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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Effects of Different Nitrogenous Fertilizers and Potassium Doses on Yield, Yield Components, and Fruit Quality of Tomato Grown in Alkaline and Acidic Soils*

Farklı Azotlu Gübreler ve Potasyum Dozlarının Alkalin ve Asidik Topraklarda Yetiştirilen Domatesin Verim, Verim Unsurları ve Meyve Kalitesine Etkileri

Mahmoud NAZZAL[1*], Mehmet ZENGİN[2], Fatma GÖKMEN YILMAZ[3], Sait GEZGİN[4], Fırat UZUN[5]

Abstract

Different nitrogen fertilizers and potassium applications have an important impact on the yield and yield components and fruit-quality parameters of tomatoes in both alkaline and acidic reaction soils. This study investigated the effects of different nitrogenous fertilizers and potassium doses on the yield, yield components, and fruit quality of tomatoes grown on alkaline and acidic soils. The experiment was carried out in the research greenhouse of the Agriculture Faculty, at Selcuk University. It was performed by using two different soil types, three nitrogen fertilizers [ammonium sulfate (AS), ammonium sulfate with inhibitor (AS+inh.), and calcium nitrate (CaNit)], and three different concentrations of potassium sulfate (0, 240, and 480 mg K_2O kg^{-1}). We conducted the study by using a randomized experimental plot design with four replications. According to the research results, the highest fruit yield in alkaline soil was 'inh. AS and 480 mg K_2O kg^{-1}', while the highest fruit yield in acid soils was obtained with 'calcium nitrate and 240 mg K_2O kg^{-1}'. Furthermore, different nitrogen sources and potassium doses significantly affected tomato yield components such as stem diameter, plant height, number of fruits per plant, fruit weight, fruit diameter, fruit hardness, fruit pH, and Brix values. According to the results of the completed soil analysis, the applications demonstrated the importance of accurate and balanced fertilization for high-yield and quality tomato production in different soils. In conclusion, this study highlights the importance of selecting appropriate nitrogen fertilizers and potassium doses to increase tomato yield and yield components in alkaline and acidic soils. It provides valuable insights for tomato farmers and researchers seeking to improve tomato cultivation techniques in different soil conditions.

Keywords: Acidic and Alkaline soil, Fruit quality, Nitrogen, Potassium, Tomato, Yield

[1]***Sorumlu Yazar/Corresponding Author:** Mahmoud Nazzal, Selcuk University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Konya, Türkiye. E-mail: mahmutnazzal@gmail.com OrcID: 0000-0002-9399-773X

[2]Mehmet Zengin, Selcuk University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Konya, Türkiye. E-mail: mzengin@selcuk.edu.tr OrcID: 0000-0001-9330-0253

[3]Fatma Gökmen Yilmaz, Selcuk University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Konya, Türkiye. E-mail: fgokmen@selcuk.edu.tr OrcID: 0000-0001-8523-1825

[4]Sait Gezgin, Selcuk University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Konya, Türkiye. E-mail: sgezgin@selcuk.edu.tr OrcID: 0000-0002-3795-4575

[5]Fırat UZUN, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Konya, Türkiye. E-mail: firatuzun4225@gmail.com OrcID: 0000-0002-5389-0516

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Öz

Farklı azotlu gübreler ve potasyum uygulamaları, alkalin ve asidik reaksiyon topraklarda domatesin verim ve verim unsurları ile meyve kalite parametreleri üzerinde önemli bir etkiye sahiptir. Bu çalışmada, farklı azotlu gübreler ve potasyum dozlarının alkalin ve asidik topraklarda yetiştirilen oturak sofralık domatesin verim, verim unsurları ve meyve kalitesi üzerine etkileri araştırılmıştır. Deneme Selçuk Üniversitesi Ziraat Fakültesi araştırma serasında, iki farklı toprak, üç azotlu gübre [amonyum sülfat (AS), inhibitörlü amonyum sülfat (AS+inh.) ve kalsiyum nitrat (CaNit)] ve üç farklı potasyum dozu (0, 240 ve 480 mg K_2O kg^{-1}; potasyum sülfat) kullanılarak tesadüf parselleri deneme desenine göre dört tekerrürlü olarak yürütülmüştür. Araştırma sonuçlarına göre, alkalin toprakta en yüksek meyve verimi 'inh. AS ve 480 mg K_2O kg^{-1}' interaksiyonundan elde edilirken, asidik toprakta en yüksek meyve verimi 'kalsiyum nitrat ve 240 mg K_2O kg^{-1}' interaksiyonundan alınmıştır. Sonuç olarak, azotlu gübre ve potasyum dozlarının farklı uygulamalarının çeşitli toprak koşullarında domates üretimini artırabileceği ortaya konulmuştur. Ayrıca, farklı azot kaynakları ve potasyum dozları domatesin gövde çapı, bitki uzunluğu, bitki başına meyve sayısı, meyve ağırlığı, meyve çapı, meyve sertliği, meyve pH'sı ve briks değerleri gibi verim unsurlarını da istatistiksel olarak önemli düzeylerde etkilemiştir. Farklı azot kaynakları ve potasyum dozlarının verim ve verim unsurları üzerindeki etkilerinin istatistiksel olarak önemli olduğunu tespit edilmiş olup, yüksek kalitede domates yetiştiriciliği için doğru ve dengeli gübrelemenin önemini ortaya çıkarmaktadır. Sonuç olarak, bu çalışma alkali ve asidik topraklarda domates verimini ve verim unsurlarını artırmak için uygun azotlu gübre ve potasyum dozlarının belirlenmesinin gerektiğini açıklamaktadır. Farklı toprak koşullarında domates yetiştirme tekniklerini geliştirmek isteyen çiftçiler ile araştırmacılar için önemli bilgiler sağlanmıştır.

Anahtar Kelimeler: Alkalin ve asidik toprak, Azot, Domates, Meyve kalitesi, Potasyum, Verim

