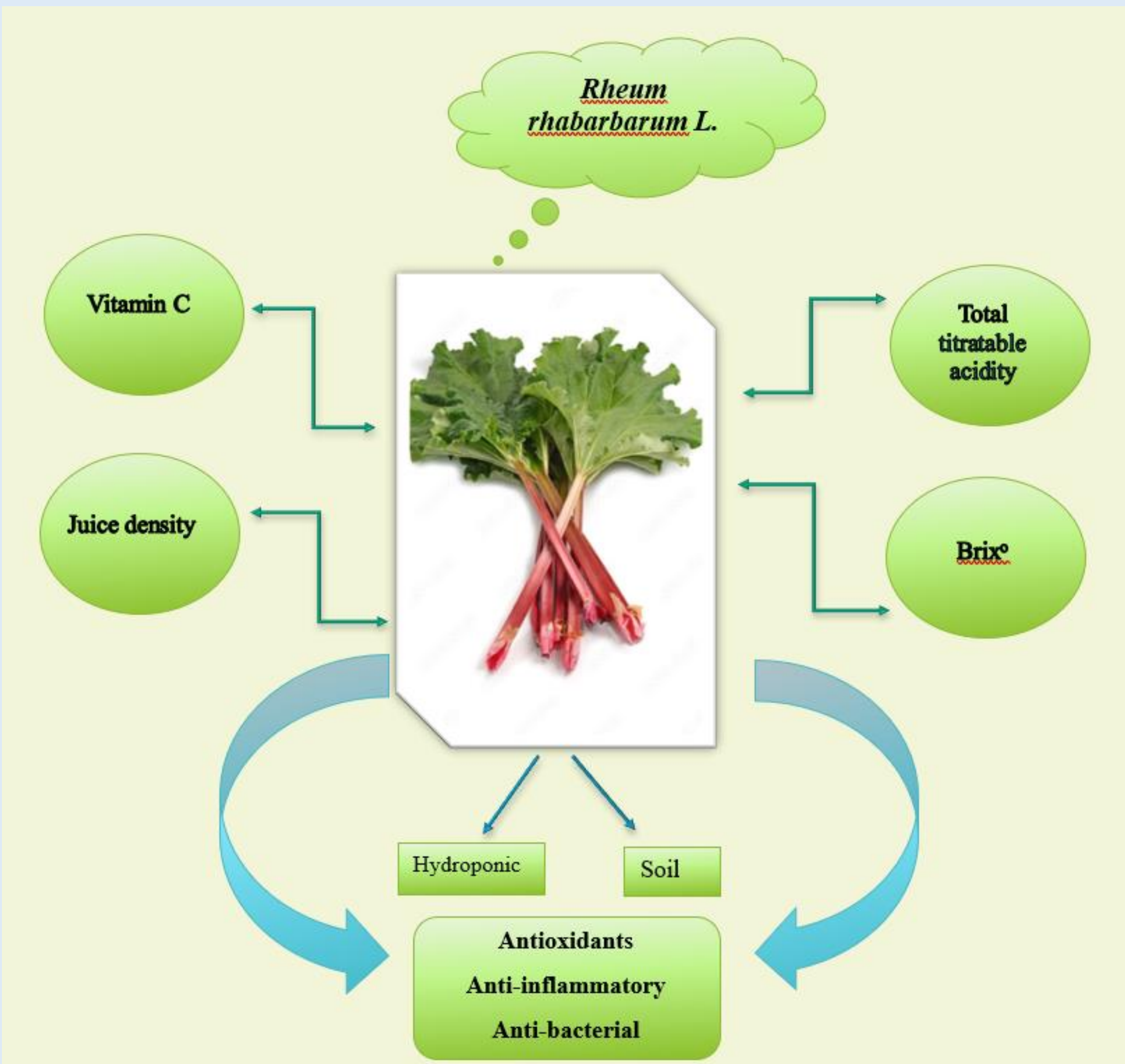
Today, the rhubarb plant is selectively included in the diet. Rhubarb juice offers a unique flavor with a surprising range of potential health benefits. Rhubarb is rich in antioxidants, particularly anthocyanins, the pigments responsible for its red hue. These antioxidants are believed to possess anti-inflammatory and anti-bacterial properties, potentially aiding in the fight against various health concerns. Rhubarb juice is an excellent source of vitamins C, and K, crucial for bone health and blood clotting, and also contains vitamin A, contributing to healthy skin and vision.

