The effect of sowing density on morphological traits and yield of hydroponically grown spinach

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Abstract

The aim of this research was to determine the effect of sowing density on the morphological traits and yield of hydroponically grown spinach. During a harvest conducted 32 days after sowing, morphological characteristics were analysed and spinach yield was determined. No significant effect of sowing density on spinach rosette height was found, while statistical differences between the tested treatments were determined for other morphological traits and yield. The highest weight of spinach rosettes (6.5 g) was obtained at the lowest sowing density, while the highest yield (2 kg m^{-2}) was obtained at the highest sowing density.

Keywords: *Spinacea oleracea* L., floating system, rosette mass and height, leaves number

Introduction

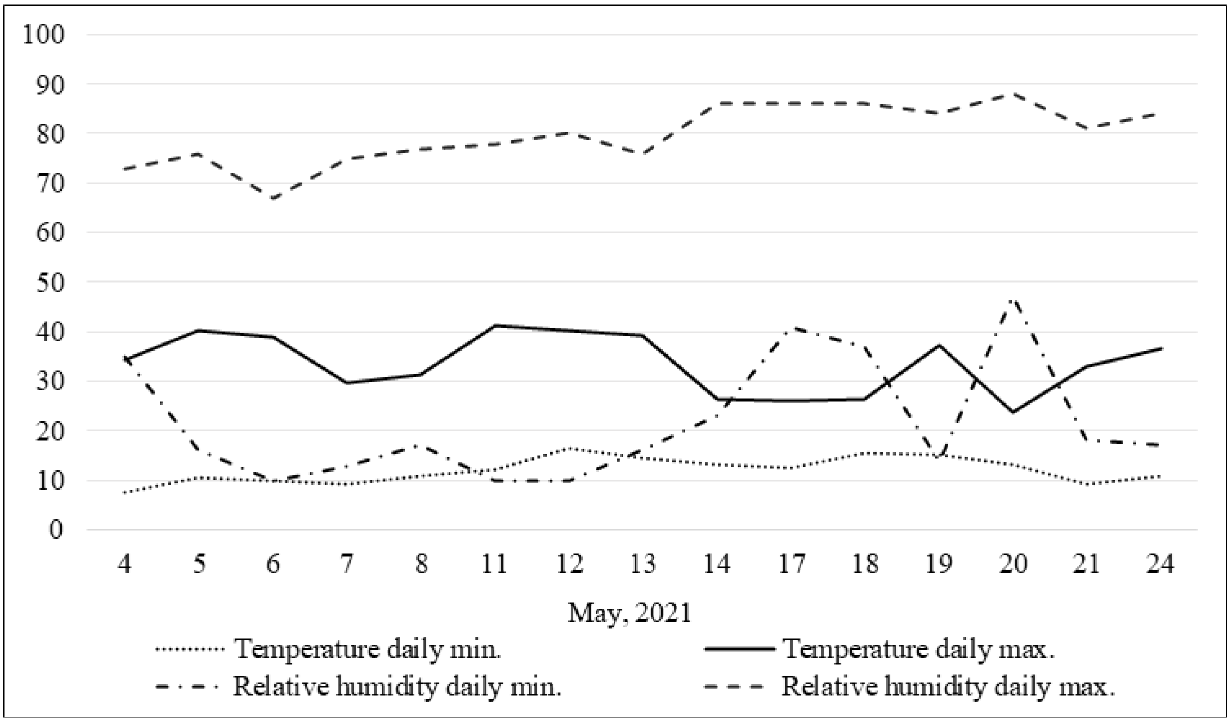
Recently, the consumption of young spinach in combination with other leafy vegetables has been continuously increasing in Croatia. Also, in greenhouses, it is increasingly common to replace conventional cultivation of plants on the soil with hydroponic cultivation which reduces soil degradation, the accumulation of harmful organisms and harmful effects on the environment, and increases yield and quality (Kacjan Maršić, 2017.). According to Öztekin et al. (2018.), higher yield and nutritional value of spinach are obtained in floating hydroponics and the cultivation is shorter compared to soil cultivation. The same authors report that yield and quality of leafy vegetables are influenced by cultivation techniques, sowing density, concentration of macronutrients in the nutrient solution, length of the production cycle, and other factors. According to Toth et al. (2012.), in hydroponic cultivation, it is necessary to determine the optimal composition of the nutrient solution, sowing density, and appropriate assortment depending on the growing period to achieve higher yield and quality for each type of leafy vegetable. Janeczko and Timmons (2019.) state that the sowing density and the volume of the growing pots influence the morphological characteristics of cut leafy vegetables. For the cultivation of spinach in floating hydroponics, different data on sowing density are given. Cocetta et al. (2007.) indicate 1150 seeds m^{-2} for sowing density of spinach, while Öztekin et al. (2018.) in their study indicate 957 plants m^{-2} as a plant density of spinach. The aim of this research was to determine the effect of sowing density on the morphological characteristics and yield of spinach using the floating hydroponic technique during the spring-summer growing period.

