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Use of Waste Nutrition Solution in Soilless Ornamental Kale Cultivation under Saline Conditions

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ABSTRACT

This study aimed to contribute to the reduction of environmental pollution through the reuse of the Hoagland solution drained from lettuce by soilless growth system in ornamental kale. The study was set up in two greenhouses using lettuce and ornamental kale in soilless culture. The lettuce cultivation was conducted to supply the waste drainage solution; therefore, the lettuce analyses were not included in the study. Both plants were set up with 3 replicates random blocks trial design in solid media culture and open feeding system. In the study, 3 salinity levels (S0: Control, S1: Waste drainage solution salinity concentration, S2: S1+1 dS m^{-1} NaCI) were used. The greatest plant height and leaf width were obtained in the control and in the S1, in which a drainage solution was used in ornamental kale cultivation. The plant diameter, leaf height and visual value decreased with increasing salinity. It was concluded that appropriate management of recycled drainage water could be an alternative for ornamental kale production in soilless culture.

Keywords: Ornamental cabbage, Recycled drainage solution, Salinity, Soilless culture.

INTRODUCTION

Soilless culture was introduced in the early 2000s as an alternative to methyl bromide, which is used for chemical soil disinfection since the 1980s and has negative environmental impacts. In Turkey, soilless culture is implemented as an open feeding system in the substrate culture (Tüzel and Gül, 1999) and its applicability in greenhouse establishment has been demonstrated. Since the use of soilless culture and open systems in greenhouses could lead to environmental pollution due to the drainage of the nutrient solution from the system, several countries have switched to closed systems (Vernooij, 1992).

The quality of irrigation water is more significant in soilless culture than conventional agriculture. It is known that the salt content in the nutrient solution accumulates around the plant root in time, and the nutrient solution often has high salinity (Sonneveld *et al*., 2000). In soilless cultivation systems, accumulation of the salt in the nutrient solution around the plant roots over time leads to similar salinity problems that are observed in traditional cultivation systems (Gilabert *et al*., 2014; Kılıç, 2022). Furthermore, since the root volume is limited by the growth media in soilless culture when compared to traditional agriculture, salt accumulation is faster in the root region and could lead to a serious salinity problem (Sonneveld *et al*., 2000). In recent years, national and international soilless culture studies mostly have focused on the effects of salinity on plant yield and quality. Studies on environmental conservation has also become popular in recent years.

Due to the preference of high-quality water for human consumption, bitter, salty or recycled water with lower quality and high Electrical Conductivity (EC) may be used in

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irrigated agricultural fields for crop cultivation (Villora *et al.*, 2000; Cassaniti *et al.*, 2013). Reclaiming the drained irrigation water is a method to diversify sources of water supply. Therefore, there has been increased interest in the availability of low-salt irrigation resources, the use of alternatives such as recycled wastewater, and innovative plant and water management strategies to reduce the negative effects of salt and certain ions. Previous studies emphasized that low-quality water would not affect plant growth, yield and quality (Grieve *et al.,* 2013). The addition of deicers, such as sodium chloride, to the existing landscapes soils leads to further salinity. Ornamental plants grown in urban areas due to their aesthetic properties are further affected by unfavorable conditions. Thus, it is necessary to select more tolerant species in adverse environmental conditions in parks, gardens and roadside landscapes (Akat and Akat Saraçoğlu, 2017; Akat *et al.,* 2020).

Salinity is a global problem that limits crop cultivation (Zuluaga *et al.,* 2021) with a potential to reduce visual quality, especially of ornamental plants (Veatch-Blohm *et al*., 2014). Thus, since the ornamental plants around urban transportation axes, road medians, parks and gardens would be exposed more to pollutants such as salinity, exhaust gases, and dust, crop selection should be based on these factors. Although leaf or flower damage and losses due to salt stress do not seem to affect growth, they may reduce market quality. The number of studies on the effects of salinity and salt tolerance on flower species are quite limited. In the study conducted by Sonneveld and Voogt (1983), it was reported that the ornamental kale could be considered salt-sensitive (Grieve *et al*., 2013). It was suggested that research on the effects of salinity on ornamental kale cultures was limited in the literature. However, due to the increase in soil salinity in recent years, the demand for the employment of salt-tolerant species has increased in landscaping (Salachna *et al*., 2017). Thus, the selection of plants that could maintain visual quality even during retarded growth is quite important in saline soil (Cassaniti *et al*., 2012; Villarino and Mattson, 2011).

This study aimed to determine the effect of salinity on development and quality in soilless culture of lettuce and to contribute to the reduction of environmental pollution by increasing the efficiency of water and fertilizer through the reuse of the nutrient solution drained from the mentioned system in ornamental kale.

