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THE EFFECTS OF NaCl SOLUTION APPLICATION FREQUENCY ON HAZELNUT SUCKER MANAGEMENT

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Abstract: Hazelnut is a nut species that is strategically important to Türkiye. Hazelnut cultivation has various cost factors, with the highest share belonging to the harvesting. Following harvesting, sucker management, and fertilization are the most significant cost factors. Due to high labor requirements and costs, sucker removal, which is recommended to be performed twice a year, is often conducted only once a year or every two years. This situation leads to reduced yield per hectare and income loss for producers. To reduce costs, some growers use herbicides to remove hazelnut suckers. However, the widespread use of herbicides causes irreversible environmental damage and can lead to erosion, particularly on sloped lands. Moreover, the continuous use of herbicides poses risks such as leaving residues in the soil, harming soil microorganisms, and threatening the health of hazelnut plants. This research aimed to determine the effects of the application frequency of a 15% salt (NaCl) solution on hazelnut sucker removal, focusing on its impact on soil EC and pH. The research was conducted at the Ondokuz Mayıs University Ali Nihat Gökyiğit Research Station from 2019 to 2021. NaCl solution applications were planned to be performed once, twice, and three times a year. The effects of application frequency on the drying rate of suckers, the number and length of newly emerged suckers, and changes in soil pH and EC were evaluated. The results revealed that applying the NaCl solution three times a year was the most effective method for sucker management and did not cause adverse changes in soil pH or EC levels.

Keywords: *Corylus avellana*, Sucker, Hazelnut, Salt

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1. Introduction

The hazelnut (*Corylus*), native to Central Asia, the Caucasus, and Anatolia, belongs to the Betulaceae family within the Fagales order. According to FAOSTAT (2024), world hazelnut production in 2022 is 1195732 tonnes, and hazelnuts are produced in 32 countries. Türkiye, benefiting from its favorable ecological conditions and high-quality cultivars, ranks first among these countries, producing 765000 tons (FAOSTAT, 2024). This production accounts for approximately 64% of the world's hazelnut output.

In Türkiye, many hazelnut orchards are located in slopy areas. These slopes make mechanization challenging, increasing production costs and higher overall production expenses, thereby reducing profitability. One way to enhance profitability is by lowering production costs. The most significant cost factors in hazelnut cultivation are harvesting, sucker management, and fertilization (Okay et al., 1986; Karadeniz et al., 2009). The most grown hazelnut species, *Corylus avellana*, is known for its tendency to develop suckers. These suckers significantly reduce the orchard's ventilation and sunlight exposure, which harms productivity by competing with the main branches that provide fruit for nutrients and minerals. In modern, well-maintained hazelnut orchards, it is recommended to remove the suckers twice annually (Okay et al., 1986; Tous et al., 1994; Beyhan et al., 1995). However, due to high labor costs and intensive labor requirements, most growers perform sucker control only once a year or every two years (Kurnaz and Serdar, 1993).

Failing to remove hazelnut suckers as frequently as recommended negatively impacts the quality and yield of the hazelnut orchard. Figen et al. (2021) reported that removing hazelnut suckers twice a year increased yield by 27.7-55.9%, while cleaning them only once increased yield by 3.9-17.0%.

Sucker management in hazelnut orchards is predominantly carried out manually using pruning knives. Herbicides and other chemicals have been used instead of control by hand (Beyhan et al., 1996, Beyhan, 1997). However, the extensive and inappropriate use of herbicides harms the environment irreparably. Additionally, it leads to erosion, especially on sloped surfaces. Moreover, continuous use of herbicides poses risks such as residue accumulation in soil, harm to soil microorganisms, and potential threats to the health of hazelnut plants.

Some fertilizers have been tested as an alternative to herbicide use. In the research conducted by Serdar et al. (2022), the effects of different doses of ammonium sulfate (21% N) and calcium ammonium nitrate (26% N) on sucker wilting rates were evaluated. The results revealed that a 10% solution of ammonium sulfate was the most effective method on hazelnut suckers. In another research, sodium chloride (NaCl) solutions at different concentrations were tested as a more cost-effective alternative to fertilizer applications. The research found that a 15% NaCl solution had a positive result against suckers (Kondiloğlu, 2018). However, the frequency of the NaCl solution to be used has not been determined.

