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Comparison of spinach cultivation in floating hydroponic system and soil in glasshouse and open field conditions

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ABSTRACT

The objective of this study was to investigate the effect of glasshouse and outdoor conditions on the growth of spinach plants in floating hydroponic culture and soil. In the floating hydroponic culture, the plants were grown in a plastic tank (120x50x30 cm) and a volume of 80 L in a glasshouse and open field. Each seed was inserted at 13x5 cm in rock wool in styrofoam and then placed in the nutrient solution. There was no significant change in EC values measured in the glasshouse and outside, and the pH of the solutions in the outdoor environment was higher (except in late December) than those in the glasshouse. The earliest and late harvests were made in floating hydroponic culture in the glasshouse and outdoor cultivation at 64 and 97 days, respectively. The highest yield was 1.54 kg m^{-2} in open field cultivation, it was followed by 1.45 kg m^{-2} in the greenhouse and 1.32 kg m^{-2} in the open field in floating hydroponic culture, respectively. Despite the high yield that can be obtained from floating hydroponic culture cultivation in the glasshouse and outside, the fact that there is a lower marketable amount is a negative aspect. However, the floating hydroponic culture could be preferred to soil cultivation due to many advantages such as production 2-3 times a year, low labor costs, and less pesticide use. Spinach cultivation in the open field does not have any problems in terms of nitrate, but nitrate accumulation can be a problem in hydroponic culture.

1. Introduction

Growing the same crop for many years in greenhouses (monoculture) triggers soil fatigue, soil salinity, diseases, and pest formation. Therefore, in recent years short vegetation period plants such as lettuce, spinach, chard, leek, green onions, green garlic, all kinds of green leafy aromatic vegetables, parsley, cress, arugula, mint, basil have been grown in floating hydroponic systems (Çelikel 2002; Ergün 2011). The hydroponic system has important advantages compared to cultivation in the soil such as the ability to adjust the structure of the growing medium, better drainage, fewer risks of weed and soil-borne pathogens, and low worker wages. Besides the reusability of the nutrient solution, it is easier to control parameters such as temperature, light intensity, light quality, application time, nutrient composition and density, and the amount of gas given to the roots (Marr 1994). The impact of the increase of the human population can be seen with more land needed for housing and decreasing land for agriculture, especially in urban areas. One solution for farming in urban areas is by utilizing rooftop farming by hydroponic cultivation. Water and electricity consumption for one growing period was 300.63 L and 31.816 kW, respectively in the floating raft fertigation system for spinach growing. The efficiency of water use was determined as 99.6 kg m^{-3} (Fadhlillah et al. 2019).

Spinach was harvested 52 days after planting in the autumn and 37 days in the floating hydroponic culture in spring. The highest yields in autumn were in 'Olympia' with 2093 g m^{-2} and in spring were in F91-415' with 1649 g·m^{-2}. 'F91-415' for autumn greenhouse production, and 'F91-415' and 'Padre' for spring production were recommended (Brandenberger et al. 2007).

The study aims to determine growing potential, earliness, and yield in an unheated glasshouse and outside in a floating hydroponic system and soil in winter in the ecological conditions in Antalya.

2. Material and Methods

The research was carried out in a glasshouse and an open field in the Research and Application Station of the Faculty of Agriculture, Akdeniz University, Antalya in winter (Figure 1). The glasshouse is 5 m wide, 6 m long, and 2 m side height with a double side ventilation system. The land is located at 36° 54 028' north latitude, 30° 38 810' east longitude, 1.5 km from the sea, and 38 m altitude. According to the soil analysis made at the Western Mediterranean Agricultural Research Institute; the soil type in the glasshouse and outside is clay loam with low organic matter (2.69%) and a pH of 8.23.

Matador (*Spinacia oleracea* var. Matador) spinach cultivar was used as the plant material. In floating hydroponic culture, the plants were grown in plastic tanks (120x50x30 cm) and a volume of 80 L. Styrofoam seedling trays (120x50x4.9 cm) was used and rock wool (Belagro Substrate) was placed in styrofoam trays at 13x5 cm intervals for seed sowing (Figure 1). Oxygen was provided to the nutrient solutions through the aquarium air motor and air stones. Cooper (1988), the nutrient solution was used (Table 1), and the pH and EC of the solution were kept around 6.0-6.5 and 1.5-1.7, respectively.