MATERIALS AND METHODS

Plant Material and Growing Conditions

In the study, two crops were cultivated in greenhouses located at Ege University Bayındır Vocational School Campus (38° 12' 09.9″ N, 27° 40' 20.8″ E) in 2017 and 2019. In the first phase, lettuce (*Lactuca sativa* var. *capitata* ‘Bombola’) was cultivated in an unheated greenhouse (240 m^2, 6×40 m) covered with Polyethylene (PE). In the second phase, ornamental kale (*Brassica oleracea* var. *acephala* ‘Nagoya’) was cultivated in an unheated PE greenhouse (110 m^2, 6.85 x 16 m). To measure air temperature (^{0}C) and relative humidity (%), a HOBO-Onset data logger (HOBO UX100–003) mini climate station was placed in both greenhouses. Ornamental kale was carried out open feeding system in substrate culture. The study was organized based on the trial design, balcony type pots (76×23×21 cm) with drainage plates filled with super coarse perlite to provide a total root volume of 24 and 8 L $plant^{-1}$ and ornamental kale plants were planted in pots within a 40×38 cm space (7 plants m^{-2}).

Experimental Design

The study was conducted in 3 replicates with the random blocks trial design in the cultivation fields. The following factors were analyzed in the study:

Test Groups

The First Phase of the Study
• Lettuce cultivation
Salinity
Control (EC0)
The Second Phase of the Study
• Ornamental kale cultivation

Salinity

Control (S0))(The average EC: 1.69 dS m^{-1})
Drainage solution collected from the EC0 level (S1)
S1 salinity+1 dS m^{-1} (S2)

The trials were conducted 1st Cultivation Period (1st CP): November 27, 2017 (1st week) - April 2, 2018 (19th week) and 2nd Cultivation Period (2nd CP): November 19, 2018 (1st week) - March 21, 2019 (18th week) in two years, and the data were analyzed separately.

Irrigation and Nutrition Applications

In the study, water and nutrients were applied using modified Hoagland Solution obtained by the addition of plant nutrients to irrigation water (Maloupa, 2002). Automated drip irrigation system was employed in the application and distribution of the nutrient solution. The nutrient solution drained from the root zones in the lettuce media in the first stage of the study was collected in 30 L drainage solution cans via the drainage holes on canal outlets. The collected drainage solution was stored in another 0.15 m^3 tank for irrigation of ornamental kale culture, which was the second study phase. The drainage solution stored in the tank was automatically transferred by an electric motor pump into another tank located in the ornamental kale greenhouse to allow recycling of the waste nutrient solution, which was the main aim of the study. During the study, irrigation was done in such a way to prevent the discharge of the nutrient solution through the pot drainage outlets. The irrigation water volume (nutrient solution with different salt concentrations) was distributed equally among all levels based on climatic parameters. Hoagland nutrient solution (mmol L^{-1}) included 12N-NO_3, 3.8N-NH_4, 2.8 P, 8.4 K, 3.5 Ca, 1.4 Mg, 9.5 Na, 8.0 Cl, 2.7 S, and 0.04 Fe (Alberici *et al*., 2008). During the growth period, the pH of the nutrient solution used for lettuce cultivation was kept about 6.67 and EC=1.77 dS m^{-1}; in ornamental kale, average pH: 6.55 and average EC: 1.69 dS m^{-1}.

Salinity Treatments

The measured salinity in nutrient solution used for ornamental kale cultivation was considered as the Control (Control-S0) and was among the studied salinity levels. The salinity (EC0) of the waste drainage solution collected from the lettuce was another salinity level (S1). The salinity of the waste drainage solution was increased by 1 dS m^{-1} to make the final salinity treatment (S2). Instead of using the collected drainage solution, salinity of Hoagland solution was increased by adding stock NaCl solution. When the plants reached a uniform appearance, treatments started based on the nutrient solution and salt application.

Growth and Quality Evaluations

In the trial, plant height (cm), diameter (cm), leaf width (cm) and length (cm) (with digital caliper, ranking in at a 0.01 mm), leaf number (per plant), upper plant section and root wet weight-dry weight (g), upper plant section and root dry weight percentage (%), leaf relative water and turgor loss (%), plant visual score (points), and drained nutrient solution EC (dS m^{-1}) were measured.

Relative Water and Turgor Loss

To determine the Relative Water Content (RWC) of the leaf samples collected from the study groups (once a month after the salinity treatment), they were transferred to the laboratory in ventilated black bags (9: 00-11: 00). After that, 1.5 cm wide discs were removed from the leaf samples and fresh weight, turgor weight (after storage in pure water for 4 hours) and dry weight (after storage at 85^{0}C for 24 hours) were determined. Leaf Relative Water Content (RWC, %) and Turgor Loss (TL, %) were calculated using Equation 1 and 2 relatively (Küçükahmetler, 2003; Akat, 2008) :

Eq. 1 is to be:

RWC % = [(Wet Weigth – Turgor Weight)/ Turgor Weigth- Dry Weigth)* 100]

Eq. 1 is RWC % , but Eq. 2 is "turgor loss" = TL %

Eq.2 is given to be:

TL (%) = [(Turgor Weigth – Wet Weight)/ Turgor Weigth)* 100]

Measuring the Visual Score

The visual score of plants was determined with the bonitation scale scored between 1 and 5 points. It is based on the growth rate of the plant in the pot, leaf color, and leaf strength. To ensure a fair evaluation, observations were conducted by three individuals. The plants with the highest quality and decorative value were scored 5 points, the worst quality plants were scored 1 point (Salachna *et al.,* 2017).