This research aims to determine the effects of application frequency of a previously proven 15% NaCl solution on hazelnut sucker control, as well as its impact on soil pH and EC.

2. Materials and Methods

This research was conducted on the 'Çakıldak' hazelnut cultivar in an orchard with a bush planting system from 2019-2021 (Serdar and Demir, 2005). The orchard is located at the OMÜ Ali Nihat Gökyiğit Research Station in the Kayagüney neighborhood of Atakum district, Samsun. In the first week of March 2019, all suckers were removed using a pruning knife. To prepare a 15% NaCl solution, 2.25 kg of rock salt was dissolved in 15 liters of water. The solution was then applied to the hazelnut suckers using a motorized sprayer. During the application, care was taken to thoroughly wet the suckers while avoiding any contact with the fruit-bearing branches. Approximately 1 liter of solution was sprayed onto each bush.

To evaluate the effects of NaCl solution application frequency on the control of hazelnut suckers as well as soil EC and pH, applications were conducted once, twice, and three times in 2019 and 2020 (Table 1 and 2). In 2020, due to ecological conditions, the application made in July was delayed by 15 days compared to 2019s.

Table 1. Application dates of the solutions made in 2019

Application Frequency	Application Dates		
	1st Application	2nd Application	3rd Application
Once a year	30 August	-	-
Twice a year	15 July	30 August	-
Three times a year	30 May	15 July	30 August

Table 2. Application dates of the solutions made in 2020

Application Frequency	Application Dates		
	1st Application	2nd Application	3rd Application
Once a year	30 August	-	-
Twice a year	30 July	30 August	-
Three times a year	31 May	30 July	30 August

All Bushes were fertilized with 1 kg 20:12:15+2 MgO+0.3B+0.5Zn in March and 0.5 kg calcium ammonium nitrate (CAN 26% N) in May.

To evaluate the effect of application frequency, measurements were taken at the end of the vegetation period for sucker length, wilting ratio of the suckers, number of newly emerged suckers, and length of newly emerged suckers. These measurements were conducted in the 30 x 30 cm area where the highest number of suckers was observed.

Soil samples were collected on 10.03.2019, 05.11.2019, 20.04.2020, 20.12.2020, and 02.06.2021 to determine the effect of NaCl solution application frequency on pH and EC changes in soil. Soil samples were taken from three different points within the canopy drip line of the bush at a depth of 0–20 cm, then mixed to create a composite soil sample for each replicate. Additionally, for control purposes, soil samples were collected from a 30 cm outside the canopy drip line of the bush (OCDL) to compare the effects of each treatment. Soil samples were brought to the laboratory, and pH and EC values were determined on the same day (Black, 1965).

2.1. Statistical Analysis

The research was conducted in 45 bushes with three treatment frequencies x 5 replications and three bushes in each replicate. A randomized plot experimental design was used for the research. Data analysis for each year was performed separately, using ANOVA in the SPSS statistical package. Differences between means were determined using Duncan's Multiple Comparison Test.

3. Results and Discussion

In 2019, the application frequency of once a year resulted in the longest sucker length (80.88 cm) with the lowest wilting ratio (6.73%) (Table 3). In contrast, applying the solution twice or three times a year significantly reduced sucker length (57.09 and 53.99 cm, respectively) while substantially increasing both the length of wilted suckers and wilting ratios (39.92 and 39.32 cm; 69.95% and 72.86%, respectively.

Table 3. The effects of salt solution application frequency on sucker length, length of the wilted part, and wilting ratio in 2019

Application Frequency	Sucker Length(cm)	Length of the Wilted Sucker (cm)	Wilting Ratio (%)
Once a year	80.88[a]*	5.47[b]	6.73[b]
Twice a year	57.09[b]	39.92[a]	69.95[a]
Three times a year	53.99[b]	39.32[a]	72.86[a]
P	≤0.01	≤0.01	≤0.01

* There is no difference between the means shown with the same letters in the column.