Table 1. Cooper's nutrient solutions.

Elements	Amount mg l^{-1}
N	236
P	60
K	300
Ca	185
Mg	50
S	68
Fe (EDTA)	12
B	0.3
Mn	2
Zn	0.1
Cu	0.1
Mo	0.2

Spinach seeds were directly sown in 13x5 cm in rock wool in Styrofoam on December 21, and then placed in a greenhouse and outside in plastic tanks including a nutrient solution. The tank outside was covered with a round roof with plastic to protect it from external environmental factors such as rain (Figure 2). Changes in pH, EC, and temperature of the growing solution in the greenhouse were recorded. For cultivation in the glasshouse, the same soil as the open field was filled into 120x50x30 cm boxes with a 10 cm space at the top, and spinach seeds were sown in the soil by hand at 13x5 cm (Figure 3).

For open field cultivation in the soil, the soil was ploughed at a depth of 30 cm and, then smoothed, and made ready for seed sowing. Spinach seeds were sown by hand at a depth of 1 cm, with a row spacing of 13x5 cm (Figure 3). Cultural treatments such as irrigation, fertilization, plant protection, and harvesting were carried out in a timely and appropriate manner. Yield, plant height, root length, marketable plant weight (Ercan and Bayyurt 2014) chlorophyll content "Konica Minolta SPAD-502" (Geravandi et al. 2011), K, Ca, Mg, Fe, Z, Mn, Cu and nitrate accumulation (Kacar and İnal 2008) and P (Kacar and Kovancı 1982) content, vividness and color conditions of the leaves (Minolta Chorometer Reflectance) were determined.

The study was conducted in a split plots trial design in three replications, and 16 seeds were used in each replication. Glasshouse and open field growing factors were located in the main plot; cultivation technique was located in the subplots. Statistical analysis was carried out in the Statistical Package for the Social Science (SPSS, version 17), and the Tukey test was used to determine the differences between means (ns: nonsignificant, *: significant at $P \leq 0.05$).

Figure 1. Glass (left) glasshouse in which the research was conducted (left), and Styrofoam trays with rock wool in which spinach seeds were sown (right).

Figure 2. Spinach growing in floating culture in the glasshouse (left) and open field (right).

Figure 3. Spinach growing in the soil in the glasshouse (left) and open field (right).

3. Results

3.1. Temperature changes

The temperature values measured inside the glasshouse were higher than in the outdoor environment. The temperature in the glasshouse ranged from 14-20°C from December 21 to February 14, then it slightly increased, and was 25°C on February 23 at harvest time. The outdoor temperature changed more than inside the glasshouse and dropped to 8°C in mid-January. The maximum outdoor temperature was measured as 22-23°C in March (Figure 4).

The solution temperatures inside and outside were found to be lower than the glasshouse inside temperature during the experiment period. However, the solution temperatures inside and outside, except for early December and January, were measured at almost the same levels as the outside temperature. Only the outside temperature was determined to be lower than the solution temperatures in mid-January (Figure 4).

3.2. EC and pH changes

There was not much change in EC values measured in the glasshouse and outside. Although solution EC's were tried to be kept between 1.5-1.7, the measured values were higher. EC increase in the glasshouse was higher than in the outdoor environment, and the highest EC increase in solutions in the greenhouse was detected in February during harvest (Figure 5). Although 0.1 N nitric acid (HNO_3) was continuously given to the environment to keep the pH value constant between 6-6.5 in the solutions, the pH could not be kept at the desired values. Except for the period when the experiment started, the pH of the solutions in the outdoor environment was recorded to be higher than those in the greenhouse. The highest pH rise occurred at the beginning of the trial (7.34 in the greenhouse and 7.32 in outside), in January (7.1 in outside), and early February (7.13 in outside) (Figure 6).