Measuring EC and pH

EC and pH levels (WTW EC meter and WTW pH meter) were measured in nutrient solution. During the preparation of the nutrient solution for the lettuce cultivation, pH and EC levels were measured after the salt application in the samples collected from the main nutrient solution tanks after the stock solution source was exhausted, and these levels were measured in the drainage solutions every 2 weeks. EC and pH levels were controlled in the drainage solution collected from the lettuce cultivation in both cultivation periods and the nutrient solution applied to the ornamental kale cultivation groups during the preparation of the solutions.

Statistical Analysis

The data were evaluated using the TARIST statistical analysis program. The Least Significant Difference (LSD) test was applied to determine significant differences ($P \leq 0.05$).

RESULTS AND DISCUSSION

After the nutrient solutions were applied on October 20, 2017, in the first cultivation and on November 08, 2018, in the second cultivation, plant height, plant width, leaf number, and the width and length of selected plants were measured every month, and plant visual scores were determined at the end of the cultivation period with the observation method. In order to determine the impact of salinity on the plants, the measurement and observation results were analyzed statistically (Table 1).

It was determined that the impact of salinity on plant height was statistically significant (Table 1). The highest plant height was determined in S0 and S1. The interaction between salinity and cultivation period led to significant differences. The plant height was higher in the second cultivation period, probably due to climatic factors. The temperature inside the greenhouse was 12.58% lower in the second cultivation period. Since ornamental kale is a winter season plant, low temperatures positively affected the plant growth. The impact of salinity on ornamental kale diameter was similar to plant height, and there was a significant difference between the main and interactive effects of salt treatments. The lowest plant diameter was in S1 and S2 levels. The analysis of the effect of cultivation period revealed that the highest plant diameter was in the first period (28.19 cm) and the lowest plant diameter was in the second

Table 1. Plant properties based on salinity treatment.[a]

		Plant height (cm)	Plant diameter (cm)	Leaf number (per plant)	Leaf width (cm)	Leaf length (cm)	Visual score (points)
Applications	S0	29.63 a	26.92 a	51.00	16.17 a	8.33 a	4.42 a
	S1	28.96 a	24.08 b	49.83	15.50 a	7.50 b	3.56 b
	S2	26.50 b	23.29 b	46.17	13.67 b	7.17 b	2.89 b
	$LSD_{0.05}$	2.436**	1.721**	n.s.	1.068 **	0.407 **	0.672**
	SD.	1.65	1.91	2,52	1,29	0,60	0,77
Periods	1st CP	25.56 b	28.19 a	57.22 a	14.33 b	8.00 a	3.56
	2nd CP	31.17 a	21.33 b	40.78 b	15.89 a	7.33 b	3.69
	$LSD_{0.05}$	1.989**	1.405**	5.749**	0.872**	0.332**	ns
	SD	3.97	4.85	11.62	1.10	0.47	0.09
1st CP	S0	27.41 a	29.67 a	59.33	15.00	8.67	4.43 a
	S1	26.58 a	28.00 ab	60.17	15.00	8.00	3.56 ab
	S2	22.67 b	26.92 b	52.17	13.00	7.33	2.67 b
	$LSD_{0.05}$	3.445**	2.434**	ns	ns	ns	0.950**
	SD	2.53	1.39	4.40	1.15	0.67	0.88
2nd CP	S0	31.83	24.17 a	42.67	17.33	8.00	4.39 a
	S1	31.83	20.17 b	39.50	16.00	7.00	3.56 ab
	S2	30.83	19.67 b	40.17	14.33	7.00	3.11 b
	$LSD_{0.05}$	ns	2.434**	ns	ns	ns	0.950**
	SD	0.58	2.47	1.67	1.50	0.58	0.65

[a] S0: Control, S1: Waste drainage solution salinity concentration, S2: S1+1 dS m^{-1}; CP: Cultivation Period; SD: Standart Deviation. * $P \leq 0.05$ significance level; ** $P \leq 0.01$ significance level; [ns]: Not significant.