Context and purpose of this study: to investigate for the first time the cultivation of rhubarb (*Rheum rhabarbarum*) in the Ararat Valley of Armenia in both hydroponic and soil conditions. The research focuses on identifying the optimal growth period to maximize key quality indicators of rhubarb stalks and juice for food and medicinal applications: Brix value, juice density, total titratable acidity, and vitamin C content.

Results: Hydroponic cultivation significantly (by three folds) increased the fresh weight of rhubarb petioles (stalks) compared to soil plants. The maximum accumulation of vitamin C in hydroponic plants was observed at the beginning (June) and end (September) of the growing season (19.4 and 17.3 mg%) respectively. However, there was not a significant difference in vitamin C content during July and August (14.3 and 14.0 mg% respectively). Soil plants showed the highest accumulation of vitamin C in September (41.5 mg%), exceeding the values in June by 1.2 times and from July to August by 1.5 times. Total titratable acidity showed seasonal variations: the highest acidity (1.2 to 1.3-fold higher) of hydroponic rhubarb juice was observed in July compared to other months. Soil-grown rhubarb reached peak acidity at the beginning of the growing season (approximately 1.2 times higher than in other months). The Brix° value and juice density peaked in July for hydroponic rhubarb and in August for soil rhubarb.

Conclusion: This study highlights the potential of hydroponics for maximizing rhubarb yield and potentially influencing the vitamin C content and acidity profile throughout the growing season in Armenia. The results of further research could be used to optimize nutrient composition and environmental parameters for even greater control over rhubarb quality for food and medicinal purposes.

Keywords: Vitamin C, Total titratable acidity, Brix°, Juice density



INTRODUCTION

Rheum rhabarbarum L., commonly known as rhubarb, belongs to the Polygonaceae family. This family encompasses various flowering plants, including buckwheat and sorrel [1]. Rhubarb is an herbaceous perennial, meaning it lives for several years with aerial parts dying each winter and re-emerging in spring [2]. The most recognizable feature of rhubarb is its thick, fleshy petioles (leaf stalks). These petioles are the edible portion of the plant and come in various colors, ranging from red to green [2]. The actual rhubarb leaves are large, lobed structures with a characteristic sour taste. However, they are inedible due to the presence of high levels of oxalic acid, a toxic compound [3]. Rhubarb petioles are primarily consumed when cooked, featuring prominently in various culinary creations. They are often incorporated into sweet dishes like pies, jams, and crumbles due to their characteristic tartness. Rhubarb can also be used in savory applications, adding a unique acidic element to sauces and chutneys [4]. It's crucial to emphasize that only the petioles of rhubarb are safe for consumption [5].

A vibrantly colored drink made from the stems of the rhubarb plant, rhubarb juice offers a unique flavor with a surprising range of potential health benefits. Today, the rhubarb plant is selectively included in the diet. Rhubarb boasts a wealth of antioxidants, particularly anthocyanins [6], the pigments responsible for its red hue [7]. These antioxidants are believed to possess anti-inflammatory and anti-bacterial properties, potentially aiding in combating various health concerns. Rhubarb juice isn't just about vibrant color; it provides a punch of essential vitamins and minerals. It's an excellent source of vitamins C and K, crucial for bone health and blood clotting, and contains vitamin A, contributing to healthy skin and vision [8].

The main organic acid in the rhubarb plant is malic acid, which is present in smaller amounts compared to other organic acids. Malic acid contributes to its

sourness. Oxalic acid, which is the main contributor to sour taste, requires caution due to potential health risks associated with high consumption. Citric acid, another key organic acid, also adds sourness and offers potential health benefits. Additional organic acids in rhubarb juice include succinic acid, sorbic acid, and benzoic acid though they are present in smaller amounts [4].