3.3. Plant growth and yield values

The spinaches were harvested when they had five to six true leaves. The parameters measured during the harvest of spinach grown in the glasshouse and outside in floating hydroponic culture and soil had changed significantly ($P \leq 0.05$) (Table 2).

The earliest and latest harvest was made with 64 days on February 23 and with 97 days on March 28 in the floating hydroponic culture in the glasshouse and open field, respectively. However, the spinach grown in the glasshouse in the soil was harvested (72 days) earlier than grown in the floating hydroponic culture (83 days) outside (Table 2).

The highest yields were obtained with 1.54 kg m^{-2} in the open field and with 1.45 kg m^{-2} in floating hydroponic culture in the greenhouse. It was followed by floating hydroponic culture outside with 1.32 kg m^{-2} and soil in the glasshouse with 1.07 kg m^{-2}. After removing non-market value outer leaves (the choice was made based on personal experience), the yield was highest 1.18 kg m^{-2} in the open field, followed by the soil in the greenhouse with 0.94 kg m^{-2}, floating hydroponic culture outside with 0.87 kg m^{-2} and floating hydroponic culture in the glasshouse with 0.81 kg m^{-2} (Table 2).

The growing systems also affected the plant height. The length of spinach grown in floating hydroponic culture and soil was determined longer than that grown in the glasshouses. The length of spinach grown in the soil in the open field and glasshouse was higher than grown in floating hydroponic culture, and the length in the soil in the open field with 47.94 cm was measured to be twice as long as the other treatments. The shortest root length was in floating hydroponic culture in the glasshouse with 18.86 cm (Table 2).

The root length of spinach grown in floating hydroponic culture in the glasshouse (36.10 cm) and outdoor (30.02 cm) was measured as longer than spinach grown in soil. The root length of spinach grown in soil outside and glasshouse were 27.79 and 19.10 cm, respectively (Table 2).

While the most marketable spinach was in the open field with 1.18 kg m^{-2}, the amount in other applications were found to be close to each other. The marketable amount was determined as 0.94 kg m^{-2} in the soil in the glasshouse, 0.87 kg m^{-2} in the floating hydroponic culture outside, and 0.81 kg m^{-2} in the floating hydroponic culture in the glasshouse. The amount of marketable spinach was determined as 87.85% in the soil in the glasshouse, 76.62% in the soil in the open field, 65.91% in floating hydroponic culture outdoor, and 55.86% in floating hydroponic culture in the glasshouse (Table 2).

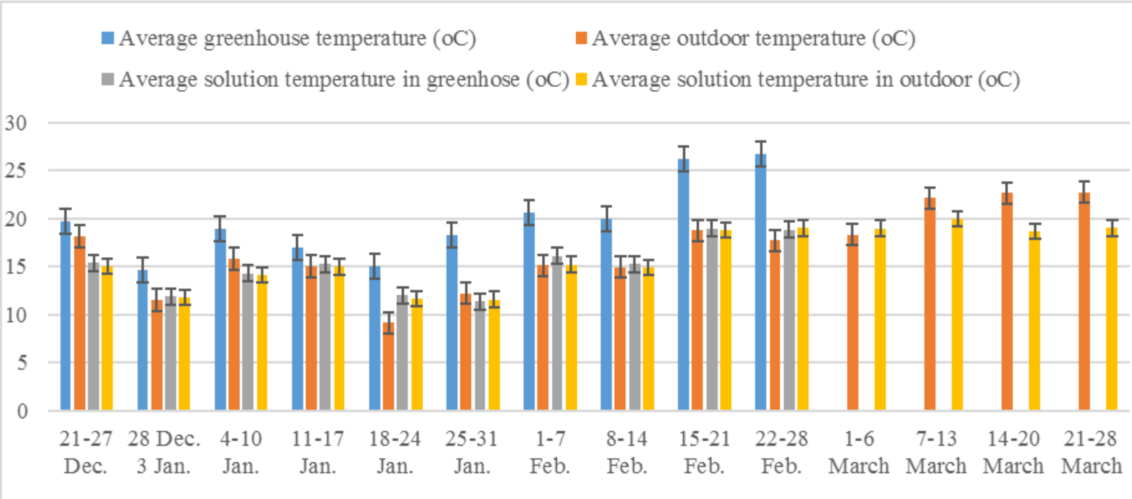

Figure 4. Average temperature values determined in the glasshouse, outdoor environment, and solutions.