Material and methods

The research was set up in the greenhouse at the University of Zagreb Faculty of Agriculture in Zagreb during the spring-summer growing season of 2021. A one-factorial experiment was set up according to the randomized complet block design in 3 replications with the spinach cultivar 'Eagle F1' (Rijk Zwaan). Seeds were sown on April 23. One polystyrene board (0.96 m x 0.6 m) with 102 splits (17 cm long and 0.5 cm wide) represented scoring lot (0.57 m^2). Boards were filled with perlite of granulation 0 - 6 mm. Three sowing densities were tested: A - 1252, B - 2505 and C - 3758 seeds m^{-2}, i.e. 21.3, 42.7 and 64.2 g m^{-2}) and covered with perlite of finer granulation (0-3 mm). Before sowing, the mass of 1000 seeds of cultivar 'Eagle F1' was determined (17.2 g). After sowing, the boards were placed in a dark place with a temperature suitable for germination (21°C, relative humidity 42 to 60%) of spinach seeds. Germination was detected on May 4, when the nutrient solution for growing spinach was prepared according to the Tessi (2002.) and the polystyrene boards with the germinated spinach were placed in the pool with the nutrient solution. The spinach harvest was performed on May 25, i.e. 32 days after sowing. On 10 plants per repetition of each sowing density, next morphological characteristics of spinach were analysed: mass and height of the rosette, number of leaves, and the yield was determined. The statistical program Windows SAS® Software v.9.3 (2010.) was used for statistical procedures of the obtained results. The differences between the tested sowing densities for all the observed traits were analyzed by analysis of variance, and the significant differences between the average values were tested by LSD test and were considered significantly different at p≤0.05.