While information readily available online confirms the presence of various organic acids and their contribution to the sourness of rhubarb juice, specific data on refractive index and Brix values for rhubarb juice are scarce [9]. There is a lack of available scientific data directly citing the refractive index of rhubarb juice. Refractive index is often used in the food industry to determine sugar content. However, in this case, the presence of organic acids alongside sugars may complicate a direct correlation. Similar to the refractive index, specific Brix° values for rhubarb juice are not widely documented. Brix° shows the percentage of dissolved solids, primarily sugars. While rhubarb juice contains sugar, the significant presence of organic acids likely affects the Brix value, making it an imperfect measure of sweetness for rhubarb juice [10, 11]. Consulting scientific articles and research databases focused on the specific analysis of rhubarb juice composition may yield more specific data on the refractive index and Brix° values. Experimentation by measuring the refractive index and Brix° of homemade rhubarb water can provide insights while acknowledging the limitations due to potential variations. In general, while information on refractive index and Brix° specifically for rhubarb juice is limited, understanding the high organic acid content helps explain its sour flavor profile more clearly [12].

This study aims to investigate the cultivation of rhubarb (*Rheum rhabarbarum*) for the first time in the Ararat Valley of Armenia, comparing its growth in both hydroponic and soil conditions. The research focuses on identifying the optimal growth period to maximize key quality indicators in rhubarb petioles and juice for food and medicinal applications: Brix° value, juice density, total titratable acidity, and vitamin C content.

MATERIALS AND METHODS

Plant growth and sample collection: In Armenia's Ararat Valley (AAV), an experiment compared plant growth under two conditions: hydroponics and soil. The hydroponic system utilized an EBB and Flow method with automatic irrigation, planting density was 6 plants per square meter [13]. In early April, four-year-old plants were carefully removed from the soil. Their roots were divided and transplanted into a hydroponic substrate with a nutrient area of 1 square meter, alongside soil (maintaining a density of 6 plants per square meter). Volcanic slag was used as the hydroponic substrate. In hydroponics plants were nourished with a specific nutrient solution developed by Davtyan [14] to 1-2 times daily. In contrast, the rhubarb grown in soil was irrigated every two days.

Determination of Vitamin C Content: A 5-gram sample of fresh leaves was crushed in a mortar with 20 mL of 1% hydrochloric acid solution until a homogenous mixture was obtained. The crushed leaves were then transferred to a volumetric flask containing 80 mL of 1% oxalic acid solution. Two 10 mL aliquots were pipetted from the mixture and titrated with a 0.001 N solution of 2,6-dichlorophenolindophenol dye using a micro burette [15].

Determination of Total Titratable Acidity: The juice of rhubarb stems was squeezed with distilled water to reach the 150 mL mark, then this solution was filtered. From this filtrate, 50 mL was taken, and 70 ml add 1 mL phenolphthalein to that and titrate with 0.1n NaOH.

$$X = (a \times V \times 0.0067 \times 100)/(H \times V1 \times V2)$$

a - amount of NaOH consumed for titration, V-volume (juice + distilled water) (150 mL), 0.0067 - constant conversion to malic acid, H-hitch, V1(V2) - volume that is taken from the filtrate (50 mL, 70 mL) [16].

Determination of Refractive Index and Brix°: The refractive index, measured by a refractometer, determines how light bends as it passes through the sample solution compared to a reference medium like air or water. Higher concentrations of dissolved solids cause a greater degree of bending, resulting in a higher refractive index value. This method offers a rapid and non-destructive technique for quantifying solutes but is not specific to sugars. Brix°, on the other hand, is a unit specifically designed to measure sugar content in a solution, typically expressed as grams of sucrose per 100 grams of solution. While Brix° values can also be obtained using a refractometer, the instrument needs to be calibrated for this specific conversion. This method provides a straightforward interpretation of sugar concentration but is less accurate for solutions containing significant amounts of non-sugar solutes [17].

