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Salicylic acid, ascorbic acid and wood vinegar effects on fenugreek (*Trigonella foenum-graecum* L.) plant germination at various salt concentrations

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Abstract

The aim of this study was to ascertain the impact of applying ascorbic acid (AsA), salicylic acid (SA) and wood vinegar at varying concentrations of salt (NaCl) on the germination and other physiological parameters of fenugreek (*Trigonella foenum-graecum* L.) seeds. Four different NaCl concentrations (0, 50, 100, and 150 mM), four separate SA and AsA applications (0, 50, 100, and 150 mM) and wood vinegar (0.05 %, 0.10 %, 0.15 %) were used in the study for each application. The study looked at the following criteria: germination rate (%), germination duration (day), root length (cm), and stem length (cm).

This investigation showed that higher salt concentrations had a negative effect on germination. Positive effects on germination and other parameters were also found with treatments of 50 mM and 100 mM AsA and SA. It has been found that the optimal administration of AsA and SA can positively impact fenugreek plant germination in saline environments. In addition, 0.10 % dose of wood vinegar had a more positive effect than other application doses.

Keywords: *Trigonella foenum*-graecum; Salicylic acid (SA); Ascorbic acid (AsA); Salt; Wood vinegar

1. Introduction

Fenugreek is an annual plant with taproot roots that belongs to the Leguminosae family. Fenugreek is an important spice and medicinal herb. The Mediterranean region and South of Europe are regarded as its home (Er and Yıldız, 2007; Esmaeili et al., 2012). Globally, fenugreek is cultivated in India, North Africa, Western Asia, and Central and Southeastern Europe (Er and Yıldız, 2007; Esmaeili et al., 2012; Elmnan et al., 2012). It is grown in the Central and Southeast provinces of Turkey, where it grows wild (Er and Yıldız, 2007).

There are several uses for fenugreek herb. Fenugreek seeds are used to make pasta and are marinating and preserving meats. Certain spice combinations contain flour made from the seeds of this plant (Elmnan et al., 2012). The plant's expectorant, stimulant, anti-inflammatory, anti-ulcer, and antibacterial properties make it useful in traditional medicine (Doshi et al., 2012). Because of its anticancer action and application in the treatment of diabetes, it is also a significant medicinal plant (Baytop, 1999; Esmaeili et al., 2012; Doshi et al., 2012; Fikreselassie et al., 2012). Fixed oil, essential oil, choline, trigonelline, mucilage, phosphorus organic compounds (phytin), and saponins (gitogenin, tigogenin, and neotigogen) are among the components of fenugreek plant seeds (Baytop 1999;Doshi et al., 2012).

Applications of salicylic acid are reported to help seeds germinate at both high and low temperatures (Korkmaz, 2005; Özdener and Kutbay, 2008; Ekinci et al. 2011). According to Rivas-San Vicente and Plasencia (2011), salicylic acid is a phenolic molecule that functions as a phytohormone, helping to regulate several stages of growth and development including photosynthesis, respiration, blooming, and senescence, with germination being a key component. Numerous

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research have demonstrated that using salicylic acid as a priming treatment lessens the impacts of salinity on plants (Jini and Joseph, 2017; Anaya et al. 2018). Ascorbic acid increases the availability of nutrients and water to plants under salt stress by regulating plant metabolism and development (Torlak 2019). An alternate strategy to lessen the detrimental effects of salt stress on plants is the application of non-enzymatic antioxidant molecules such ascorbic acid (Khan et al. 2006).

Wood vinegar is a complex aqueous liquid fraction resulting from the thermochemical degradation of components of plant biomass such as cellulose, hemicellulose and lignin. The composition of wood vinegar varies depending on the starting wood material and production temperature (Birol and Günal, 2022).