cultivation period (21.33 cm). Based on the salinity x cultivation period interaction, the lowest plant diameter in the first period (26.92 cm) was in S2. During the second cultivation period, the highest plant diameter was determined in S0, while the lowest was determined in S1 and S2 levels (20.17 and 19.67 cm, respectively) that were in the same statistical group. Zurayk *et al.* (1993) determined the responses of *Begonia, Chlorophytum, Coleus, Geranium* and *Mesembryanthemum* to salinity, and reported that the higher EC in irrigation water reduced the plant height, consistent with the present study findings. In another study, the effects of waste sludge on ornamental kale were determined, and it was reported that the plant height varied between 11.58-13.83 cm and the plant diameter between 14.75-17.08 cm (Akın and Kahraman, 2018). The plant height and diameter they reported were lower than the present study. The differences were associated with the differences between the applications (sewage sludge and salinity level) and the differences between the analyzed varieties in the studies. The ornamental kale in the highest NaCl concentration (800 mmol dm^{-3}) had the smallest leaves and the shortest height (28.2-43.0 cm) when compared to other NaCl concentrations (0, 50, 100, 200, 400 mmol dm^{-3}) (Salachna *et al*., 2017).

Although the previous findings on plant height were higher when compared to the present findings, the fact that the shortest plants were observed in high salinity treatments was similar. The plant height differences in the two studies were associated with the differences in salt application times and cultivated varieties. In another study, it was reported that the variations in salinity did not affect the aesthetic appearance of the cut flowers; however, the increase in salinity reduced the flower diameter and weight (Sonneveld, 2000). The reduction in plant diameter due to higher NaCl demonstrated in the present study was consistent with the finding of Sonneveld (2000). Although the effect on leaf number was not statistically significant, salinity decreased leaf number in ornamental kale (Table 1). The effect of cultivation period on leaf number was significant. The highest leaf number was 57.22 $plant^{-1}$ in the first year, while the lowest leaf number was 40.78 $plant^{-1}$ in the second year. These findings were consistent with the results reported by Salachna *et al.* (2017) that 'Scarlet' ornamental kale grown under salt stress had lower leaf number compared to the control plants. Similar to our findings, it was reported that the lowest leaf number was determined in the group with the highest NaCl (800 mmol NaCl). The author reported that the leaf number varied between 14.0-17.7 $plant^{-1}$. The leaf number varied between 46.17 $plant^{-1}$ and 51.00 $plant^{-1}$ based on salinity to achieve the present study aim. It could be suggested that the numerical difference between the leaf numbers in two studies was due to the difference between cultivation periods and varieties. Ibrahim *et al.* (1991) determined that high salinity led to lower leaf number in both *Coleus blumei* 'Xenia Field' and *Salvia splendens* 'Flare Path' plants in saline conditions, similar to our findings. Based on the statistical analysis that reflected the effect of salinity on the width and length of the plant leaves, the impact of salinity on the width and height of ornamental kale leaves was significant (Table 2). Thus, the widest leaves were 16.17 cm and 15.50 cm in S0 and S1, respectively, and the narrowest leaves were in S2 (13.67 cm). The longest leaf was 8.33 cm in S0, while the shortest leaves were 7.50 and 7.17 cm in S1 and S2, respectively. There was a statistically significant difference between plant leaf width and length based on the growing season. The highest leaf width was 15.89 cm in the second cultivation period and the highest length was 8.00 cm in the first cultivation period. According to Salachna *et al.* (2017) on ornamental kale in saline conditions (0, 50, 200, 400 and 800 mmol dm^{-3}) for 8 weeks, leaf width varied between 23.0-26.7 cm and leaf length: 7.83-10.2 cm.

Table 2. The dry weight ratio in plant organs based on salinity.[a]

Plant		Plant dry wet(%)	Upper section dry wet (%)	Root dry wet (%)	Leaf dry wet (%)
Applications	S0	16.38	12.86	11.76	27.54 b
	S1	20.58	13.09	13.61	33.60 ab
	S2	22.27	13.61	14.59	35.89 a
	$LSD_{0.05}$	**ns**	**ns**	**ns**	**7.369****
	SD	2.80	0.38	1.44	4.31
Periods	1st CP	20.38	10.78 b	9.50 b	33.15
	2nd CP	19.12	15.59 a	17.14 a	31.54
	$LSD_{0.05}$	**ns**	**1.120****	**2.357****	**ns**
	SD	0.89	3.40	5.40	1.14
1st C.P.	S0	15.58	10.57	7.33	29.01
	S1	23.59	10.66	10.14	34.28
	S2	21.98	11.10	11.03	36.15
	$LSD_{0.05}$	**ns**	**ns**	**ns**	**ns**
	SD	5.66	0.28	1.93	3.70
2nd C.P.	S0	17.19	15.16	16.19	26.07
	S1	17.60	15.52	17.08	32.93
	S2	22.56	16.11	18.15	35.62
	$LSD_{0.05}$	**ns**	**ns**	**ns**	**ns**
	SD	2.99	0.25	0.98	4.92

[a] S0: Control, S1: Waste drainage solution salinity concentration, S2: S1+1 dS m^{-1}; CP: Cultivation Period; SD: Standart Deviation. * P≤ 0.05 significance level; ** P≤ 0.01 significance level; [ns]: Not significant.