According to the newly emerged suckers, it was found that there were significant statistical differences between the application frequencies. The highest number of new shoots were obtained from 3 and 2 times a year application, with 12.00 and 10.66. (Table 4). Regarding the length of the newly emerged suckers, the longest suckers were obtained from the 1 and 2 times a year application (45.31 and 48.70 cm, respectively). In the 3 times a year application, the shortest newly emerged shoot length was measured (33.04 cm).

Table 4. The effects of different application frequencies of salt solution on the number and length of newly emerged suckers in 2019

Application Frequency	Number of the Newly Emerged Sucker	Length of the Newly Emerged Sucker (cm)
Once a year	6.66[b]*	45.31[a]
Twice a year	10.66[a]	48.70[a]
Three times a year	12.00[a]	33.04[b]
P	≤0.01	≤0.01

* There is no difference between the means shown with the same letters in the column.

A single application per year led to the most sucker growth (123.97 cm), with the shortest wilted sucker length (10.52 cm) and the lowest wilting ratio (8.68%) in 2020 (Table 5). Conversely, higher application frequencies (two and three times a year) reduced sucker length (70.72 and 49.94 cm, respectively) and increased both wilted sucker length (47.45 and 44.78 cm, respectively) and wilting ratios (68.03% and 89.66%, respectively). It was found that there was an inverse relationship between the frequency of application and the length of the suckers (Figure 1, 2).

Table 5. The effects of salt solution application frequency on sucker length, length of the wilted part, and wilting ratio in 2020

Application Frequency	Sucker Length(cm)	Length of the Wilted Sucker (cm)	Wilting Ratio (%)
Once a year	123.97[a]*	10.52[b]	8.68[c]
Twice a year	70.72[b]	47.45[a]	68.03[b]
Three times a year	49.94[c]	44.78[a]	89.66[a]
P	≤0.01	≤0.01	≤0.01

* There is no difference between the means shown with the same letters in the column.

Figure 1. Appearance of non-dried suckers after one application per year.

Figure 2. Appearance of dried suckers after three applications per year.

When the effects of NaCl solutions on the number and length of newly emerged shoots were analyzed, no statistical difference was found between the treatments (Table 6). While the number of suckers remained relatively low across all treatments (2.40, 1.00, and 1.10), their lengths showed a declining trend with increased frequency (67.68, 54.55, and 49.36 cm).

Table 6. The effects of different application frequencies of salt solution on the number and length of newly emerged suckers in 2020

Application Frequency	Number of the Newly Emerged Sucker	Length of the Newly Emerged Sucker (cm)
Once a year	2.40	67.68
Twice a year	1.00	54.55
Three times a year	1.10	49.36
P	N.S.	N.S.

N.S.= not significant

The research evaluated the effects of NaCl solution application frequency according to years. The results of all 2 years showed that the highest wilting ratio was obtained from the application 3 times a year. It is thought that this is due to the lack of sufficient lignification of the suckers in the 3 times a-year application. In addition, the lowest wilting ratios were obtained from the once-a-year treatment. Serdar et al. (2022) and Kondiloğlu (2018) also obtained similar results in their studies. In our research, it was determined that the most critical criterion affecting the wilting ratio was the lignification status along with the length of the suckers. In comparison, Serdar et al. (2022) noted that the optimal management of hazelnut suckers required at least three nitrogen solution applications annually to achieve effective sucker suppression without adverse impacts on plant health. However, they highlighted the importance of targeting suckers at specific growth stages (15-20 cm) to optimize wilting efficiency.