Its specific gravity is between 1.005-1.050 g mL-1 and its color is reported to range from pale yellow to bright brown and reddish brown. Mostly, neutral substances such as aldehyde, ketone, alcohol (methanol, butanol, amylalcohol), acid (acetic, formic, propionic, valeric), formaldehyde, acetone, furfural, valerolactone, phenols (Akkurt et al., 2020).

It consists of basic substances such as (syringol, cresol, phenol), hydrocarbons and nitrogen compounds such as ammonia, methyl amine and pyridine.

Wood vinegar is used in plant production due to its effects on improving soil quality, reducing the effects of plant pests and promoting plant growth (FFTC, 2005).

The purpose of this study was to ascertain the impact of applying ascorbic acid, salicylic acid and wood vinegar on the germination of fenugreek (*Trigonella foenum-graecum* L.) seeds at varying salt concentrations.

2. Material and methods

The study was carried out in 2024 at the Medicinal and Aromatic Plants Laboratory of Balıkesir University Altınoluk Vocational School. Seeds of fenugreek were employed as plant material. In the study, two distinct priming applications (SA and AsA), four distinct concentrations (0, 50, 100, and 150 mM) NaCl and four dose wood wvinegar (0, 0.05 %, 0.10 % and 0.15 %) for each priming application were taken into consideration. Salt stress was produced using analytical grade NaCl. The seeds were surface sterilized in a 5 % sodium hypochlorite solution for ten minutes before to germination (Uyanık et al., 2014). According to Nazarian (2016), seeds that had been surface sterilized were held in varying concentrations of SA and AsA solutions for 12 hours in order to prime them. After that, they were dried on drying papers at room temperature for 24 hours in order to restore their original moisture content. Following these treatments, the seeds were sown in petri plates at a temperature of 20±1 °C. Seeds were first deemed viable based on ISTA (1996) guidelines. Four-by-twenty-five seeds were germination tested for fourteen days in petri dishes sandwiched between two layers of blotting paper (ISTA, 1996). This study looked at the following values: average germination time (cm), root length (cm), stem length (cm), germination power (%), germination rate (%), and germination index (%). By dividing the total number of sowed seeds by the number of germinated seeds acquired on the 7th and 14th days, germination power and germination rate were calculated (Akıncı and Çalışkan, 2010). The TARIST statistical tool was used to statistically examine the experiment's data. The means were compared using the LSD test.

3. Results

3.1. Effect of Ascorbic Acid on Germination Rate

The results of the study indicated that the germination rate of fenugreek seeds in NaCl solution with varying concentrations should be compared at the 5 % significance level for differences in NaCl doses, Ascorbic acid dosages, and NaCl x AsA interaction (Table 1).

The greatest germination rate was discovered at 0 mM NaCl with 94.25 %, and the lowest germination rate was identified at 150 mM NaCl with 70.75 %, when the average NaCl concentrations were tested.

The greatest germination rates were determined to be 91.25 % at 50 mM AsA and 90.75 % at 100 mM AsA, while the lowest germination rate was 76.25% at 0 mM AsA, according to an analysis of the average ascorbic acid dosages.

When the NaCl x AsA interaction was examined, the highest germination rate was determined as 98.00 % in the 0 mM x 50 mM and 0 mM x 100 mM interaction, and the lowest germination rate was 61.00 % in the 150 mM x 0 mM interaction.

Table 1 Ascorbic acid's effect on the rate of seed germination (%)*

NaCL /AsA	0 mM	50 mM	100 mM	150 mM	Means
0 mM	86.00 g	98.00 a	98.00 a	95.00 c	94.25 a
50 mM	82.00 h	97.00 b	93.00 e	91.00 f	90.75 b
100 mM	76.00 k	94.00 d	93.00 e	82.00 h	86.25 c
150 mM	61.00 m	76.00 k	79.00 i	67.00 l	70.75 d
Means	76.25 c	91.25 a	90.75 a	83.75 b	

LSD $_{NaCl}$: 3.161; LSD $_{AsA}$:2.391; LSD $_{Int.}$: 0.869; *There is no statistical ($p < 0.05$) differences between values with the same letters in the same colums.