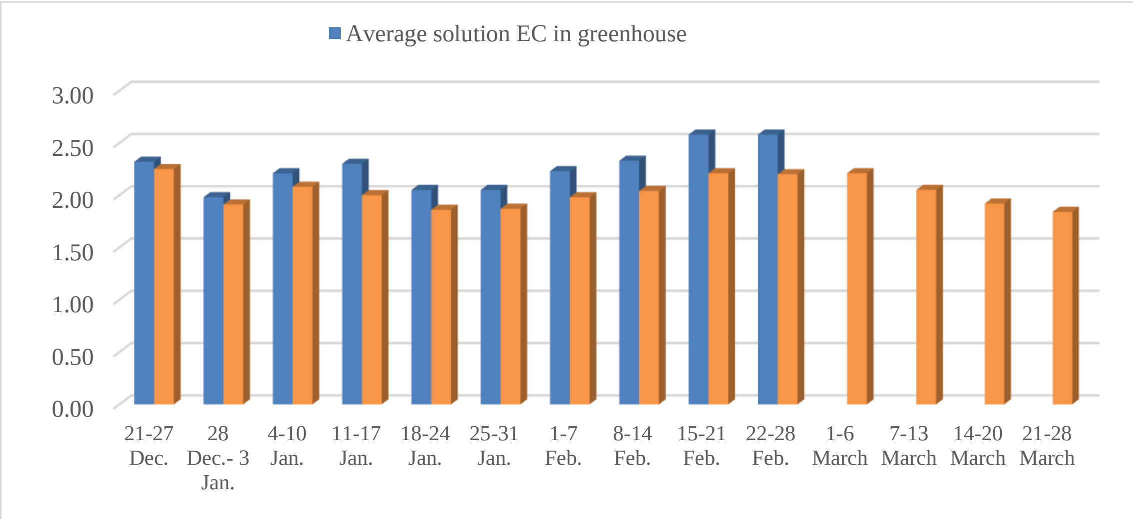

Figure 5. Average EC values determined in solutions in the glasshouse and outdoor environment.

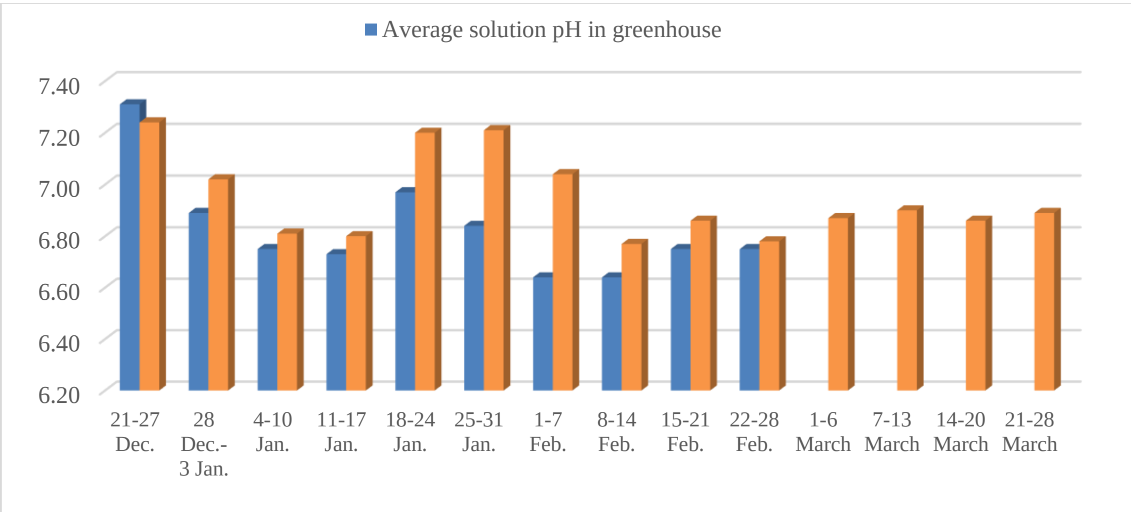

Figure 6. Average pH values determined in solutions in the glasshouse and outdoor environment.