Probably, the lower and similar control level findings in the present study when compared to the findings of Salachna *et al.* (2017) were due to the difference between the nutritional solutions applications.

The influence of salinity levels on the visual score was statistically significant (Table 1). The lowest visual score belonged to S1 and S2 (3.56 and 2.89 points), which were in the same statistical group. Salt application x cultivation period interaction led to a significant difference between the groups in both growing seasons, in which the lowest visual scores were 2.67 and 3.11 points in the S2 level in the first and second season, respectively. Salachna *et al.* (2017) reported that saline irrigation led to a significant decrease in plant quality, and the visual score of the plant decreased with the increase in NaCl concentration. Thus, the present study findings were consistent with the findings reported by Salachna *et al.* (2017) in that high NaCI content would reduce the visual score. The main and interactive effects of NaCl applications on plant dry weight, upper section dry weight, and root dry weight in both seasons were not significant (Table 2).

The plant dry weight, upper section dry weight, root dry weight reached highest values with the increase in salinity (Table 2). However, the impact of salinity on the leaf dry weight was significant. Similar to the variations in dry weight in other plant sections, the highest leaf dry weight was in S2 (35.89%). Salinity level×cultivation period interaction did not have a significant impact on the leaf dry weight. Salinity generally led to a decrease in the wet and dry plant weight, chlorophyll content, deterioration in the fruit taste and quality, reduced yield (Asraf, 2004). The present study findings, which demonstrated that increased salinity led to a decrease in plant height, leaf width, and height were not observed in the decrease in dry weight due to the increase in salinity. Thus, the findings of the present study were consistent with the above-mentioned study.

The various salinity levels led to statistically significant differences in leaf relative water content and turgor loss, while the impact of salinity application x cultivation period interaction was insignificant (Table 3).

The increased salt concentration decreased leaf relative water content. Thus, the lowest leaf relative water content was in the treatment with the highest salinity (S2). The effects of salinity on turgor loss were inconsistent with the leaf relative water content findings. Turgor loss was highest in levels with high salinity (S2: 17.44%). The previous study findings in various species (tomato, melon, chili pepper, bean, zucchini) under saline conditions were consistent with the present study, and it was concluded that the leaf relative water content decreases under stress conditions induced by increase in NaCl, and the highest values were observed in the control plants without salt application (Kuşvuran, 2010; Kaya, 2011). Our findings on leaf relative water content and turgor loss were consistent with the results of a previous study that showed high salinity decreased leaf relative water content and increased turgor loss in grapevine cultivation under saline conditions (Sivritepe, 2000).

The variations in the mean EC between the 1st and 2nd growing seasons with the application of the drainage solution obtained in lettuce cultivation (EC0) as one of the salinity treatments in ornamental kale cultivation (S1) are presented in Figures 1 and 2.

The EC values in the nutrient solution drained from EC0 level were between 1.49-1.97 dS m^{-1} in the first growing season and between 1.80-2.08 dS m^{-1} in the 2nd season. The mean EC in 5 repeated measurements conducted on the nutrient solution drained from the EC0 level was 1.69 dS m^{-1} in the first season and 1.98 dS m^{-1} in the second.

Comparison of the EC levels measured in the two seasons revealed that the EC values of the nutrient solution (EC0) were higher in the second season when compared to the first. This was associated with the higher EC

Table 3. The leaf Relative Water Content (RWC) and Turgor Loss (TL) findings.[a]

		RWC (%)	TL (%)
Applications	S0	95.19 a	4.45 b
	S1	94.36 b	5.23 b
	S2	81.52 b	17.44 a
	$LSD_{0.05}$	1.264**	1.610**
	SD	7.66	7.29
Periods	1st CP	89.68 b	9.78 a
	2nd CP	91.03 a	8.30 b
	$LSD_{0.05}$	1.032**	0.948**
	SD	0.95	1.05
1st C.P.	S0	94.77	4.85
	S1	93.90	5.65
	S2	80.38	18.84
	$LSD_{0.05}$	ns	ns
	SD	8.07	0.57
2nd C.P.	S0	95.62	4.05
	S1	94.81	4.81
	S2	82.65	16.04
	$LSD_{0.05}$	ns	ns
	SD	7.27	6.71

[a] S0: Control, S1: Waste drainage solution salinity concentration, S2: S1+1 dS m^{-1}; CP: Cultivation Period; SD: Standart Deviation. * P≤ 0.05 significance level; ** P≤ 0.01 significance level; [ns]: Not significant.