The hazelnut plant grows in shrub form and is generally cultivated using the bush system in Türkiye. In the bush system, plants should be replaced with the help of the suckers. In this respect, the applications should not negatively affect the number of newly emerged suckers. The frequency of applications showed varying effects on the number of new suckers. However, an increase in application frequency did not result in a significant decrease in the number of new suckers. On the contrary, in 2019, the highest number of new suckers was observed in areas where applications were performed three times a year. That shows 15% NaCl solution application did not have an adverse effect on newly emerged suckers

Soil samples were taken from the canopy drip line and outside the canopy drip line at five different times (March 10, 2019; November 5, 2019; April 20, 2020; December 20, 2020; and June 2, 2021). The changes in pH and EC values of these soil samples are presented in Table 7. Changes in soil pH and EC showed statistically significant differences (P<0.01) according to the sampling times. Still, these differences were generally insignificant between the treated and untreated (control) soil samples at the same sampling time.

Table 7. pH changes in the soils of the bushes treated with NaCl solution 1, 2, and 3 times a year (pH 1:1)

Sampling Dates	Application Frequency		
	Once a year	Twice a year	Three times a year
10.03.2019	7.11[a]*	5.66[a]	6.54[a]
05.11.2019	7.32[a]	5.66[a]	6.66[a]
05.11.2019 (OCDL)	7.11[a]	5.66[a]	6.54[a]
20.04.2020	6.85[b]	4.55[de]	5.27[c]
20.04.2020 (OCDL)	6.48[cd]	4.80[cd]	4.85[d]
20.12.2020	5.45[e]	4.30[e]	4.71[d]
20.12.2020 (OCDL)	5.24[e]	4.93[bc]	4.69[d]
02.06.2021	6.31[d]	5.11[bc]	6.57[a]
02.06.2021 (OCDL)	6.62[c]	5.23[b]	5.82[b]
P	≤0.01	≤0.05	≤0.01

* There is no difference between the means shown with the same letters in the column. OCDL: Soil samples were taken 30 cm outside the canopy drip line of the bush

Table 8. EC changes in the soils of the bushes treated with NaCl solution 1, 2, and 3 times a year (EC, µS/cm)

Sampling Dates	Application Frequency		
	Once a year	Twice a year	Three times a year
10.03.2019	450.20[b]*	202.00[e]	305.20[cd]
05.11.2019	487.40[a]	265.00[d]	270.70[d]
05.11.2019 (OCDL)	450.20[b]	202.00[e]	395.20[b]
20.04.2020	202.85[f]	58.93[f]	92.92[f]
20.04.2020 (OCDL)	261.40[e]	55.51[f]	59.60[f]
20.12.2020	358.93[d]	385.30[b]	342.97[c]
20.12.2020 (OCDL)	189.60[f]	253.20[d]	183.30[e]
02.06.2021	404.00[c]	305.43[c]	513.00[a]
02.06.2021 (OCDL)	396.83[c]	506.53[a]	429.40[b]
P	≤0.05	≤0.01	≤0.01

* There is no difference between the means shown with the same letters in the column. OCDL: Soil samples were taken 30 cm outside the canopy drip line of the bush.

The change in soil pH showed a similar trend at sampling times in different frequencies of NaCl solution applications. The salt solution was prepared using NaCl, and since sodium (Na) can hydrolyze in the soil to form NaOH, a strongly alkaline compound, the application of the solution is expected to increase soil pH. However, in all solution treatments, soil pH decreased in the 3rd (20.04.2020) and 4th (20.12.2020) soil sampling dates and increased in the 5th (02.06.2021) sampling date. This increase was also observed in the soils taken from the outside of the canopy drip line of the bush. In addition, these increases and decreases show a similar trend in untreated soil samples in each sampling and do not show a statistically significant difference. This may be attributed to the addition of basic cations to the soil through fertilization applications or washing away from the soil during excessive rainy seasons rather than the application of NaCl solution. In 2019, rainfall was higher compared to 2020 (Table 9). This may have caused the nutrients supplied through fertilization (salts composed of cations and anions) to leach away from the soil. In contrast, the lower rainfall in 2020 may have led to the accumulation of these elements in the soil. This accumulation could have resulted in an increase in the EC value. A similar trend was also observed in the changes in EC values, which are indicators of the salt content of soils, as in soil pH. In all soil samples, the EC values being below 2000 µS/cm (2 dS/m) indicate that there is no risk of salinization in the soil. Soil samples taken from the application areas showed statistically significant increases and decreases in EC values. Similarly, soil samples collected from areas outside the canopy drip line exhibited a similar distribution. Overall, there is no significant difference in EC values between soil samples from areas with NaCl solution applications and others. In the last application of the 2 times a year NaCl solution, the EC value of the soil sample taken from the 30 cm outside the canopy drip line of the bush was found to be statistically significantly higher than the canopy drip line soil sample. This indicates that the EC changes in soil samples were not affected by the NaCl solution treatments. The variations are more likely attributed to seasonal sampling times, vegetative cover on the soil surface, or agricultural practices such as fertilization applied to the soil. Besides, the change in soil EC can be attributed to the addition of basic cations in the soil with fertilization practices or washing away from the soil during excessive rainy seasons rather than NaCl solution application.