1. Introduction

Tomatoes (*Lycopersicon esculentum* Mill.) are a highly important vegetable worldwide, offering economic benefits and high yields due to their short growth period. They belong to the Solanaceae family, along with other vegetables like potatoes, peppers, and eggplants. Tomatoes, which are rich in vitamins, originated in Peru and were brought to Europe from Bolivia and Ecuador in the 16th century (Dam et al., 2005). Tomatoes are an important product in greenhouse vegetable cultivation and are highly nutritious. They contain important vitamins and minerals, including thiamine, vitamin A, niacin, ascorbic acid, phosphorus, potassium, calcium, sodium, and iron. According to Sainju et al. (2003), 100 grams of tomatoes contain 0.06 mg of thiamine, 900 IU of vitamin A, 0.7 mg of niacin, 23 mg ascorbic acid, 27 mg phosphorus, 244 mg potassium, 13 mg calcium, 3 mg sodium, and 0.5 mg iron. Nitrogen is an essential nutrient for plants, promoting vegetative growth while reducing generative growth. It is therefore essential to maintain a balanced nitrogen-to-potassium (N/K) ratio in plant tissues. The ideal N/K ratio in leaves is between 1.2 and 1.8, according to Campbell (2000). Potassium is the most important cation in plant physiology in terms of quantity and physiological and biochemical functions (Leigh and Wyn Jones, 1984). Tomato fruits have a high uptake of potassium (K^+) from the soil, especially during the fruit growth period (Huett and Dettmann, 1988). Ideal soils for growing tomatoes are low- to medium-calcareous, salt-free, loamy, and rich in macro- and micronutrients. They should be deep, permeable, and dark in color, especially alluvial soils (Zengin and Özbahçe, 2011). Ceylan et al. (2001) studied the effects of different doses of ammonium nitrate and urea fertilizer on tomato N uptake and accumulation under field conditions. When applying 360 kg N ha^{-1}, they observed the highest levels of nitrate-N and nitrite-N in leaves and fruits during the 1st and 2nd harvests. Furthermore, ammonium nitrate applied resulted in higher nitrate and nitrite accumulation compared to urea applied. Applying 240 kg N ha^{-1} resulted in the highest yield. The effect of two different fertilizer sources as 20-20-0 (0, 1, 1.5 and 2 kg/ha) and Leonardite (0, 2.5, 5 and 7.5 kg/ha) were applied to tomato plants. According to the results of the study, the differences between fertilizer applications were statistically significant in tomato plant stem height, root length, shoot and root fresh weight, shoot and root dry weight and number of leaves (Demirkiran et al., 2012). Reboucas et al. (2015) examined how calcium nitrate, ammonium sulfate, urea, and different amounts of nitrogen (0, 140, 280, and 420 kg N ha^{-1}) affected the quality of tomatoes. They found that increasing nitrogen doses led to a decrease in fruit acidity, while fruit pH and brix values remained unaffected. The type of fertilizer used had different effects. Researchers found that nitrogen fertilizers positively affected the yield components, and they recommended applying nitrate and ammonium to improve quality. In a sandy soil experiment in Cairo, Egypt, Awaad et al. (2016) conducted a study to evaluate the effects of different N sources, including slow-release (urea-formaldehyde) and rapid-release (urea) N, on lettuce yield. The results showed that the application of nitrogen alone or in combination with potassium sulfate resulted in the highest fresh dry weight per plant and total lettuce yield per hectare compared with the control. The combination of urea and potassium sulfate resulted in the highest fresh dry weight per plant. The lettuce plants had the highest contents of P, K, Zn, and Mn when the combination of urea and potassium sulfate was used, while the highest contents of N and Fe were observed with urea fertilizer alone. The lowest nitrate levels were observed with urea alone or urea+potassium sulfate in combination. The highest protein content in the plants was also induced by the combination of urea and potassium sulfate. The study demonstrated that urea-formaldehyde slow-release nitrogen fertilizer significantly improved lettuce yield and quality on sandy soils. Natlia et al. (2018) investigated the effect of nitrogen sources and doses on tomato fruit's nutritional quality. A commercial hybrid tomato (Dominador) was grown in four replications. The treatments included nitrogen fertilizer dosages of 50 and 200 mg L^{-1} with a combination of four sources (urea, ammonium sulfate, ammonium nitrate, and calcium nitrate). The results indicated that the application of urea and ammonium nitrate led to increased pH levels in the tomato fruits. The contents of potassium, lycopene, and carotenoids did not appear to be significantly different depending on the sources and doses of nitrogen used. The study concluded that nitrogen fertilizer sources and doses have a significant impact on the nutritional quality of tomato fruit, affecting some parameters such as brix, pH, titratable acidity, and sodium content. The effects of different levels of potassium and zinc fertilization on the yield and the yield components of the artichoke were studied in the research. Different levels of potassium were applied, including 0, 6, 12, and 18 kg K_2O da^{-1}; K_2SO_4; and 50% K_2O. The results showed that the highest artichoke yield (8.972 kg da^{-1}) was obtained with the application of 18 kg K_2O da^{-1} (Öztürk et al., 2020).

About 80% of the agricultural land in Türkiye has calcareous alkaline soils, while the rest has acidic soils. The effects of different doses of potassium combined with nitrogenous fertilizers such as AS, inh. AS, and CaNit on tomato production in these soils have been the subject of very little scientific research. The study aimed to investigate the effect of different doses of potassium combined with nitrogen fertilizers on the yield, yield components, and fruit quality of tomato plants. The experiment utilized two types of soil: Konya soil with an alkaline pH and Nevşehir soil with an acidic pH.

2. Materials and Methods

The study was conducted in the greenhouse and laboratory of the Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Selcuk University, Konya. Fidesan Vegetable Company's Mirsini tomato variety was used as the study plant material. Chemical and physical analysis of the soil samples were carried out before the experiment began using the following methods: pH (pH meter with a glass electrode in a mixture of soil: pure water in a ratio of 1:2.5, Richard; 1954), EC (measured in a 1:5 soil: distilled water solution with an EC meter, Bayraklı; 1987), lime (total $CaCO_3$, by the Scheibler Calcimeter, Çağlar; 1949), organic matter (by the Smith-Weldon method, Bayraklı; 1987), texture (Bouyoucos, 1951), inorganic N (NH_4-N + NO_3-N, by the Kjeldahl method, Bremner; 1965), available P (Olsen et al., 1954), extractable K, Ca, Mg, and Na (with 1 N ammonium acetate, pH = 7.0, Jackson (1965), determining by the ICP-AES Varian-Vista device, and the available trace elements Fe, Zn, Mn, and Cu (Lindsay and Norwell, 1978), and reading by the ICP-AES, Soltanpour et al.; 1979), and B micronutrient (in the 0.01 M $CaCl_2$ + 0.01 M mannitol solution extract with the ICP-AES, Soltanpour et al.; 1979, Cartwright et al.; 1983).

According to the analysis results of the two different soil samples (Table 1), the soil from the Selcuk University campus land in Konya City has a slightly alkaline pH of 7.74. It is salt-free and has an excess of lime. The soil is low in organic matter and has a loamy texture. It is deficient in nutrients such as nitrogen (N), potassium (K), magnesium (Mg), iron (Fe), manganese (Mn), and boron (B). However, it has sufficient levels of phosphorus (P), zinc (Zn), and copper (Cu) and high levels of calcium (Ca). The other soil of Nevşehir province has a slightly acidic pH of 5.50. It is also salt-free but has low calcium content. The soil is low in organic matter and has a sandy texture. It is deficient in nutrients such as nitrogen (N), calcium (Ca), magnesium (Mg), and zinc (Zn). However, it has sufficient levels of potassium (K), manganese (Mn), boron (B), and copper (Cu), as well as high levels of phosphorus (P) and iron (Fe) (Table 1). In summary, the soils of Konya and Nevşehir have different pH values and textures. The Konya soil is alkaline with a loamy texture, while the Nevşehir soil is acidic with a sandy texture. Both soils are poor in various nutrients but also have sufficient or high levels of certain nutrients.