3.2. Effect of Salicylic Acid on Germination Rate

The study demonstrated that, in terms of the germination rate of fenugreek seeds in various concentrations of NaCl solution, the differences between NaCl doses, Salicylic acid doses, and NaCl x SA interaction should be investigated at the 5% significant level (Table 2).

Table 2 Salicylic acid's impact on the rate of seed germination (%)*

NaCL /SA	0 mM	50 mM	100 mM	150 mM	Means
0 mM	91.00 c	96.00 a	96.00 a	79.00 g	90.50 a
50 mM	88.00 d	93.00 b	93.00 b	73.00 h	86.75 b
100 mM	81.00 f	86.00 e	85.00 e	64.00 k	79.00 c
150 mM	65.00 k	68.00 i	73.00 h	61.00 l	66.75 d
Means	81.25 c	85.75 b	86.75 a	69.25 d	

LSD $_{NaCl}$: 3,128; LSD $_{SA}$:0.873; LSD $_{Int.}$: 1,924; *There is no statistical ($p < 0.05$) differences between values with the same letters in the same colums.

The greatest germination rate was found to be 90.50% at 0 mM NaCl and the lowest germination rate was found to be 66.75 % at 150 mM NaCl when the average NaCl concentrations were tested.

The greatest germination rate was seen to be 86.75 percent in 100 mM salicylic acid (SA), while the lowest germination rate was discovered to be 69.25 percent in 150 mM SA when the average salicylic acid doses were evaluated.

The maximum germination rate was found to be 96.00 % in the 0 mM x 50 mM and 0 mM x 100 mM interaction when the NaCl x SA interaction was investigated, and the lowest germination rate was 61.00 % in the 150 mM x 150 mM interaction.

3.3. Effect of Wood Vinegar on Germination Rate

The study demonstrated that, in terms of the germination rate of fenugreek seeds in various concentrations of NaCl solution, the differences between NaCl doses, wood vinegar doses, and NaCl x WV interaction should be investigated at the 5 % significant level (Table 3).

The greatest germination rate was found to be 91.25 % at 0 mM NaCl and the lowest germination rate was found to be 64.25 % at 150 mM NaCl when the average NaCl concentrations were tested.

The greatest germination rate was seen to be 84.00 % in 0.10 % doses wood vinegar while the lowest germination rate was discovered to be 76.00 % in 0.15 % doses wood vinegar when the average salicylic acid doses were evaluated.

The maximum germination rate was found to be 95.00 % in the 0 mM x 0.10 % interaction was investigated, and the lowest germination rate was 61.00 % in the 150 mM x 0.15 % interaction.

Table 3 Wood vinegar's impact on the rate of seed germination (%)

NaCL /WV	Control	0.05 %	0.10 %	0.15 %	Means
0 mM	93.00 b	93.00 b	95.00 a	84.00 de	91.25 a
50 mM	85.00 d	90.00 c	91.00 c	83.00 e	87.25 b
100 mM	80.00 fg	79.00 gh	81.00 f	76.00 h	79.00 c
150 mM	62.00 lm	65.00 k	69.00 i	61.00 m	64.25 d
Means	80.00 c	81.75 b	84.00 a	76.00 d	

LSD $_{NaCl}$: 2,265; LSD $_{WV}$: 1,749; LSD $_{Int.}$: 1,282; *There is no statistical (p ‹0.05) differences between values with the same letters in the same colums.

3.4. Effect of Ascorbic Acid on Germination Time

According to the study, fenugreek seeds in NaCl solution with varying concentrations should have their germination times compared to NaCl doses, Ascorbic acid dosages, and the NaCl x AsA interaction investigated at the 5% significant level (Table 4).