The chlorophyll levels in the leaves of spinach grown in floating hydroponic culture in the glasshouse (71.16 mg kg^{-1}) and outdoor (68.31 mg kg^{-1}) were found close to each other, and their levels were determined to be higher than those grown in the soil. The chlorophyll content was 64.58 mg kg^{-1} in the soil in the open field and was 54.30 mg kg^{-1} in the soil in the glasshouse (Table 2).

The nitrate accumulation in the leaves of spinach grown in floating hydroponic culture (3111 mg kg^{-1}) and soil (2069 mg kg^{-1}) in the glasshouse was found to have considerably higher levels than those grown in the open field. The lowest nitrate accumulation was in the open field with 87 mg kg^{-1} (Table 2).

3.4. Macro and microelement contents in leaves

The contents of N, Ca, Mg, P, K, Fe, Mn, Zn, and Cu in the leaves in floating hydroponic culture and soil outside and greenhouse were significantly changed ($P \leq 0.05$). The level of N in leaves in floating hydroponic culture (3.80 mg kg^{-1}) and soil (3.67 mg kg^{-1}) in the glasshouse were almost the same, and the highest N content was determined in the soil in the open field with 4.30%. P and K levels in leaves in floating hydroponic culture and soil outside were lower than those grown in the glasshouses. The highest P and K contents were detected in floating hydroponic culture and soil in the glasshouse with 0.90% and 12.37%, respectively. The highest Ca and Mg levels in leaves were determined in the soil in the glasshouse with 1.80% and 1.10% respectively while the lowest Ca 0.37% and Mg 0.57% were in the soil outside. The Ca and Mg levels in floating hydroponic culture in the glasshouse and outside were detected at about the same level (Table 3).

Fe levels of leaves with 303.67 mg kg^{-1} in the glasshouse and with 284.33 mg kg^{-1} in the open field in soil were higher than those grown in floating hydroponic culture. The amount of Fe in floating hydroponic culture in the glasshouse was found to be higher than for outside. The lowest Fe content was in floating hydroponic culture outside with 80.33 mg kg^{-1}. Mn levels in leaves were found in the glasshouse in soil with 62.67 mg kg^{-1} and floating hydroponic culture with 61.00 mg kg^{-1}. The highest Mn level was determined in the soil in an open field with 83.00 mg kg^{-1}. The highest Zn with 158.67 mg kg^{-1} and Cu with 19.00 mg kg^{-1} were detected in floating hydroponic culture in the glasshouse, while the lowest Zn with 75.00 mg kg^{-1} and Cu with 10.00 mg kg^{-1} were found in soil in the glasshouse (Table 3).

There was not much change in EC values measured in the glasshouse and outside. Although solution EC's were tried to be kept between 1.5-1.7, the measured values were higher. EC increase in the glasshouse was higher than in the outdoor environment, and the highest EC increase in solutions in the greenhouse was detected in February during harvesting (Figure 5).

3.5. Leaf color analysis

The brightest colored leaves were measured in the soil in the glasshouse and floating hydroponic culture outdoors. Th e brighter green color of leaves was mostly determined in the floating hydroponic culture in the glasshouse however, the green color was less intense outside in soil and floating hydroponic culture. The green color was detected more in the plants grown in greenhouses and yellowing in the plants grown in the open (Table 4).