Table 1. Some physical and chemical analysis results of the soil samples

Parameters	Results	Results	Parameters	Results	Results
Parameters	**Alkaline (Konya)**	**Acidic (Nevşehir)**	**Parameters**	**Alkaline (Konya)**	**Acidic (Nevşehir)**
pH (1:2.5 soil: water)	7.74 (Slightly alkaline)	5.50 (Slightly acidic)	Extracted K (mg kg^{-1})	86 (Low) (0.22 me 100 g^{-1})	214 (Adequate) (0.55 me 100 g^{-1})
EC (1:5 soil: water, µS cm^{-1})	74 (Saltless)	71 (Saltless)	Extracted Ca (mg kg^{-1})	4.910 (Much) (24.55 me 100 g^{-1})	621 (Low) (3.10 me 100 g^{-1})
Lime (%)	30.6 (Too much)	0.3 (Low)	Extracted Mg (mg kg^{-1})	131 (Low) (1.09 me 100 g^{-1})	100 (Low) (0.83 me 100 g^{-1})
Org. matter (%)	0.7 (Very low)	0.7 (Very low)	Extracted Na (mg kg^{-1})	20.4 (0.09 me 100 g^{-1})	12.0 (0.05 me 100 g^{-1})
Clay (%)	22.6	9.6	Extractable Sodium Percent	0.34 (Good)	1.10 (Good)
Silt (%)	32.0	3.7	Available Fe (mg kg^{-1})	1.33 (Low)	31 (Much)
Sand (%)	45.4	86.7	Available Zn (mg kg^{-1})	1.10 (Adequate)	0.46 (Low)
Texture class	Loamy	Sandy	Available Mn (mg kg^{-1})	1.52 (Low)	13 (Adequate)
Inorg. N (NH_4-N+ NO_3N) (mg kg^{-1})	2.6 (Very low)	10.9 (Low)	Available B (mg kg^{-1})	0.02 (Low)	0.72 (Adequate)
Available P (mg kg^{-1})	8.1 (Adequate)	34 (Much)	Available Cu (mg kg^{-1})	1.34 (Adequate)	0.28 (Adequate)

Table 2. The ratio of the extractable cations to each other

Rates	Results		Ideal	Resolutions	
	Konya	Nevşehir		Konya	Nevşehir
Ca:K	111.6	5.6	12	Give K	Give Ca
Ca:Mg	22.5	3.7	6	Give Mg	Give Ca
Mg:K	4.9	1.5	2	Give K	Give Mg

In the study, we used ammonium sulfate (AS), inhibited ammonium sulphate (AS+inh.; of DOĞATECH company, the fertilizer contents as shown in *Table 3*), and calcium nitrate (CaNit) as sources of nitrogen fertilizer. These fertilizers contain different percentages of nitrogen, with AS and inh. AS both containing 21% N and CaNit containing 15.5% N and 26% CaO. The study supplied potassium sulfate as the potassium source, which provided 51% K_2O. We used triple super phosphate (TSP) with a phosphorus content of 43-45% P_2O_5 for fertilization. Finally, we used Etidot-67 as the source of boron, which contains 20.8% of boron.

Table 3. The source of inhibited ammonium sulphate (AS+inh.): DOĞATECH Stable N-21 and the guaranteed content of this fertilizer according to the following table

Guaranteed Ingredients	(W/W) %
Total Nitrogen (N)	21
Ammonium Nitrogen (NH4-N)	21
Water soluble Sulfur Trioxide (SO_3)	60
Ammonium Inhibitor (DMPB)	0.25

Source: *dogatech.com.tr*

The experiment was conducted in the research greenhouse of the Soil Science and Plant Nutrition Department, Faculty of Agriculture, Selcuk University. The greenhouse was well-ventilated, with the temperature maintained at 25±3 ºC, solar radiation at 1750±50 kcal m^{-2}, and relative humidity around 60±10%. We used a randomized experimental pot design with four replications, filling the pots with 5 kg of oven-dried soil sieved to 4 mm. Totally 500 mg N kg^{-1} was applied into pot soil as ammonium sulfate (AS), inhibited ammonium sulfate (AS+inh.), and calcium nitrate (CaNit) fertilizer. Of this 250 mg N kg^{-1} at the base of the soil during seedling planting and another 250 mg N kg^{-1} at the top of the soil during the fruit ripening period, was given. For potassium doses, half of the 0, 240, and 480 mg K kg^{-1} was applied at the base during seedling planting, while the other half was given at the top during fruit ripening by the potassium sulfate (PS). According to the results of the soil analysis, the phosphorus and boron fertilizers, which contain deficient nutrients, were applied to the soil as a solution before planting. At transplanting, we supplemented the P levels in all pots to 60 mg P kg^{-1} using TSP fertilizer (45% P_2O_5). While the Konya soil is poor in boron, the Nevşehir soil has sufficient boron. At transplanting, we added Etidot-67 fertilizer as a solution at a rate of 1.5 mg B kg^{-1} into each pot, serving as an alkaline fertilizer for 36 pots of Konya soil. We planted one tomato seedling in each pot and immediately watered them. Depending on weather conditions, irrigation with pure water was carried out at a measured rate, and maintenance activities such as spraying, and grass removal were done as necessary.

The harvest: There were four harvests, the first being 65 days after planting. Tomatoes were picked when they turned red. At the end of the harvesting process, the following measurements were carried out on samples of tomato fruit and plants: In the experiment, the fruits in the pots were weighed after 4 different harvests and the total yield per pot was determined as (g pot^{-1}). Plant stem diameter (thickness): The stem of each plant in each pot was measured 5 cm above the soil and in one direction with a caliper, and the stem diameter (mm) was recorded. Plant height: A meter was used to measure the length (cm) of the plant in each pot. Number of fruits per plant: The number of fruits per plant was determined by taking the arithmetic mean and counting the fruits in each pot until the end of the harvest. Fruit diameter: The diameters of the fruits taken from each pot at each harvest were measured with calipers, and the average fruit diameter (mm) was determined by taking the arithmetic mean. Fruit weight: The average fruit weight (g) was determined by weighing the fruits taken from each pot at each harvest and taking the arithmetic mean. Fruit hardness: The peel hardness (kg cm^{-2}) of the fruits taken from each pot was calculated by measuring around the equatorial plane and outside the carpel wall with a flat-tipped hand penetrometer (Bayraktar, 1970). Fruit pH: The pH of the pulped fruit samples in the laboratory was measured directly with a pH meter without dilution and recorded. Water-soluble dry matter (brix) in fruit: The water-soluble dry matter content (%) was determined three times by taking a teaspoon of the pulped fruit sample in the laboratory, filtering it through filter paper, and dropping a drop of the obtained sample on the prism of the refractometer, and the average result was expressed as % brix (Cemeroğlu, 1992).

Statistical analyses of the yield and yield components and some fruit-quality parameter values obtained as a result of the treatments were evaluated by the randomized plots experimental design and submitted to variance analysis with the MINITAB software.

3. Results and Discussion

This study aimed to investigate different sources of nitrogen and the effect of potassium dosage on tomato yield and yield components in both alkaline and acid soils.