The earliest germination time in 0 mM NaCl was 3.65 days, and the latest germination time in 150 mM NaCl was 5.13 days, according to an analysis of average NaCl concentrations.

Table 4 Ascorbic acid's effect on the germination time of seeds (days)*

NaCL /AsA	0 mM	50 mM	100 mM	150 mM	Means
0 mM	3.72 e	3.29 f	3.16 f	4.43 c	3.65 d
50 mM	4.36 cd	3.92 e	4.12 d	4.82 b	4.31 c
100 mM	4.88 b	4.36 cd	4.25 d	5.02 b	4.63 b
150 mM	4.92 b	5.08 b	4.96 b	5.55 a	5.13 a
Means	4.47 b	4.16 c	4.12 c	4.96 a	

LSD $_{NaCl}$: 0.263; LSD $_{AsA}$:0.286; LSD $_{Int.}$: 0.417; *There is no statistical (p ‹0.05) differences between values with the same letters in the same colums.

The study looked at the average ascorbic acid doses and found that the earliest germination time in 50 mM and 100 mM AsA was 4.12 days, while the longest germination time in 150 mM AsA was 4.96 days.

The earliest germination times in the 0 mM x 100 mM and 3.29 days in the 0 mM x 50 mM interactions were found when the NaCl x AsA interaction was investigated, while the latest germination time was 5.55 days in the 150 mM x 150 mM interaction.

3.5. Effect of Salicylic Acid on Germination Time

The results of the study indicated that the germination time of fenugreek seeds in NaCl solution with varying concentrations should be compared at the 5% significance level for differences in NaCl doses, Salicylic acid dosages, and NaCl x SA interaction (Table 5).

The earliest germination time was 3.73 days in 0 mM NaCl and the latest germination time was 5.19 days in 150 mM NaCl when the average NaCl concentrations were investigated. The earliest germination period was 4.19 days in 50 mM SA and the latest germination day was 5.00 days in 150 mM SA, according to an analysis of the average salicylic acid dosages.

After looking at the NaCl x SA interaction, it was found that the earliest germination times were 3.24 days for the 0 mM x 100 mM interaction, 3.36 days for the 0 mM x 50 mM interaction, and 5.42 days for the 150 mM x 150 mM interaction.

Table 5 Salicylic acid's effect on the germination period of seeds (days)*

NaCL /SA	0 mM	50 mM	100 mM	150 mM	Means
0 mM	3.86 g	3.36 h	3.24 h	4.46 e	3.73 d
50 mM	4.36 e	3.82 g	4.08 f	4.93 c	4.30 c
100 mM	4.81 cd	4.48 e	4.61 d	5.18 b	4.77 b
150 mM	4.98 c	5.11 b	5.24 b	5.42 a	5.19 a
Means	4.50 b	4.19 d	4.29 c	5.00 a	

LSD $_{NaCl}$: 0.242; LSD $_{SA}$:0.182; LSD $_{Int.}$: 0.166; *There is no statistical (p ‹0.05) differences between values with the same letters in the same colums.

3.6. Effect of Wood Vinegar on Germination Time

The study demonstrated that, in terms of the germination time of fenugreek seeds in various concentrations of NaCl solution, the differences between NaCl doses, wood vinegar doses, and NaCl x WV interaction should be investigated at the 5 % significant level (Table 6).

Table 6 Wood vinegar's effect on the germination period of seeds (days)*

NaCL /WV	Control	0.05 %	0.10 %	0.15 %	Means
0 mM	3.72 g	3.59 i	3.63 gh	4.71 de	3.91 d
50 mM	4.25 ef	4.02 f	4.23 ef	5.24 c	4.44 c
100 mM	4.74 de	4.81 d	4.90 d	5.36 b	4.95 b
150 mM	4.93 d	5.47 b	5.56 b	5.90 a	5.47 a
Means	4.41 c	4.47 b	4.51 b	5.30 a	

LSD $_{NaCl}$: 0,461; LSD $_{WV}$: 0,093; LSD $_{Int.}$: 0.248; *There is no statistical (p ‹0.05) differences between values with the same letters in the same colums.