Table 2. Yield and biomass values of spinach grown in floating culture and soil in the greenhouse and outdoor environment

Applications		Days between seed sow and harvest (day)	Yield (kg m^{-2})	Plant height (cm)	Root length (cm)	Marketable plant weight/plant (kg)	Chlorophyll content (mg g^{-1})	Nitrate accumulation in leaf (mg kg^{-1})
Green-house	Floating culture	64^{a*}	1.45^{a}	18.86^{c}	36.10^{a}	0.81^{c} (44.14% loss)	71.16^{a}	3112^{a}
	Soil	72^{b}	1.07^{c}	22.77^{b}	19.10^{d}	0.94^{b} (12.15% loss)	54.30^{c}	2069^{b}
Outdoor	Floating culture	83^{c}	1.32^{ab}	20.21^{c}	30.02^{b}	0.87^{bc} (34.09% loss)	68.31^{a}	621^{c}
	Soil	97^{d}	1.54^{a}	47.94^{a}	27.79^{c}	1.18^{a} (23.38% loss)	64.58^{b}	87^{d}

Means within each column followed by the same letters are significantly different according to the Tukey test (*significant at $P \leq 0.05$).

Table 3. Macro and microelement contents detected in spinach leaves in floating culture and soil in the glasshouse and outside.

Applications		N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Greenhouse	Floating culture	3.80^{b*}	0.90^{a}	9.00^{b}	0.73^{b}	0.80^{b}	90.67^{c}	61.00^{b}	158.67^{a}	19.00^{a}
	Soil	3.67^{b}	0.73^{b}	12.37^{a}	1.80^{a}	1.10^{a}	303.67^{a}	62.67^{b}	75.00^{d}	10.00^{c}
Outdoor	Floating culture	3.00^{c}	0.53^{c}	3.47^{c}	0.73^{b}	0.70^{b}	80.33^{d}	32.00^{c}	94.33^{c}	13.67^{b}
	Soil	4.30^{a}	0.53^{c}	3.33^{c}	0.37^{c}	0.57^{c}	284.33^{b}	83.00^{a}	100.67^{b}	10.67^{c}

Means within each column followed by the same letters are significantly different according to the Tukey test (*significant at $P \leq 0.05$).

Table 4. Average L, a, and b values of leaves measured in the glasshouse and outside in floating culture and soil (L: brightness, a: green color, b: yellow color).

Applications		L	a	b
Greenhouse	Floating culture	42.63^{b*}	-11.96^{a}	14.81^{c}
	Soil	46.53^{a}	-14.48^{b}	20.32^{b}
Outdoor	Floating culture	44.93^{a}	-16.13^{c}	23.17^{a}
	Soil	42.06^{b}	-16.76^{c}	22.99^{a}

Means within each column followed by the same letters are significantly different according to the Tukey test (*significant at $P \leq 0.05$).

4. Discussion and Conclusion

Protected cultivation of spinach in floating hydroponic is an alternative way of year round vegetable production and has a much faster economic return (Brandenberger et al. 2007). EC and pH values of the solution affect the cultivation, and the appropriate EC value is 1 and 3 dS m^{-1}, and pH is 5.5 and 7. Solution pH in aquaponics systems is a compromise between microbial and plant demands (Cerozi and Fitzsimmons 2016). A recent study determined that pH 6.0 was optimal for plant growth and nitrogen utilization efficiency in aquaponics at the expense of increased N_2O emission due to high denitrification (Zou et al. 2016). In the experiment, although it was tried to keep solution EC between 1.5-1.7 and pH 6.0-6.5, solution EC varied between 1.7-2.5, and pH was between 6.64-7.31. Other researchers reported similar increases in EC and pH in the solution in hydroponic culture (Öztekin et al. 2018; Leal et al. 2020). On the other hand, fewer changes of EC and pH values of the solutions in the floating hydroponic culture in the glasshouse and outside can be explained by the fact that there is no significant difference between the solution temperatures.