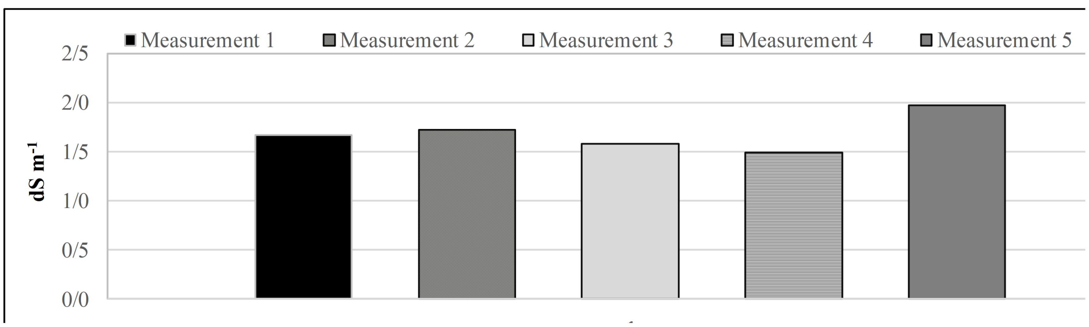

Figure 1. The variations in EC level in nutrient solution drained from the EC0 level in the first growing season.

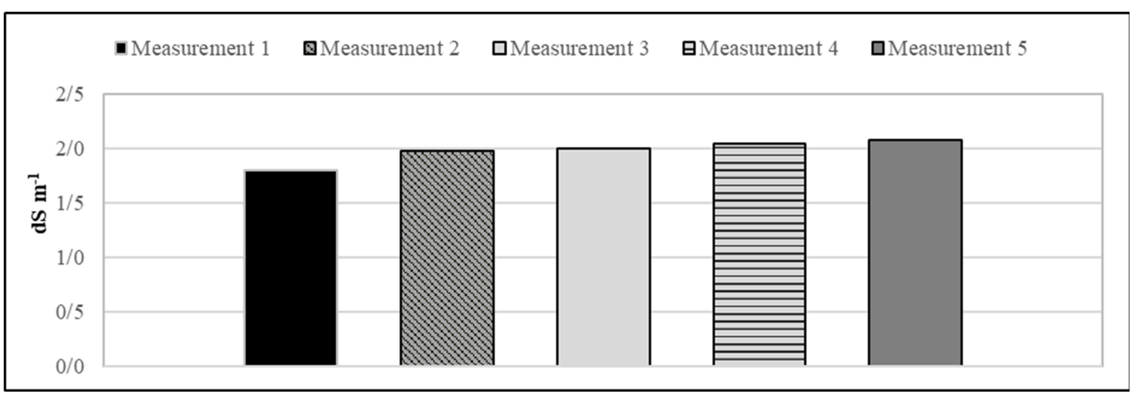

Figure 2. The variations in EC level in nutrient solution drained from the EC0 level in the second growing season.

level of the irrigation water used in the stock nutrient solution. Savvas *et al.* (2005) investigated the effects of NaCl (0.8, 5, 10 and 15 mM) in cucumber (*Cucumis sativus*) using a hydroponic system and reported that the EC of the non-discharged drainage solution increased rapidly around the root. The authors also found that 6-7 weeks after recycling initiation, the EC of the drainage water approached asymptomatically a maximal level depending on the treatment. They reported that the concentration of some macronutrients showed also an increasing trend with time, but this increase was relatively small and could not account for the observed rise of EC. Hence, this pattern of EC increase was ascribed to accumulation of Na and Cl, which was initially rapid but tended to be minimized as uptake of Na and Cl were approaching the corresponding concentrations in the irrigation water used to compensate for the transpiration losses.

The study findings showing higher EC levels of the drainage solution collected from high salinity applications were consistent with the results of Savvas *et al.* (2005), who reported association of the rapid increase in the EC of the drainage solution in the root zone with Na and Cl accumulation. In a study by Raya *et al.* (2005) that aimed to use saline water to reduce the drainage wastewater use in Israel, it was reported that to degree reuses be a viable alternative. This finding was consistent with the present study results that waste drainage solution could be used for plants with medium and high salt tolerance.

CONCLUSIONS

The highest plant height and diameter were observed in the control (S0) and S1, where the drainage solution obtained from lettuce cultivation was used in ornamental kale. The plant diameter, leaf height and visual score decreased with the increase in NaCl. The lowest RWC in ornamental kale was determined in the highest salinity treatment. The effect of salinity on turgor loss was inconsistent with RWC findings; turgor loss was higher in the highest salinity. The plant total dry weight increased with the increase in salinity.

Since no diseases or hazardous factors were recorded in lettuce cultivation, the problem of fungi, bacteria or virus contamination due to the use of drainage solution in ornamental kale was not observed. Based on the present findings, use of the recycled drainage nutrient solution in ornamental plant cultivation would not adversely affect the aesthetic appearance and certain physical properties of the products when compared to soilless open systems where the drained nutrient solution is removed from system. This could be adopted in the above-mentioned cultivation. It could be suggested that the method, which could be called a semi-closed drainage system, would reduce the risk of environmental pollution. It was concluded that recycling the drainage water with this system could be an alternative in ornamental kale production, if it would be managed adequately, both due to the associated economic and environmental benefits. Further studies are required to investigate the economic issues associated with this application.