The study looked at the average wood vinegar doses and found that the earliest germination time in 0 WV was 4.41 days, while the longest germination time in 0.15 % WV was 5.30 days.

The earliest germination times in the 0 mM x 0.05 % WV 3.59 days was found, while the latest germination time was 5.90 days in the 150 mM x 0.15 % WV interaction.

3.7. Effect of Ascorbic Acid on Root Length

According to the study, the variation in fenugreek seed root length in NaCl solution with varying concentrations between salt doses, Ascorbic acid doses, and the NaCl x AsA interaction should be investigated at the 5% significant level (Table 7).

Table 7 Ascorbic acid's impact on root length (cm)*

NaCL /AsA	0 mM	50 mM	100 mM	150 mM	Means
0 mM	2.09 de	2.53 a	2.42 b	2.18 c	2.31 a
50 mM	1.88 g	2.16 c	2.35bc	2.02ef	2.10 b
100 mM	1.39 k	1.96 fg	2.17 c	1.59 h	1.78 c
150 mM	0.72 m	1.50 i	1.86 g	1.24 l	1.33 d
Means	1.52 d	2.04 b	2.20 a	1.76 c	

LSD $_{NaCl}$: 0.195; LSD $_{AsA}$:0.148; LSD $_{Int.}$: 0.074; *There is no statistical (p ‹0.05) differences between values with the same letters in the same colums.

The longest root measured 2.31 cm in 0 mM NaCl and the shortest 1.33 cm in 150 mM NaCl when the average NaCl values were looked at. The greatest root length was 2.20 cm at 100 mM AsA, and the lowest root length was 1.52 cm at

0 mM AsA, according to an analysis of the average ascorbic acid dosages. The highest root length in the 0 mM x 50 mM interaction was found to be 2.53 cm when the NaCl x AsA interaction was studied, and the shortest root length was found to be 0.72 cm in the 150 mM x 0 mM interaction.

3.8. Effect of Salicylic Acid on Root Length

The investigation revealed that, when comparing the root length of fenugreek seeds in NaCl solution with varying concentrations, the differences in NaCl doses, Salicylic acid doses, and the NaCl x SA interaction analyzed at the 5% significant level (Table 8).

The longest root length measured when the average NaCl concentrations were looked at was 2.08 cm in 0 mM NaCl and the shortest root length measured 1.08 cm in 150 mM NaCl.

Table 8 Salicylic acid's impact on root length (cm)*

NaCL /SA	0 mM	50 mM	100 mM	150 mM	Means
0 mM	1.78 g	2.26 b	2.32 a	1.96 d	2.08 a
50 mM	1.54 k	1.91 e	2.11 c	1.83 f	1.85 b
100 mM	1.16mn	1.54 k	1.76gh	1.62 i	1.52 c
150 mM	0.78 p	1.07 o	1.27 l	1.19m	1.08 d
Means	1.32 d	1.70 b	1.87 a	1.65 c	

LSD_{NaCl}: 0.182; LSD_{SA}:0.159; $LSD_{Int.}$: 0.044; *There is no statistical ($p < 0.05$) differences between values with the same letters in the same colums.

Examining the typical salicylic acid doses, the longest root length measured 1.74 cm in 100 mM SA and the shortest 1.87 cm in 0 mM SA. The longest root length measured in the NaCl x SA interaction was 2.32 cm in the 0 mM x 100 mM interaction, while the shortest root length was 0.78 cm in the 150 mM x 0 mM interaction.

3.9. Effect of Wood Vinegar on Root Length

The investigation revealed that, when comparing the root length of fenugreek seeds in NaCl solution with varying concentrations, the differences in NaCl doses, wood vinegar doses, and the NaCl x WV interaction analyzed at the 5 % significant level (Table 9).