Results and discussion

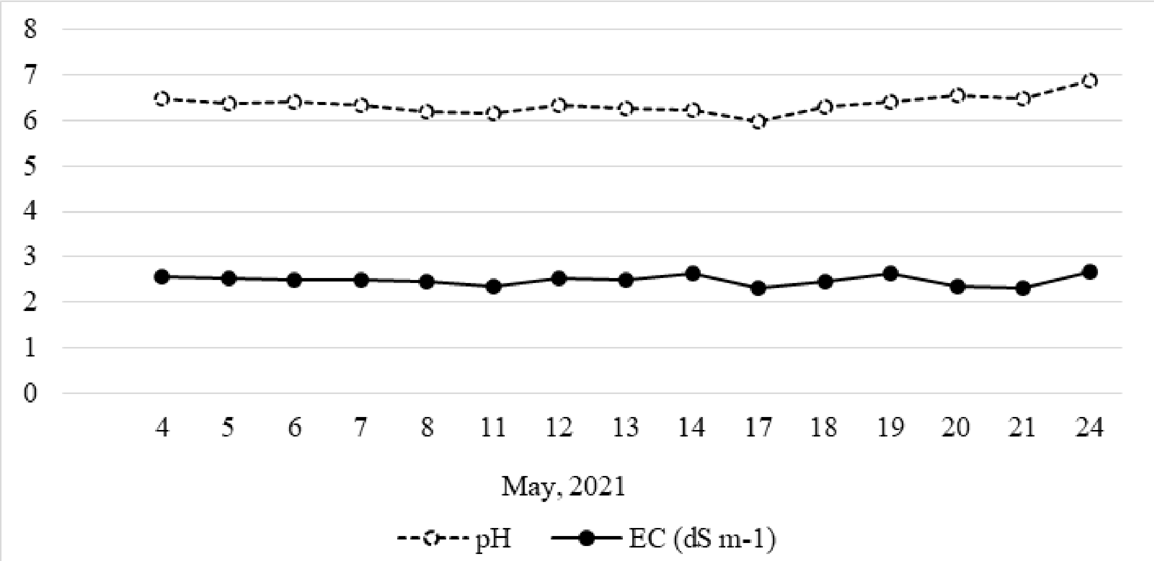
During the experiment (from May 4 to 25), the minimum and maximum temperature and relative humidity (graph 1) were measured daily in the greenhouse equipped with side and roof ventilation. The lowest minimum air temperature (7.5°C) was measured at the beginning of cultivation (May 4) and the highest maximum air temperature in the greenhouse (41.3°C) was measured on May 5 and 11. The values of minimum and maximum relative humidity ranged from 10 to 47% and from 73 to 88%, respectively. The average daily value of relative humidity varied between 38.5 and 67.5% during the reaearch (data not shown).



Graph 1. Minimum and maximum air temperature (°C) and relative air humidity (%) in greenhouse during spinach cultivation, Zagreb, 2021.

According to Albright (2005.), the optimal air temperature for hydroponic cultivation of spinach is 25°C (day) and 20°C (night), while the preferred relative humidity is 30% to 70%. Gent (2017.) recommends temperatures of 17 to 22°C with horizontal circulation, installation of shading and humidifiers. During the research, the average daily air temperature varied between 18.6 and 28.4°C (data not shown), which is higher than the optimal values for spinach growth (15 to 18°C) reported by Lešić et al. (2016.).

During spinach cultivation, the nutrient solution pH varied from 5.99 to 6.88 (Graph 2) and corresponded to the optimal values of 5.8 to 6.2 reported by Toth et al. (2012.) and 6.0 to 7.0 reported by Sharma et al. (2018.). According to Albright (2005.), the optimum values for pH and electrical conductivity (EC) of the nutrient solution in spinach cultivation are 5.8 and 1.2 dS m^{-1}, respectively. During cultivation, the EC value of the nutrient solution varied slightly, i.e., it was in the range of 2.30 to 2.66 dS m^{-1}, which was slightly different from the values (1.8 to 2.3 dS m^{-1}) reported by Sharma et al. (2018.).



Graph 2. pH and EC values of nutrient solution during spinach cultivation

The results of morphological characteristics and yield of spinach depending on the tested sowing densities, are presented in Table 1. The highest rosette mass (6.5 g) was measured at the lowest sowing density (A 21.3 g m^{-2}), while the smallest rosette mass (4.1 g) was determined at the highest seeding density (C 64.2 g m^{-2}). In the study conducted by Toth et al. (2016) on the influence of fluid drilling of germinated spinach seeds on agronomic traits in spring growing period, higher spinach rosette mass (8.45 g) was obtained.

Rosette height varied from 14.0 (A 21.3 g m^{-2}) to 17.0 cm (C 64.2 g m^{-2}). It can be assumed that the highest seeding density (C) resulted with elongation of plants due to an insufficient amount of light. The spinach rosette height achieved in this study, regardless of seeding density, was significantly lower than the value of 26.96 cm to 28.04 cm reported by Gaikwad and Mallick (2020.) in the study of growing spinach with different hydroponic systems. Lamut (2011.) reported that the average height of spinach plants grown in a commercial substrate (7.5 cm) was lower than that of plants grown in a floating hydroponic system (14.7 cm), regardless of the substrate used.