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REFERENCES

1. Akat, Ö. 2008. Effects of Different Salinity Levels and Leaching Fractions on Plant Growth, Yield, Quality and Water Consumption of Gerbera Plants. Ph.D. Diss., Grad. Sch. Nat. Sci. and App. Sci., Ege Univ., Izmir, Turkey.
2. Akat, H. and Akat Saraçoğlu, Ö. 2017. The Effects of Organic Substances and Foliar Calcium Applications on *Limonium sinuatum* Cultivation in Saline Conditions.

In: "*Current Trends in Science and Landscape Management"*, (Eds.): Efe, R., Zencirkıran, M., Wendt, J. A., Tümsavaş, Z., Unal, H. and Borisova, B.), Sofia St. Kliment Ohridski University Press, PP. 285-295.

3. Akat, H., Saraçoğlu, O. A. and Çakar, H. 2020. Yield response of Limonium sinuatum cultivars under salinity stress. *J. Environ. Biol.,* 41: 302-309.
4. Akın, F. and Kahraman, O. 2018. The Availability of Sewage Sludge in Ornamental Kale Cultivation. *Anadolu J. Agr. Sci.*, **33:** 177-183.
5. Alberici A., Quattrini, E., Penati, M., Martinetti, L., Gallina, P. M., Ferrante, A. and Schiavi, M. 2008. Effect of the Reduction of Nutrient Solution Concentration on Leafy Vegetables Quality Grown in Floating System. *Acta Hortic*., **801:** 1167-1176.
6. Asraf, M. 2004. Some Important Physiological Selection Criteria for Salt Tolerance in Plants. *Flora*, **199:** 361-376.
7. Cassaniti, C., Romano, D. and Flowers, T. J. 2012. The Response of Ornamental Plants to Saline Irrigation Water. In: "*Water Management Pollution and Alternative Strategies",* (Ed.): Garcia-Garizabal, I. InTech Rejika Croatia, PP. 131-158.
8. Cassaniti, C., Romano, D. I., Hop, M. E. C. M. and Flowers, T. J. 2013. Growing Floricultural Crops with Brackish Water. *Environ. Expt. Bot*., **92:** 165-175.
9. Gilabert, C. E., Ruiz-Hernández, M. C., Parra, M. A. and Fernández, J. A. 2014. Characterization of Purslane (*Portulaca oleracea L.*) Accessions: Suitability as Ready-to-Eat Product. *Hort. Sci.*, **172:** 73–81.
10. Grieve, C. M., Grattan, S. R. and Mass, E.V. 2013. Plant Salt Tolerance. In: "*Agricultural Salinity Assessment and Management",* (Eds.): Wallender, W. and Tanji, K. American Society of Civil Engineers Press, Reston, Virginia, PP. 405-459.
11. Ibrahim, K. M., Collins, J. C. and Collin. H. A. 1991. Effects of Salinity on Growth and Ionic Composition of *Coleus blumei* and *Salvia splendens*. *Hort. Sci.*, **66(2)**: 215–222.
12. Kaya, E. 2011. Screening of the Bean Genotypes for Their Tolerans to Salinity And Drought Stresses at the Early Plant Growth Phase. MS.C. Diss., Grad. Sch. Nat. Sci. and App. Sci., Cukurova Univ., Adana, Turkey.
13. Kılıç, C. C. 2022. Effect of Nitrogen and Planting Dates on Yield and Yield Components of Head Lettuce Grown in Soilless Culture. *J. Plant Nut.*, **45(20):** 3159-3173.
14. Kuşvuran, S. 2010. Relationships Between Physiological Mechanisms of Tolerances To Drought and Salinity in Melons. Ph.D. Diss., Grad. Sch. Nat. Sci. and App. Sci., Cukurova Univ. Adana, Turkey.
15. Küçükahmetler, 2003. The Effect of Salt Stress on Grovwth and Development of Different Lisianthus (*Eustoma grandiflorum* raf. shinn) Cultivarsin Vitro and in Vivo Conditions. Ph.D. Diss., Grad. Sch. Nat. Sci. and App. Sci., Uludag Univ., Bursa, Turkey.
16. Maloupa, E. 2002. Hydroponic Systems. In: "*Hydroponic Production of Vegetables and Ornamentals",* (Eds.): Savvas, D. and Passam, H. Embryo Publications, Athens.
17. Raya, V., Díaz, M. A., Mansito, P., Socorro, A. R. and Cid, M. C. 2005. Recirculating Nutritive Solution in Soilless Culture of Rose Using Saline Alkaline Water. In: "*International Symposium on Soilless Culture and Hydroponics",* (Ed.)*:* Gavilán, M. U. Acta Hortic.*,* Almeria, Spain, 697 PP.
18. Salachna, P., Piechocki, R. and Byczynska, A. 2017. Plant Growth of Curly Kale Under Salinity Stress. *J. Ecol. Eng.*, **18(1):** 119–124.
19. Savvas, D., Pappa, V. A., Kotsiras, A. and Gizas, G. 2005. NaCl Accumulation in a Cucumber Crop Grown in a Completely Closed Hydroponic System As İnfluenced By Nacl Concentration in İrrigation Water. *Europ. J. Hort. Sci.*, **70(5):** 217–223.
20. Sivritepe, N. 2000. Physiologycal Changes in Grapevines Induced by Osmatic Stres Originated from Salt and Their Role in Salt Resistance. *Turk. J. Biol.,* **24:** 97-104.
21. Sonneveld, C. and Voogt, W. 1983. Studies on the Salt Tolerance of Some Fower Crops Grown under Glass. *Plant Soil.*, **74:** 41-52.
22. Sonneveld, C. 2000. Effects of Salinity on Substrate Grown Vegetables and Ornamentals in Greenhouse Horticulture. Ph.D. Diss., Wageningen Univ., The Netherlands.