Table 9 Wood vinegar's impact on root length (cm)*

NaCL /WV	Control	0.05 %	0.10 %	0.15 %	Means
0 mM	2.11e	2.38 b	2.44 a	2.03 f	2.24 a
50 mM	1.75 i	2.17 d	2.27 c	1.92 g	2.03 b
100 mM	1.24 m	1.82 h	1.89 g	1.85gh	1.70 c
150 mM	0.91 0	1.21mn	1.42 k	1.34 l	1.22 d
Means	1.50 d	1.90 b	2.00 a	1.79 c	

LSD_{NaCl}: 0.162; LSD_{WV}:0.085; $LSD_{Int.}$: 0.051; *There is no statistical ($p < 0.05$) differences between values with the same letters in the same colums.

The longest root length measured when the average NaCl concentrations were looked at was 2.24 cm in 0 mM NaCl and the shortest root length measured 1.22 cm in 150 mM NaCl.

Examining the typical wood vanegar doses, the longest root length measured 2.00 cm in 0.10 % WV and the shortest 1.50cm in control WV. The longest root length measured in the NaCl x WV interaction was 2.44 cm in the 0 mM x 0.10 % WV interaction, while the shortest root length was 0.91cm in the 150 mM x 0 WV interaction.

3.10. Effect of Ascorbic Acid on Stem Length

According to the study, stem length of fenugreek seeds in NaCl solution with varying concentrations should be compared between NaCl doses, Ascorbic acid dosages, and the NaCl x AsA interaction at the 5 % significant level (Table 10).

Table 10 Ascorbic acid's effect on stem length (cm)*

NaCL /AsA	0 mM	50 mM	100 mM	150 mM	Means
0 mM	1.54 d	1.87 b	1.93 a	0.65 l	1.50 a
50 mM	1.32 e	1.74 c	1.71 c	0.57 m	1.34 b
100 mM	1.10 g	1.24 f	1.32 e	0.40 n	1.02 c
150 mM	0.94 h	0.84 i	0.77 k	0.25 o	0.70 d
Means	1.23 b	1.42 a	1.43 a	0.47 c	

LSD_{NaCl}: 0.141; LSD_{AsA}:0.089; $LSD_{Int.}$: 0.049; *There is no statistical (p ‹0.05) differences between values with the same letters in the same colums.

The largest stem length was 1.50 cm in 0 mM NaCl and the lowest stem length was 0.70 cm in 150 mM NaCl when the average NaCl concentrations were looked at. Upon analyzing the average ascorbic acid dosages, it was shown that the maximum stem length was 1.42 and 1.43 cm at 50 mM and 100 mM AsA, while the minimum stem length was 0.47 cm at 150 mM AsA. The largest stem length in the 0 mM x 100 mM interaction and the lowest stem length in the 150 mM x 150 mM interaction were found when the NaCl x AsA interaction was investigated. These values were 1.93 cm and 0.25 cm, respectively.

3.10. Effect of Salicylic Acid on Stem Length

The results of the study indicated that the stem length of fenugreek seeds in NaCl solution with varying concentrations should be compared across NaCl doses, Salicylic acid dosages, and the NaCl x SA interaction at the 5% significant level (Table 11).

Table 11 Salicylic acid's effect on stem length (cm)*

NaCL /SA	0 mM	50 mM	100 mM	150 mM	Means
0 mM	1.64 c	1.73 b	1.85 a	0.81 h	1.51 a
50 mM	1.12 f	1.64 c	1.65 c	0.69 l	1.28 b
100 mM	1.07fg	1.23 e	1.44 d	0.56 m	1.08 c
150 mM	0.82 h	0.78ik	0.73ik	0.32 n	0.66 d
Means	1.16 c	1.35 b	1.42 a	0.60 d	

LSD_{NaCl}: 0.116; LSD_{SA}:0.063; $LSD_{Int.}$: 0.057; *There is no statistical (p ‹0.05) differences between values with the same letters in the same colums.