While the harvest period for spinach grown in autumn and winter in soil cultivation can be extended by up to 150-180 days, harvesting takes up to 60 days in spring planting (Anonymous 2011). Spinach has a good development below 26°C and the best yield and quality characteristics are obtained at 22°C (Lee and Takakura 1995; Brandenberger et al. 2007). The germination and growing period of spinach in hydroponics and aquaponics were earlier than the soil growing method (Ranawade et al. 2017). Similarly, in the research, spinach in floating hydroponic culture in the glasshouse (64 days) came to harvest 29 days before the outside soil (93 days). However, the fact that spinach grown in the soil in the glasshouse (72 days) came to harvest before the floating hydroponic culture outside (83 days) shows that spinach cultivation in floating hydroponic culture outside does not affect the earliness. The earlier harvest of spinach in floating hydroponic culture in the glasshouse can be explained by the higher temperature of glasshouse than outside. During the experiment period (December 21 to February 15), while the temperature inside the glasshouse varied between 14-24°C the outside temperature decreased to 8°C in January and the temperature varied between 8-23°C. However, the solution temperatures in the glasshouse and outside did not change much except for December and early January. This can be explained by the high specific heat of the water. Because water can absorb large amounts of heat energy and releases heat energy slowly (Kacar et al. 2002).

In the cultivation of spinach in soil, the yield per decare depending on the climate, soil structure, growing season, harvest type and variety could be 1.1-1.5 tons (Cocetta et al. 2007), 0.86-1.8 tons (Engindeniz 2008), 1.5-3.0 tons (Anonymous 2011), 1.01-4.54 tons (Sensoy et al. 2011) and 0.40 tons (Ranawade et al. 2017). In floating culture, in winter 1.25 tons, in early spring 1.99 tons (Öztekin et al. 2018), and in glasshouses between 1.88 and 2.09 tons (Brandenberger et al. 2007) of spinach per decare can be produced. In the research, the yield value of 1.45 tons da^{-1} obtained from floating hydroponic culture in the greenhouse during the winter period was similar to other research results. The fact that 1.45 tons of yield obtained from the floating hydroponic culture in the glasshouse in winter were close to 1.54 tons obtained from the soil outside showed that spinach can be grown economically in floating hydroponic culture in winter in the ecological conditions in Antalya.

While color, length, vitality, and the number of leaves is important factors for the sale of spinach, the amount of marketable quantity from the produced part is also substantial for economical gain. The most important factor is how much of the spinach produced can be marketed. In floating hydroponic culture, the marketable produce in the glasshouse and outdoor was 55.86% (yield decreases from 1.45 kg m^{-2} to 0.81 kg m^{-2}) and 65.91% (yield decreases from 1.32 kg m^{-2} to 0.87 kg m^{-2}) respectively. On the other hand, the marketable amount in the open field was 87.85% (yield decreases from 1.54 kg m^{-2} to 1.18 kg m^{-2}) and 76.62% in the soil in the glasshouse (yield decreases from 1.07 kg m^{-2} to 0.94 kg m^{-2}). The decrease in the marketable amount in floating hydroponic culture in the glasshouse and outside can be explained by the plant being constantly in water, and at high temperatures in the glasshouse. Although the marketable amount is low in floating hydroponic cultivation in a glass greenhouse and outdoor compared to outdoor cultivation in the soil, this situation should not be perceived as negative. It is more advantageous compared to cultivation in the soil due to being able to cultivate 2-3 times in a year, low labor costs. Besides, due to the high temperatures in the glass greenhouse in the Mediterranean coastal zone during the summer months, outdoor floating cultivation may be seen to be more suitable during hot periods.

Although plant height in the soil (especially open field) was taller than those grown in floating hydroponic culture, the root lengths were shorter in the soil. Similarly, the height of the spinach in the soil (23 cm) was determined to be taller than the floating hydroponic culture (18 cm) (Ranawade et al. 2017). The results indicate that floating hydroponic culture makes spinach shorter in height. This can be explained by the fact that the N level determined in the leaves of spinach grown in the soil in the open fields was higher than in the floating culture.

The nutrient content of spinach in leaves varies according to the growing medium. Research results differed from those of other researchers (Shah et al. 2009; Vandam et al. 2017; Öztekin et al. 2018), and in the study, N, Ca, and Mg levels were lower in spinach grown in winter whereas P, and Fe levels were found to be higher. In the spinach leaves, K, Ca, Mg, and Fe contents in the soil and P, Zn, and Cu in the floating hydroponic culture in glass greenhouse were found to be higher, but N and Mn were found more frequently in the open field.