3.1. Effects of different nitrogen sources and potassium doses on yield and yield components of tomato grown in alkaline and acidic soils

3.1.1. The tomato yields

The interaction between the application of nitrogen fertilizer and potassium dosage showed a statistically significant effect (at a 1% level) on tomato production in both alkaline and acidic soils. *Table 4* provides the values and Duncan groups of the treatments' effect on tomato production per pot. *Figure 1* shows that in alkaline soil, the lowest yield (334.10 g pot^{-1}) was obtained from the inh. AS control treatment and the highest yield (549.00 g pot^{-1}) from the 'inh. AS x K_{480}' interaction. Similarly, when considering nitrogen fertilizer in alkaline soil, the highest tomato yield (520.70 g pot^{-1}) was obtained with AS fertilizer (*Table 4*), and tomato yield increased with increasing potassium doses from 0 mg K_2O kg^{-1} dose to 480 mg K_2O kg^{-1} dose. On the other hand, in acidic soil, the lowest yield (408.80 g pot^{-1}) was obtained in the CaNit control treatment, and the highest yield (747.70 g pot^{-1}) was obtained in the 'CaNit x K_{240}' interaction (*Figure 1*). Moreover, considering nitrogen fertilizers, the highest tomato yield (656.00 g pot^{-1}) was found in the inh. AS fertilizer application, and the highest yield (683.90 g pot^{-1}) was found in 240 mg K_2O kg^{-1} dose application as average yield results to different potassium doses (*Table 4*).

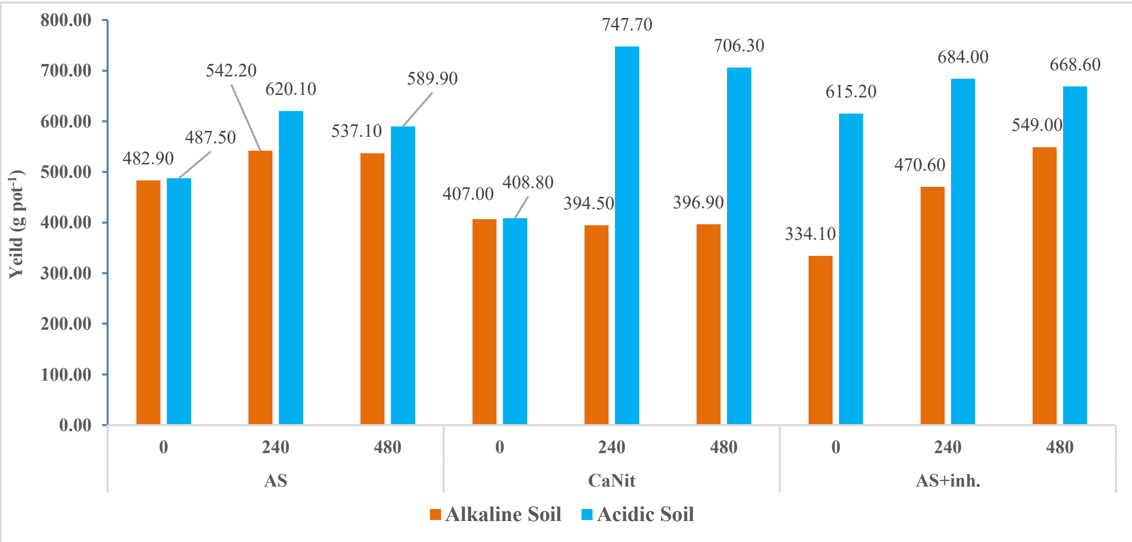


Figure 1. Effects of nitrogenous sources and potassium doses on tomato yield in alkaline and acidic soils

The AS fertilizer is acidic. As a result, it can be easily used in both neutral and calcareous alkaline soils. In the control application of AS+inh. in alkaline soils, because the plant was not able to utilize the slow-release nitrogen effectively, there was an absence of potassium, and these nutrients in the soil were not sufficient for normal plant growth. As expected, fruit weight and, consequently, yield per pot remained low due to poor plant nutrition. In acidic soils, AS+inh. provides nitrogen in a plant-absorbable form for an extended period. Plants slowly and regularly absorb it in a balanced way, without any loss. Fertilizers that include nitrogen in the form of ammonium contain nitrification inhibitors. Their function is to reduce the loss of nitrogen from soils through leaching and denitrification. Additionally, they assist in improving the efficiency of NH_4^+ ions by maintaining soil pH for a long period. The optimal yield was obtained in acidic soils with low calcium levels through 500 mg N kg^{-1}, 840 mg CaO kg^{-1} with CaNit fertilizer, and 240 mg K_2O kg^{-1} with potassium fertilizer. As the nutrient balance of the plant is more optimal with this treatment than with other treatments, fruit weight is increased with this application, and, as a result, higher tomato yields were obtained. In the acidic soil, N, and Ca are low, and K is at a medium level. In terms of K/Ca/Mg balance, K and Mg are required for alkaline soil, while Ca and Mg are required for acidic soil. Ca supplied with CaNit and K supplied with potassium sulfate to the acidic soil may have provided a favorable balance for more optimum growth of the plant. According to Zengin et al. (2009), growing sugar beet by adding increasing amounts of K and Mg into soils that were similar but had an imbalanced Ca/K and Mg/K balance showed that adding potassium increased the yield and quality of the sugar beet. The results of our study about the weight of fruit in tomatoes correspond closely with the results of some researchers. Karaman and Brohi (1996) demonstrated that using 320 kg N ha^{-1} of ammonium nitrate (AN) fertilizer in colluvial soil resulted in the highest tomato production (46.650 kg ha^{-1}). Kotsiras et al. (2005) reached the highest cucumber production by using a ratio of NO_3:NH_4 at 100:0. In their study, Ashraf et al. (2008) found that the combination of calcium and diammonium phosphate-DAP (200 kg N ha^{-1} +100 kg P_2O_5 ha^{-1}) fertilizers, together with an interaction of 150 mg K kg^{-1}, resulted in a maximum sugarcane yield of 7,320.00 kg ha^{-1}. They also noticed that CaNit fertilizer performed better than urea. In their study, Souri and Dehnavard (2017) investigated the impact of several nitrogen fertilizers (AS, urea, and CaNit) on the nutritional content of tomato leaves and the quality of the fruit. They found that the application of CaNit resulted in the maximum yield of fruit. Since AS fertilizer is an acid fertilizer, it can be easily used in neutral and calcareous alkaline soils. Altıntaş (2017) reported that the highest total productivity, early production, and marketable fruits were obtained for tomato plants in the application of K/N: K/N= 2.5; 110 mg L^{-1} N and 275 mg L^{-1} K).

3.1.2. Stem diameter

The interaction between the 'nitrogen fertilizer and potassium dosage' had a statistically significant (1%) effect on tomato stem diameter in acidic soil. However, in alkaline soil, this interaction never had a statistically significant effect on the stem diameter. The data and Duncan groups related to the impact of treatments on stem diameter are shown in *Table 4*. The statistical analysis in *Table 4* shows that the interaction between 'nitrogen fertilizer and potassium dosage' did not have an important effect on stem diameter in the alkaline soil. The application of various nitrogen fertilizers to the soil resulted in the highest stem diameter (12.08 mm) when AS fertilizer was used. When different potassium dosages were applied, the control treatment produced the highest stem diameter of 11.58 mm. Conversely, the 'AS x K_{240}' interaction led to the lowest stem diameter of 12.33 mm, while the 'CaNit x K_0' interaction resulted in the highest stem diameter of 14.67 mm in the acidic soil (*Figure 2*). Plants have a higher and more rapid uptake of nitrate in acidic pH conditions. Furthermore, the *Table 4* indicates that CaNit fertilizer resulted in the greatest average stem diameter (13.83 mm) when used, while AS+inh. fertilizer had the second-highest stem diameter (13.42 mm).