23. Sonneveld, C., Baas, R., Nijssen, H. M. C. and De Hoog, J. 2000. Effect of Salinity Substrate Grown Vegetables and Ornamentals in Greenhouse Horticulturae. *J. Plant. Nut.*, **22:** 1033-1048.
24. Tüzel, Y. and Gül, A. 1999. Soilless Culture in Turkey. *1st Meeting of FAO Thematic Working Group For Soilless Culture*. 2 Sept., Halkidiki, Greece.
25. Veatch-Blohm, M. E., Sawch, D., Elia N. and Pinciotti, D. 2014. Salinity Tolerance of Three Commonly Planted *Narcissus* Cultivars. *Hort. Sci.,* **49(9):** 1158-1164.
26. Vernooij, C. J. M. 1992. Reduction of Environmental Pollution by Recirculation of Drain Water in Substrate Cultures. *Acta Hortic.,* **303:** 9-13.
27. Villarino, G. H. and Mattson, N. S. 2011. Assessing Tolerance to Sodium Chloride Salinity in Fourteen Floriculture Species. *Horttechnology,* **21:** 539-545.
28. Villora, G., Moreno, A., Pulgar G. and Romero, L. 2000. Yield Improvement in Zucchini under Salt Stress: Determining Micronutrient Balance. *Hort. Sci.,* **86:** 175-183.
29. Zuluaga, M. Y. A., Milani, K. M. L., Miras-Moreno, M. B., Lucini, L., Valentinuzzi, F., Mimmo, T., Pii, Y., Cesco, S., Rodrigues, E. P. and De Oliveira, A. L. M. 2021. The Adaptive Metabolomic Profile and Functional Activity of Tomato Rhizosphere are Revealed upon PGPB Inoculation under Saline Stress. *Environ. Exp. Bot.*, **189**: 104552.
30. Zurayk, R., Tabbarah, D. and Banbukian, L. 1993. Preliminary Studies on the Salt Tolerance and Sodium Relations of Common Ornamental Plants. *J. Plant. Nut.*, **16(7):** 1309-1316.

کاربرد زه‌آب محلول غذایی در کشت بدون‌خاک کلم‌پیچ زینتی در شرایط شور

ا. آکات ساراکوغلو

چکیده

با هدف کمک به کاهش آلودگی محیط از طریق استفاده مجدد از محلول هوگلند زهکشی‌شده از کاهو، در سامانه رشد بدون خاک کلم‌پیچ زینتی، این پژوهش در دو گلخانه با استفاده از کاهو و کلم پیچ زینتی در کشت بدون خاک اجرا شد. کشت کاهو برای فراهم کردن محلول غذایی (زه‌آب) زهکشی‌شده انجام شد. بنابراین، تجزیه و تحلیل کاهو در این پژوهش گنجانده نشد. هر دو گیاه با طرح آزمایشی بلوک های تصادفی با ۳ تکرار در محیط کشت جامد و سامانه تغذیه باز (open feeding system) اجرا شد. در این پژوهش از ۳ سطح شوری (S0= شاهد، S1= غلظت شوری محلول زه‌آب زهکشی شده، و S2= دسی زیمنس بر متر S1+1) استفاده شد. بیشترین ارتفاع بوته و عرض برگ در شاهد و در S1 به دست آمد که در آن از محلول زهکشی (زه‌آب) در کشت کلم پیچ زینتی استفاده شد. قطر بوته، ارتفاع برگ و ارزش چشمی (visual value) با افزایش شوری کاهش یافت. نتیجه گیری شد که مدیریت مناسب آب زهکشی (زه‌آب) بازیافتی می تواند جایگزینی برای تولید کلم پیچ زینتی در کشت بدون خاک باشد.