The longest stem measured 1.51 cm in 0 mM NaCl and the shortest 0.81 cm in 150 mM NaCl when the average NaCl values were investigated. The highest stem length was 1.42 cm in 100 mM SA and the lowest stem length was 0.60 cm in 150 mM SA when the average salicylic acid dosages were investigated.

The largest stem length in the 0 mM x 100 mM interaction and the lowest stem length in the 150 mM x 150 mM interaction were found when the NaCl x SA interaction was investigated. These values were 1.85 cm and 0.32 cm, respectively.

3.11. Effect of Wood Vinegar on Stem Length

According to the study, stem length of fenugreek seeds in NaCl solution with varying concentrations should be compared between NaCl doses, dosages, and the NaCl x WV interaction at the 5% significant level (Table 12).

Table 12 Wood Vinegar's effect on stem length (cm)*

NaCL /WV	Control	0.05 %	0.10 %	0.15 %	Means
0 mM	1.74 d	1.96 b	2.01 a	0.86 k	1.64 a
50 mM	1.55 e	1.83 c	1.76 d	0.72 l	1.47 b
100 mM	1.28 g	1.38 f	1.55 e	0.58 m	1.20 c
150 mM	1.08 h	0.92 i	0.92 i	0.31 n	0.81 d
Means	1.41 c	1.53 b	1.56 a	0.62 d	

LSD $_{NaCl}$: 0.148; LSD $_{WV}$:0.024; LSD $_{Int.}$: 0.041; *There is no statistical ($p < 0.05$) differences between values with the same letters in the same colums.

The largest stem length was 1.64 cm in 0 mM NaCl and the lowest stem length was 0.81 cm in 150 mM NaCl when the average NaCl concentrations were looked at. Upon analyzing the average wood vinegar dosages, it was shown that the maximum stem length was 1.56 cm at 0.10 % WV, while the minimum stem length was 0.62 cm at 0.15 % WV.

The highest stem length in the 0 mM x 0.10 % WV interaction was found to be 2.01 cm when the NaCl x AsA interaction was studied, and the shortest root length was found to be 0.31 cm in the 150 mM x 0.15 % WV interaction.

4. Discussion

Apart from controlling the physiology of stress in plants, ascorbic acid (AsA) plays a crucial role in the germination phase (Arrigoni et al. 1997; Noctor and Foyer, 1998; Conklin, 2001). et al. (2006); Mohsen et al. (2013); Bassuony et al. (2008); The research outcomes of this study align with those of Erkoyuncu and Yorgancılar's (2020) investigation. In this study, rising SA concentrations in tandem with rising salt concentrations were found to have detrimental consequences on the criteria analyzed. According to Lee et al. (2010), salicylic acid promotes seed germination in high salt stress conditions by decreasing oxidative damage.

The results of this research are consistent with the literature, as demonstrated by Farahbakhsh (2012), Jam et al. (2012), Soliman et al. (2016), Ramanujam et al. (1998), Mendoza et al. (2002), Tari et al. (2002), El-Tayeb (2005), and Erkoyuncu and Yorgancılar (2020).

In the research conducted on the germination and development of tomato and pepper seeds, they reported that wood vinegar had little effect on the germination of seeds, and that wood vinegar at low concentrations (0.002% and 0.02%) increased root and shoot lengths (Luo et al., 2019).

5. Conclusion

This investigation revealed that higher salt concentrations had a detrimental impact on germination. Furthermore, in 50 mM and 100 mM AsA and SA treatments, high values were obtained for the stem length and root length criterion. It has been found that the optimal administration of AsA and SA can positively impact fenugreek plant germination in saline environments. In addition, 0.10 % dose of wood vinegar had a more positive effect than other application doses.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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