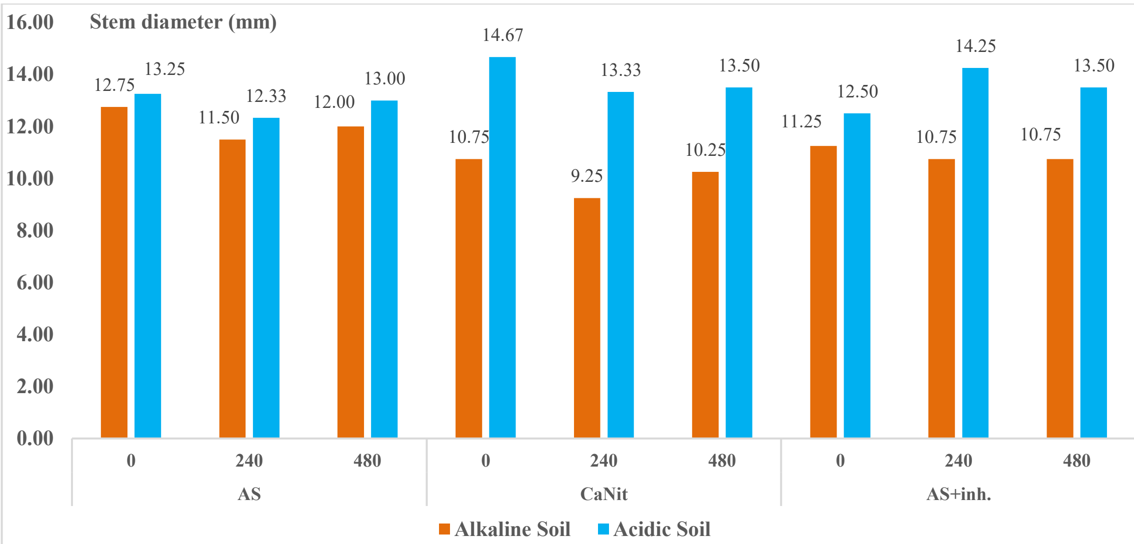


Figure 2. Effects of nitrogenous sources and potassium doses on the stem diameter of tomato in alkaline and acidic soils

Due to high Ca in alkaline soil, the Ca/K/Mg balance may have been upset, and Ca application with CaNit may have resulted in low stem diameter due to insufficient nutrient supply of K and Mg to the plant. According to Haby (1990), for ideal plant growth, Ca:Mg is 6.5:1, Ca:K 13:1 and Mg:K 2:1 (*Table 2*). The study showed that CaNit fertilizer resulted in the highest stem diameter in calcium-poor acidic soil with 500 mg N kg^{-1} and 840 mg CaO kg^{-1}, due to the optimal nutrient balance of the plant. The acidic soil had low levels of N and Ca and moderate levels of K and Mg. The CaNit fertilizer may have provided a favorable balance for optimal plant growth. The results are similar to previous research, such as the study of Ashraf et al. (2008) on sugarcane plants using CaNit and urea fertilizers, which reported that CaNit gave better results than urea. Demirkiran et al. (2012) found that 20-20-0 and leonardite, two different nitrogen sources, did not have a statistically significant effect on the diameter of tomato stems in neutral soil (pH: 6.8).

3.1.3. Plant height

The relationship between 'nitrogen fertilizer x potassium dose' showed a statistically significant (1%) impact on tomato plant height in soils with alkaline and acidic reactions. The *Table 4* shows that the treatment effects on plant height and Duncan groups. The *Figure 3* shows that the control treatments of AS and inh. AS had the lowest plant height, at 49.50 cm and 51.00 cm, respectively. On the other hand, the 'CaNit x K_{240}' interaction had the highest plant height, at 77.25 cm. In contrast, in the acidic soil, the 'CaNit x K_0' interaction resulted in the lowest plant height of 63.00 cm, while the 'CaNit x K_{240}' interaction led to the highest plant height of 76.00 cm.

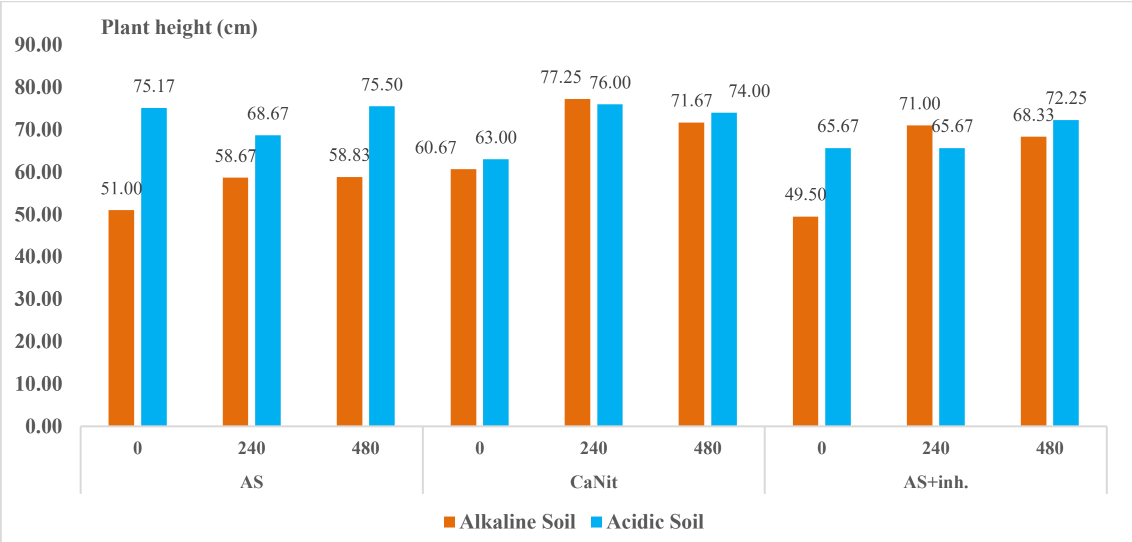


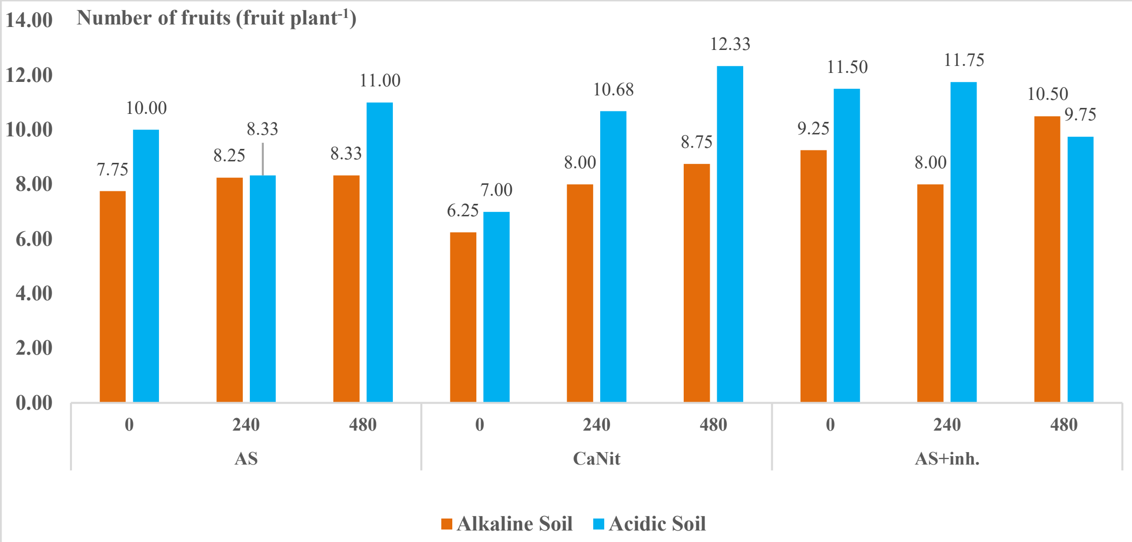
Figure 3. Effects of nitrogenous sources and potassium doses on the plant height of tomato in alkaline and acidic soils