RESULTS

Analysis of Rhubarb Yield and Biometric Indicators in Hydroponic and Soil Cultivation Systems: The yield and characteristics of the biometric indicators of the rhubarb were studied in the hydroponic substrate and soil culture conditions. From Table 1, the hydroponic substrate did not have a significant effect on the fresh and dry masses of the total petiole yield per plant, the number of petioles obtained per plant, and the fresh and dry masses of individual petioles. Soil plants were inferior to the hydroponic version by a factor of 3.0 in petiole mass. The hydroponic plants outperformed the soil plants by 3.0 times with petiole in fresh petiole mass, 2.0 times in dry petiole mass, and 1.6 and 1.1 times in fresh and dry weight per petiole, respectively. From the analysis of the biometric data of the petioles, it becomes clear that the width of the petioles of hydroponic plants was 1.2 times higher than that of soil plants.

Table 1. The yield and characteristics of biometric indicators of rhubarb in different growing media

Growing media	Petioles weight, g/plant		Number of petioles	1 Petiole weight		Width of petioles, mm	Length of petioles, cm
	Fresh	Dry		Fresh	Dry		
Hydroponic substrate	913.0±59.3^{a}	67.4±2.21^{a}	74±12.6^{a}	12,3±1.3^{a}	0,9±0.06^{a}	10,6±0.4^{a}	14.2±0.7^{b}
Soil	302.0±26.5^{b}	33.2±3.3^{c}	41±5.1^{b}	7.4±0.7^{b}	0,8±0.07^{b}	9,0±0.3^{b}	15.9±1.9^{a}

*Different letters indicate significant differences

Vitamin C Content in Rhubarb: During the vegetation period, biochemical analysis of vitamin C in rhubarb petioles was performed each month (June to September) under different plant-growing conditions (Fig. 1). The results have shown that the content of vitamin C in hydroponic plants was highest at the beginning (June) and at the end (September) of vegetation, and in July and August its content was approximately the same and was 1.2-1.4 times lower compared to June and September. In soil conditions, no significant change in vitamin C content was observed in July and August, and it was 1.2-1.5 times lower than in June and September. During the vegetation period, the maximum accumulation of vitamin C in soil plants was observed in September: it was 1.2 times higher than in June. From Figure 1, during the vegetation period, soil-grown exceeded the hydroponic version in vitamin C content in June by 1.7 times, in July and August by 1.9 times, and in September by 2.4 times.

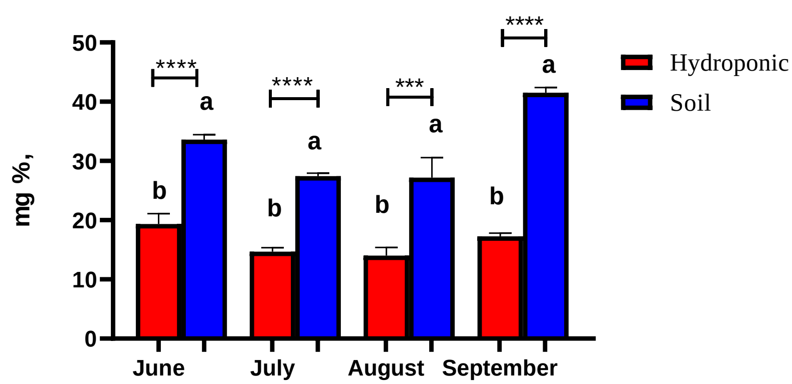


Figure 1. Dynamics of vitamin C content in rhubarb petioles under different growing conditions (DGC) (Different letters indicate significant differences, *** P < 0.001, **** P<0.0001)

Although in June the hydroponic plants were 1,7 times inferior to the soil plants in vitamin C content, they provided a 3.4 times higher yield of vitamin C compared to soil plants, due to their petiole's high yield (Fig. 2). Cultivation conditions did not significantly affect vitamin C content in July to August, but in September, hydroponic plants were 1.6 times inferior to the soil version.