In 2020, however, the lower rainfall may have led to the accumulation of these elements in the soil, resulting in an increase in EC values (Table 9).

Table 9. In 2019 and 2020, precipitation amounts by months (mm)

Months	Years	
	2019	2020
January	45.1	97.6
February	26.0	43.0
March	33.8	33.8
April	58.1	30.7
May	58.0	36.7
June	73.5	27.2
July	38.5	1.6
August	18.3	21.0
September	25.5	15.8
October	86.0	22.8
November	57.6	122.5
December	67.3	20.5

In the field, approximately 1 liter of a 15% NaCl solution is applied per bush in a single application, giving a total of 150 g of NaCl. With 3 applications, this amount reaches a total of 450 g. In a one-decare area (1,000 m^2), each tree has approximately 30 cm root depth, corresponding to a total of 300 m^3 of soil. Assuming the bulk density of the soil is 1.30 tons/m^3, the total soil weight is calculated as 390,000 kg. If there are 50 bushes in one decare, the soil weight per bush is 390,000 kg / 50 = 7,800 kg. In the case of 3 applications, a total of 0.45 kg of NaCl is added to 7,800 kg of soil, increasing the NaCl content in the soil by 0.0057%. According to Tüzüner (1990)'s soil salinity classification, reaching the lower limit of light salinity in the soil, which is 0.15%, would require repeating this application 26 times (equivalent to 26 years) without any rainfall (Table 10).

Table 10. Soil salinity classification (Tüzüner, 1990)

Total salt (%)	EC µS/cm	Degree of salinity
0.00-0.15	0-4000	Unsalted
0.15-0.35	4000-8000	Lightly salted
0.35-0.65	8000-15000	Moderately salty
More than 0.65	More than 15000	Excessive salty

Moreover, due to the structure of the NaCl, it dissolves very easily and washed away from the soil. In this case, it does not seem possible to increase soil EC or salinity in the long term by applying 1 L of 15% NaCl solution in the Black Sea region with high rainfall. The increase in soil salinity with the addition of plant nutrients in the soil applications made by farmers with fertilization can increase the EC in the soil even more than this application. Another negative effect of this application on the soil should have been an increase in soil pH due to Na, whereas soil pH generally decreased.

5. Conclusion

NaCl solution applications at different frequencies show statistically significant differences in pH and EC values between soil sampling times.

However, within the same sampling times, the changes in areas with and without NaCl applications are generally similar. This indicates that there is usually no statistically significant difference between these areas. Therefore, it can be concluded that NaCl solution applications do not cause significant changes in soil salinization or pH values. In this respect, it was observed that 3 times application frequency did not have a negative effect on the soil.

In conclusion, it has been determined that applying a NaCl solution once a year has a low impact on the wilting ratio. Therefore, it is recommended to implement sucker control three times a year in hazelnut orchards that have similar ecological condition as Atakum district

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	Ü.S.	N.B.	C.G.	B.A.
C	25	25	25	25
D	30	30	10	30
S	100			
DCP	30	10	30	30
DAI		30	30	40
L	25	25	25	25
W	20	20	20	40
CR	25	25	25	25
SR				100
PM	60			40
FA	25	25	25	25

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because there was no study on animals or humans.

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