Armstrong (1998) found that the effect of NO_3-N on tomato plant growth was higher than that of NH_4-N. Our results on plant height in tomatoes are similar to the results of some researchers. Souri and Dehnavard (2017) applied AS, CaNit, and urea to tomatoes and obtained the highest plant height from CaNit. Ashraf et al. (2008) applied CaNit and urea fertilizers and a 150 mg K kg^{-1} dose to sugarcane and reported that CaNit gave better results than urea on plant height. Çolpan et al. (2013) obtained the lowest plant height (173.05 cm) at 40 kg K_2O ha^{-1} dose and the highest plant height (181.81 cm) at 160 kg K_2O da^{-1} dose.

3.1.4. Number of fruits

The interaction between nitrogen fertilizer application and potassium dosage had a statistically significant (1%) effect on the number of fruits of tomato plants grown on both alkaline and acidic soils. The values and Duncan groups for the effect of the treatments on the number of fruits in the plant are given in *Table 4*. The CaNit control treatment caused the lowest number of fruits (6.25 pcs $plant^{-1}$), while the 'inh. AS x K_{480}' interaction provided the highest number of fruits (10.50 pcs $plant^{-1}$), as the *Figure 4* shows. The application of inh. AS nitrogen fertilizers to alkaline soil resulted in the highest average number of fruits (9.25 pcs $plant^{-1}$). However, in the acidic soil, the 'CaNit x K_0' interaction caused the lowest fruit number (7.00 pcs $plant^{-1}$), while the 'inh. AS x K_{240}' interaction yielded the highest number of fruits at (11.75 pcs $plant^{-1}$). The number of fruits in the acidic soil had a positive correlation with the increasing rates of potassium, varying from 0-480 mg K_2O kg^{-1}.

The number of fruits in the plant is an important factor in yield and provides an effect on the total tomato production, together with the weight of the fruits. According to Javaria et al. (2012), Potassium application significantly increased number of flowers/plant, fruit set rate, fruit/plant and yield/ha. As a result, they need more potassium fertilization. The study showed that optimum fruit production was obtained with 500 mg N kg^{-1}, 840 mg CaO kg^{-1} with CaNit fertilizer, and 480 mg K_2O kg^{-1} with potassium fertilizer in calcium-deficient acidic soil. The Ca was supplied by CaNit and the K was supplied by potassium sulfate to the acid soil may have provided a favorable balance for optimum plant development. Our results for tomato fruit numbers are similar to those of some researchers. Karaman and Brohi (1996) found the highest number of tomato fruits at a 320 kg N da^{-1} dose of AN fertilizer in colluvial soils. Jung et al. (1994) found the highest number of tomato fruits at a NO_3:NH_4 ratio of 10:0. In other words, nitrate nitrogen increased the number of fruits more than ammonium. In our study, CaNit had



a higher fruit number than other nitrogen fertilizers. Similarly, Gelmez and Müftüoğlu, (2018) they found that the use of AN fertilizer increased the number of fruits of tomato plants.

Figure 4. Effects of nitrogenous sources and potassium doses on the fruit number of tomatoes in alkaline and acidic soils

3.1.5. Fruit diameter

The interaction between the application of nitrogen fertilizer and potassium dosage had a statistically significant (1%) impact on the fruit diameter of tomato plants in both alkaline and acidic soils. The values and Duncan groups of the effects of treatments on fruit diameter are given in *Table 4*. The results show that the 'AS x K_{480}' treatment released the lowest fruit diameter (53.59 mm), whereas the 'CaNit x K_0' interaction obtained the largest fruit diameter (60.64 mm; *Figure* 5) offers this relationship. In contrast, in the acidic soil, the smallest fruit diameter (52.89 mm) was seen in the 'AS x K_{240}' combination, while the largest fruit diameter (59.43 mm) occurred in the 'inh. AS x K_0' combination.

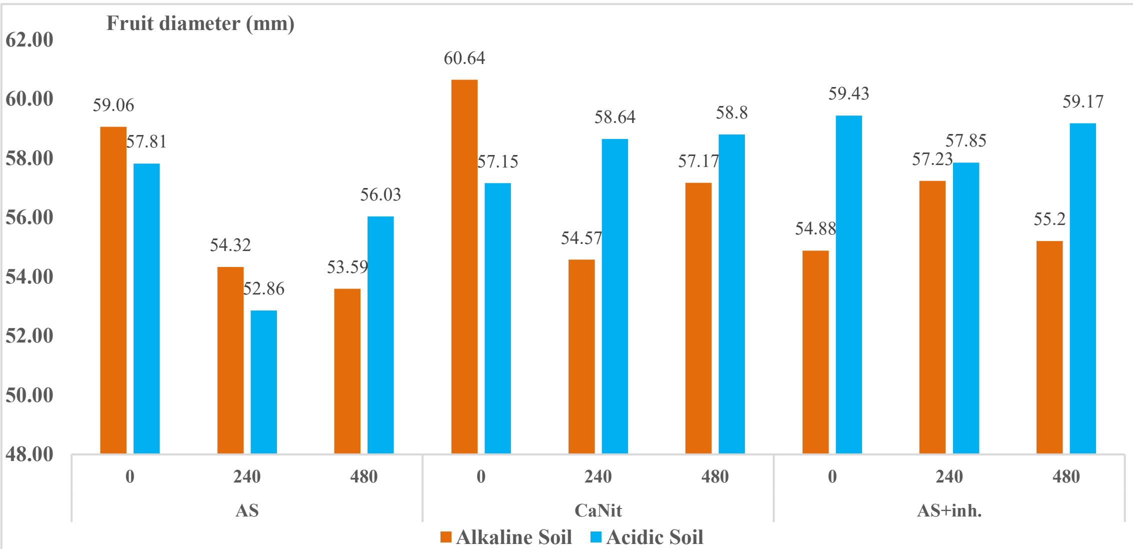


Figure 5. Effects of nitrogenous sources and potassium doses on the fruit diameter of tomato in alkaline and acidic soils

The results of our study about the fruit diameter in tomatoes correspond significantly with the results of some researchers. According to Yağmur et al. (2004), the application of potassium at various dosages (0, 120, 240, and 360 kg K_2O ha^{-1}) resulted in a variety of fruit diameters for tomato plants, weighing between 59.2 and 61.6 mm. Kotsiras et al. (2005) obtained the highest cucumber fruit diameter by applying a NO_3:NH_4 ratio of 100:0. In their study, Woldemariam et al. (2018) observed that the tomato plants showed the largest fruit diameter when treated with a dose of 150 kg K_2O ha^{-1}. At a dose of 200 kg K_2O ha^{-1}, the tomato plants showed the second-highest fruit diameter, whereas the absence of K_2O application resulted in the smallest fruit diameter.