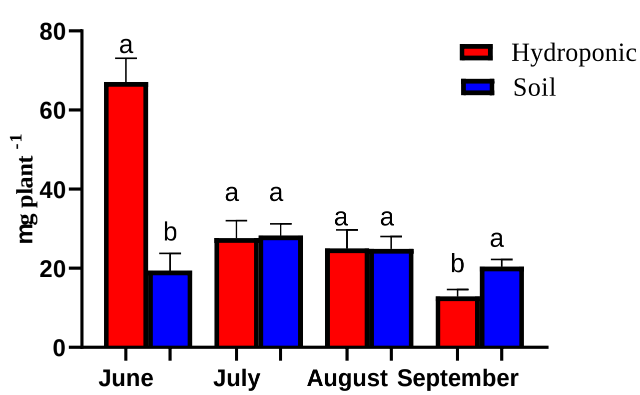


Figure 2. Vitamin C yield in rhubarb petioles under DGC (Different letters indicate significant differences)

Impact on Rhubarb Total Titratable Acidity: From the analysis of the data in Fig. 3, during the vegetation period, the highest total titratable acidity in hydroponic rhubarb petioles was in July being 1.2-1.3 times higher than the results in other months. The soil plants provided the highest total titratable acidity in July which was 1.2 times higher than in other months. Compared to soil plants, hydroponic plants produced a 1.2-4.3 times higher yield in total titratable acidity due to their higher petiole yield. (Fig. 4).

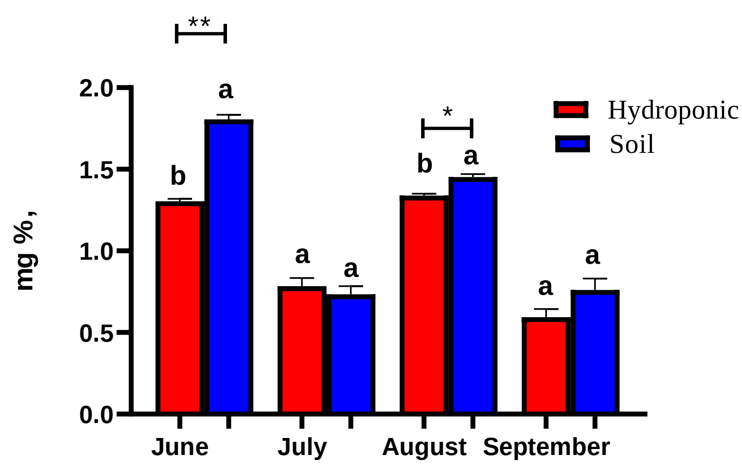


Figure 3. Total titratable acidity content during vegetation in DGC (Different letters indicate significant differences, * P < 0.05, *P < 0.01)

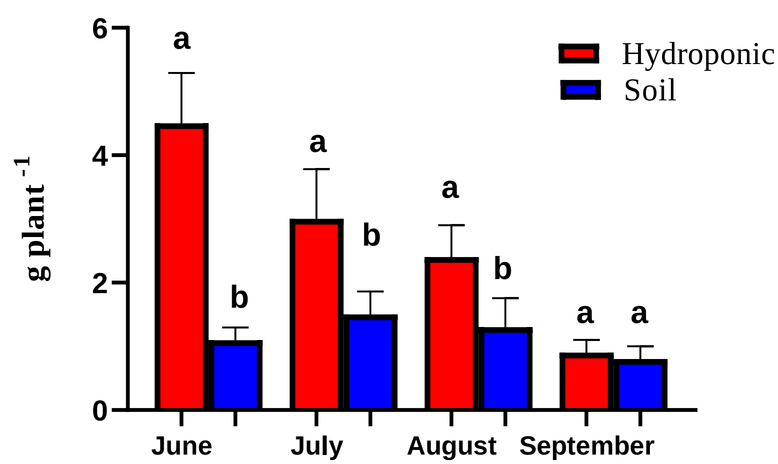


Figure 4. Total titratable acidity yield during vegetation in DGC (Different letters indicate significant differences)