At the lowest sowing density (A 21.3 g m^{-2}), the highest average number of leaves (7.2) was found and was statistically equal to the number of rosette leaves (6.7) of plants grown at a sowing density of 42.7 g m^{-2} (B). The obtained results are in agreement with the values reported by Lamut (2011.) when spinach was grown in a floating hydroponic system, where the number of spinach rosette leaves at harvest varied from 6.4 in the cultivar 'Matador' to 7.0 in the cultivar 'Spokane'. In a study, Shah et al. (2009.) compared the cultivation of spinach in two nutrient solutions in a non-circulating hydroponic system and found that the maximum number of leaves (12.44 and 12.33) was obtained in plants grown in 50% and 100% Cooper's solution, respectively.

Table 1. The effect of sowing density on morphological properties and yield of spinach in floating hydropon

Sowing density			Rossete			Yield, kg m^{-2}
	Seeds m^{-2}	g m^{-2}	Mass, g	Height, cm	Number of leaves	
A	1252	21.3	6.5 a	14.0 n.s.	7.2 a	1.1 b
B	2505	42.7	5.5 ab	16.9	6.7 ab	1.6 ab
C	3758	64.2	4.1 b	17.0	6.5 b	2.0 a
		average	**5.37**	**16.0**	**6.8**	**1.56**

Different letters indicate significant differences between mean values according to LSD test, p≤0.05

The highest yield (2.0 kg m^{-2}) was obtained at the highest sowing density (C 3758 seeds m^{-2}). In the study by Cocetta et al. (2007.), the average yield of spinach in floating hydroponics at a sowing density of 1150 seeds m^{-2} varied from 1.1 to 1.5 kg m^{-2} depending on the nutrient concentration in the solution. The same spinach yield (1.1 kg m^{-2}) was obtained in this research with the lowest spinach sowing density (A 21.3 g m^{-2}), i.e. sowing 1252 seeds m^{-2}. Sowing densities B (2505 seeds m^{-2}) and C (3758 seeds m^{-2}) resulted in higher and statistically equal yield. However, in this research, even the lowest yield obtained with the lowest sowing density is higher than the values reported by Öztekin et al. (2018) and Ranawade et al. (2017.) for spinach grown hydroponically (0.904 and 0.934 kg m^{-2}). Also, Toth et al. (2016.) reported that fluid drilling of germinated spinach seeds with the substrate cover resulted in a yield of 0.7 kg m^{-2}. In the mentioned study, the length of spinach vegetation in conventional cultivation in the soil in the spring growing season was 48 days. In the study by Brandenberger et al. (2007.), the length of spinach cultivation in the greenhouse varied from 37 (spring) to 53 days (autumn). A higher yield was obtained in the autumn growing season (2.09 kg m^{-2}) than in the spring growing period (1.65 kg m^{-2}). In this research, which was conducted in the spring growing season, the length of spinach vegetation was slightly shorter (32 days), with an average yield 1.56 kg m^{-2}. This suggests that a higher yield of spinach in floating hydropon could be expected in the autumn growing period.

Conclusions

In the research conducted in the spring growing period using floating hydroponic system, statistically justified differences between the tested sowing densities were found for all traits except rosette height. The highest sowing density resulted in the highest rosette height and yield, but also in elongation of the plants and their lower mass. The average yield of spinach in the study was 1.56 kg m^{-2}, and statistically equal spinach yield (2.0 and 1.6 kg m^{-2}) was found at the highest and medium tested sowing densities tested (3758 and 2505 seeds m^{-2}, respectively). In the cultivation of spinach in a floating hydroponic system, a sowing of 2505 seeds m^2 could be recommended to obtain an acceptable yield.

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