The amount of nitrate in plants varies greatly depending on the type of plant, genetic structure, plant age, plant parts, environmental factors, applied N form, and agricultural processing methods (Xiang et al. 2020). Low nitrate contents are desired indirectly consumed from edible leaf vegetables. Because nitrate is converted to nitrite by mouth bacteria and conveyed to the human stomach, excess nitrate adversely affects human health (Kara 1993; Özdestan and Üren 2010). Vegetables such as beets, celery, lettuce, spinach, and radishes contain high levels of nitrates (>1000 mg kg^{-1}) (Anonymous 2019). The maximum limit of the nitrate amount in lettuce leaves is determined as 3500-4500 mg kg^{-1}, and 2500 mg kg^{-1} in cabbage, carrot, and celery tubers in Switzerland, the Netherlands, and Austria (Bergmann 1992). The maximum nitrate level in spinach is 3500 mg kg^{-1} according to the Turkish Food Codex Regulation published in Turkey in 2008 (Ayaz and Yurttagül 2006). In the spinach leaves in the experiment, the nitrate accumulation in floating hydroponic culture and soil in a glass greenhouse and outside were determined to be below these levels. Nitrate accumulation was detected at 1800 mg kg^{-1} in the spinach leaves in floating hydroponic culture during the winter period (Öztekin et al. 2018) and 3610 mg kg^{-1} in hydroponic culture in glass greenhouses (Lenzi et al. 2011). Parallel to the increase in the nutrient solution contained in the hydroponic culture in the plastic greenhouse, nitrate accumulation increased from 750 mg kg^{-1} to 1200 mg kg^{-1} (Cocetta et al. 2007) and the nitrate accumulation increased parallel to the increase in the amount of salt in the solution in hydroponic culture (Cocetta et al. 2007; Leal et al. 2020). The results show that spinach cultivation in the open field does not have many problems in terms of nitrate, but nitrate accumulation in glass greenhouse can be a problem in floating hydroponic culture and soil cultivation. Therefore, the content of the solution to be prepared becomes important in preventing nitrate accumulation in plants grown in a glass greenhouse.

The chlorophyll content varied according to the growing environment and the period in which it was grown. The chlorophyll content of spinach grown in the greenhouse in winter was 118 mg kg^{-1} (Öztekin et al. 2018), and the chlorophyll content did not change in spinach leaves in different nutrient applications in the plastic greenhouse (Cocetta et al. 2007). According to the results of the research, the detection of more chlorophyll in the leaves of spinach grown in floating hydroponic culture in the greenhouse and outside shows that hydroponic culture can promote chlorophyll content in spinach compared to soil cultivation.

Although spinach leaves have the more intense green color in the greenhouse in floating hydroponic culture, the fact that brightly colored leaves are grown in the greenhouse in soil and outside in floating hydroponic culture indicates that there may not be a linear relationship between chlorophyll content and brightness. The fact that the green color of the leaves is more intense when grown in the greenhouse, whereas the yellowing is more prominent in those grown outside can be explained by the low temperature of the external environment. The green color and yellowing of the leaves may vary by year (Brandenberger et al. 2007).

Protected cultivation is intensively utilized in the Mediterranean region of Turkey. Protected cultivation is mostly done in soil, however, in recent years, the cultivation of most vegetables, especially tomatoes, has been started in soilless culture. In addition, there has been a rapid increase in the use of the hydroponic system for the cultivation of plants with a short vegetative life. In this study, the cultivation of spinach in floating hydroponic culture was examined as an alternative and it was revealed that spinach could be grown in both greenhouse and outside floating hydroponic culture in the conditions in Antalya. Due to the portability of the floating hydroponic culture system, it seems that it will be possible to grow spinach in the open field in summer. Despite these positive conditions, the low marketable amount of spinach grown in floating hydroponic culture and high nitrate accumulation in glass greenhouse have been identified as a negative aspect.

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