3.1.5. Average fruit weight

The interaction between 'nitrogen fertilizer and potassium dosage' didn't have a statistically significant effect on the average fruit weight of tomatoes in the soil with alkaline pH. The interaction between the nitrogen fertilizer and potassium dosage in acidic soil had a statistically significant (1%) effect on the average weight of tomato fruits. *Table 4* provides the values and Duncan groups for the impact of treatments on average fruit weight.

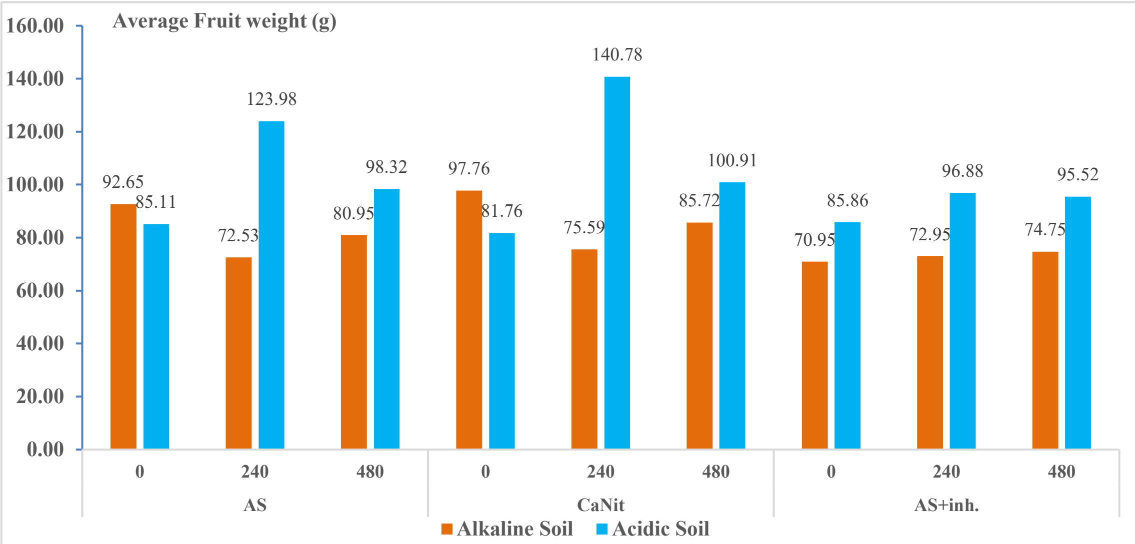


Figure 6. Effects of nitrogenous sources and potassium doses on the average fruit weight of tomato in alkaline and acidic soils

According to the data shown in *Figure 6*, the effect of the interaction between nitrogen fertilizer and potassium dosage on fruit weight was not statistically significant in the alkaline soil condition. The average results of nitrogen fertilizers indicate that the CaNit fertilizer gave the largest fruit weight of 86.35 g, while the second highest fruit weight of 82.04 g resulted from the application of AS fertilizer. The control dosage yielded the largest fruit weight (87.12 g) based on the average results of potassium doses. At the same time, the 'CaNit x K_0' interaction resulted in the lowest fruit weight of 81.76 g, while the 'CaNit x K_{240}' interaction resulted in the largest fruit weight of 140.78 g in acidic soil. The CaNit fertilizer provided the largest fruit weight (107.82 g) based on the average results of various nitrogen fertilizers. Similarly, the K_{240} dosage resulted in the highest fruit weight (120.55 g) based on the average results of different potassium doses (*Table 4*).

Fruit weight remained low due to poor nutrition as the plant had difficulty utilizing the slow-release nitrogen in the inh. AS control treatment was not efficient, and potassium was not fertilized, resulting in insufficient nutrients for normal plant growth. The study found that the highest average fruit weight was obtained with 500 mg N kg^{-1}, 840 mg CaO kg^{-1} with CaNit fertilizer, and 240 mg K_2O kg^{-1} with potassium fertilizer in calcium-deficient acid soils. This was due to the optimum nutrient balance of the plant. The study also showed that K and Mg are necessary for the alkaline soil of Konya, while Ca and Mg are necessary for the acidic soil. The balanced nutritional requirements of Ca and K may have contributed to optimal plant development. Zengin et al. (2009) also reported an increase in sugar beet yield and quality with potassium applications. Our results on fruit weight in tomatoes are like the findings of some researchers. Karaman and Brohi (1996) obtained the highest tomato fruit weight from a 320 kg N ha^{-1} dose of AN fertilizer in colluvial soil. Kotsiras et al. (2005) obtained the highest cucumber fruit weight from the NO_3:NH_4 ratio (100:0). Gelmez and Müftüoğlu, (2018) they found that the use of AN fertilizer increased the number of fruits of tomato plants.

3.2. Effect of Different Nitrogenous Sources and Potassium Doses on Some Fruit Quality of Tomato Plants Grown in Alkaline and Acidic Soils

3.2.1. Fruit hardness

The interaction between the application of nitrogen fertilizer and potassium dosage showed a statistically significant effect (1%) on the fruit hardness in both alkaline and acidic soils. *Table 5* provides the values and Duncan groups that related to the effect of treatments on fruit hardness. In the alkaline soil, the 'AS x K_0' application released the lowest fruit hardness (2.82 kg cm^{-2}), whereas the 'CaNit x K_0' interaction caused the

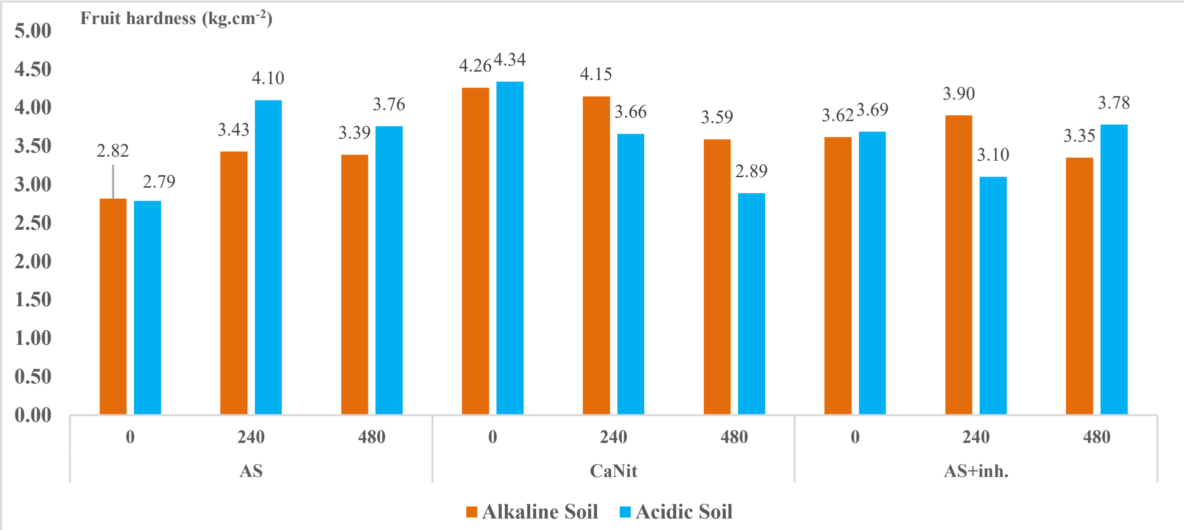


Figure 7. Effects of different nitrogenous sources and potassium doses on the fruit hardness of tomato plants grown in alkaline and acidic soils