Refractive Index, Brix°, and Density of Rhubarb Petioles: Refractive index, Brix° and density of rhubarb petioles were determined during the growing season. Since there is no reliable data on the refractive index of rhubarb juice in the scientific literature, it is likely that, the refractive index of the juice of rhubarb petioles is most likely closer to the refractive index of fruit juices and is in the range of 1.3300 - 1.3900 [18]. As shown in Table 2, the index of refraction of rhubarb juices during vegetation suits the above-mentioned ranges. During the vegetation, in July the rhubarb refraction index data was high in the hydroponic version, and in August in soil plants

Table 2. Physiological indicators of rhubarb under DGC

Growing Media	Refractive index				Brix°				Density ($g.mL^{-1}$)			
	June	July	August	September	June	July	August	September	June	July	August	September
Hydroponic	1.3392	1.3394	1.3390	1.3380	3.3	4.3	4.0	3.6	1.018	1.045	1.015	1.014
Soil	1.3392	1.3390	1.3410	1.3400	4.3	4.0	5.1	4.8	1.001	1.021	1.038	1.023

DISCUSSION

According to the literature, the total yield of rhubarb varied from 24.480 kg*ha^{-1} to 41.460 kg*ha^{-1} depending on the planting distances. It was shown that in the case of the Victoria cultivar, the highest production from 1 ha was obtained at a density of 0.75 m x 1 m, though statistically assured yields were also obtained at the density of 1 m x 1 m [18]. In our study from 1 ha, it is possible to receive 54780kg*ha^{-1} yield in the case of hydroponic cultivation exceeding the literature data and 18120 kg*ha^{-1} yield from the soil plants, which is in the range of literature results.

In the literature, the level of vitamin C in young shoots of *Rheum Ribes* L. ranged from 197.6 ± 10.47 - 282.3 ± 17.46 µg g^{-1} (which is similar to 19.76-28.23mg %) it has been shown that the resistance of these plants to free radicals, which increase under stress, improves due to higher levels of antioxidant vitamins [19]. In our obtained data, during the vegetation, the amount of vitamin C in the soil plants (27.2±2.3-41.8 ±0.8mg %) was higher than in hydroponic plants (14.0 ± 1.3 -19.4 ±1.8mg %).

Studies done in Germany showed that because of low sugar content, the relative density and Brix° (4–4.8 Brix°) are low in rhubarb juice, while the total acidity is high (about 17 g/L) [20]. Our results are close to the data reported in the literature. In our obtained data, the relative density and Brix° were between 3.3-4.8 and the total acid in the vegetation period in hydroponic plants was 11.9-13% while in soil plants it was 14.5-18.1%.

The yield and characteristics of the biometric indicators of the rhubarb were studied in the hydroponic substrate and soil culture conditions. Hydroponic substrate did not significantly affect the fresh and dry masses of the total petiole yield per plant, the number of petioles obtained from each plant, and the fresh and dry mass of a single petiole. Soil plants were inferior to the hydroponic version by a factor of 3.0 in petiole mass. Hydroponic plants outperformed soil plants by 3.0 times in petiole fresh mass,2.0 times in petiole dry mass, and 1.6 and 1.1 times with the fresh and dry weight of a single petiole, respectively. Analysis of the biometric data of the petioles shows that the width of the petioles of hydroponic plants was 1.2 times greater than that of soil-grown plants.

While hydroponics yielded superior results in terms of total and individual petiole mass, as well as petiole width, a contrasting trend emerged for vitamin C content. Soil-grown rhubarb consistently displayed a higher vitamin C concentration throughout the growing season, with the most significant difference observed during the mid-vegetation months (July and August). This suggests a trade-off between the production benefits of hydroponics and the vitamin C advantage offered by soil cultivation. Hydroponic cultivation resulted in a higher overall yield of titratable acidity, compared to soil cultivation.

In conclusion, the results of our experiments showed that the highest Brix° and juice density of the hydroponic rhubarb petioles were recorded in July, in the soil version - in August. Therefore, it can be concluded that the dates of rhubarb harvesting in Ararat Valley hydroponics and soil conditions are July and August.

Abbreviations: AAV - Armenia's Ararat Valley**;** DGC - different growing conditions

Authors Contribution: All authors contributed to this study.

Competing interests: The authors declare no conflict of interest.

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