highest fruit hardness (4.26 kg cm^{-2}; *Figure 7*). The CaNit fertilizer provided the highest fruit hardness (4.00 kg cm^{-2}) based on the average results of nitrogen fertilizers in the alkaline soil. When applying a potassium dosage of 240 mg K_2O kg^{-1}, the fruit hardness reached the highest value of (3.83 kg cm^{-2}), based on the average values. Conversely, the control treatment with AS led to the lowest fruit hardness at 2.79 kg cm^{-2}, while the 'CaNit x K_0' interaction resulted in the highest fruit hardness at 4.34 kg cm^{-2}. The CaNit fertilizer revealed the highest fruit hardness (3.63 kg cm^{-2}) based on the average results of the nitrogen fertilizers applied to the acid soil. Based on the average results from the potassium dosages, the control, and 240 mg K_2O kg^{-1} treatments showed the highest fruit hardness, measuring at 3.61 kg cm^{-2} and 3.60 kg cm^{-2}, respectively (*Table 5*).

The CaNit applied to the acid soil may have increased the Ca concentration in the peel by maintaining a favorable K/Ca/Mg balance. Kacar et al. (2002) reported that calcium increases sclerenchyma cells and cell wall thickness. Our results on the hardness of the tomato fruit are similar to the results obtained by some researchers. Souri and Dehnavard (2017) obtained the highest fruit hardness from CaNit application among different nitrogen sources (AS, urea, and CaNit) applied to tomato plants.

3.2.2. Fruit pH

The interaction between the application of nitrogen fertilizer and potassium dosage had a statistically significant (1%) impact on the pH of the fruit in both alkaline and acidic soils. *Table 5* provides the values and Duncan groups of the treatments' effects on fruit pH. The *Figure 8* indicates that the 'AS x K_{240}' application had the lowest fruit pH of 4.07, while the 'CaNit x K_0' interaction in alkaline soil had the highest fruit pH of 4.31. The average results of nitrogen fertilizers indicate that CaNit and inh. AS fertilizers had the greatest fruit pH values of 4.21 and 4.19, respectively. Similarly, the average results of potassium dosages show that the control treatment led to the highest fruit pH value of 4.23. However, in soil with high acidity, the 'inh. AS x K_{240}' interaction revealed the lowest fruit pH of 4.17, while the 'CaNit x K_0' interaction resulted in the highest fruit pH of 4.36. The AS fertilizer yielded the highest fruit pH (4.34) based on the average nitrogen fertilizer levels in acid soil. The control dosage gave the highest fruit pH (4.33) based on the average potassium doses. The application of CaNit to the acidic soil enables calcium absorption, which neutralizes fruit acidity and leads to a rise in the pH of fruits (*Table 5*).

The increase in fruit pH can be related to the neutralization of fruit acidity by the increased absorption of calcium from CaNit in acidic soil. We compared the pH results of our tomato fruit with those obtained by certain studies. According to FAO (1992), the pH level of tomato juice was below 4.5. In their study, Sahin et al. (1998) observed that the pH levels of tomato juice ranged from 4.21 to 5.65. According to Javaria et al. (2012), tomato juice had pH values that varied between 4.57 and 4.87, with 0 mg K kg^{-1} resulting in the highest pH value of 4.87. In their study, Yağmur et al. (2004) reported that the pH levels of tomato juice, when treated with varying dosages of potassium (0, 120, 240, and 360 kg K_2O ha^{-1}), ranged from 4.07 to 4.10. In a study conducted by Nzanza (2006), it was noted that the pH level of tomato juice ranged from 4.0 to 4.5. Furthermore, increasing the concentration of potassium (K) in the nutritional solution resulted in a decrease in the pH of tomato fruit. Fandi et al. (2010) reported that the pH of tomato juice varied between 4.23 and 4.39. Applying CaNit alone into acidic soils with low calcium levels can lead to a good balance of Ca, K, and Mg uptake and higher fruit dry matter because the crop can better use these three macronutrients.

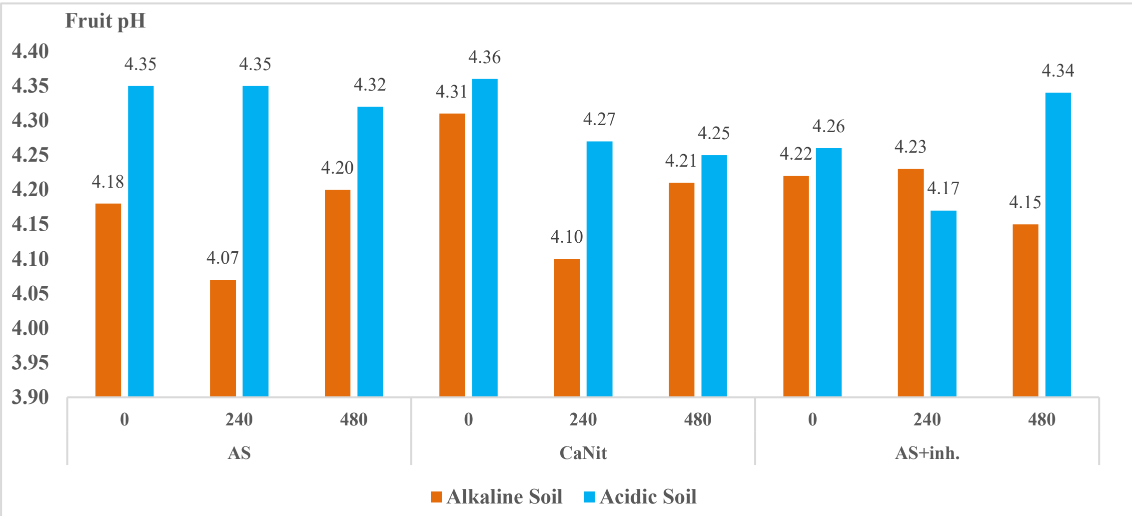


Figure 8. Effects of different nitrogenous sources and potassium doses on the pH of tomato plant fruits grown in alkaline and acidic soils

3.2.3. Fruit brix (dry matter)

The interaction between the nitrogen fertilizer and potassium dosage showed a statistically significant effect (at a 1% level) on the fruit brix in tomato plants in both alkaline and acidic soils. *Table 5* provides the values and Duncan groups for the treatments' impact on brix. *Figure 9* shows that the control treatment of 'CaNit' had the lowest brix (5.01%), while the 'CaNit x K_{240}' interaction had the highest brix (5.39%). The average results of potassium doses

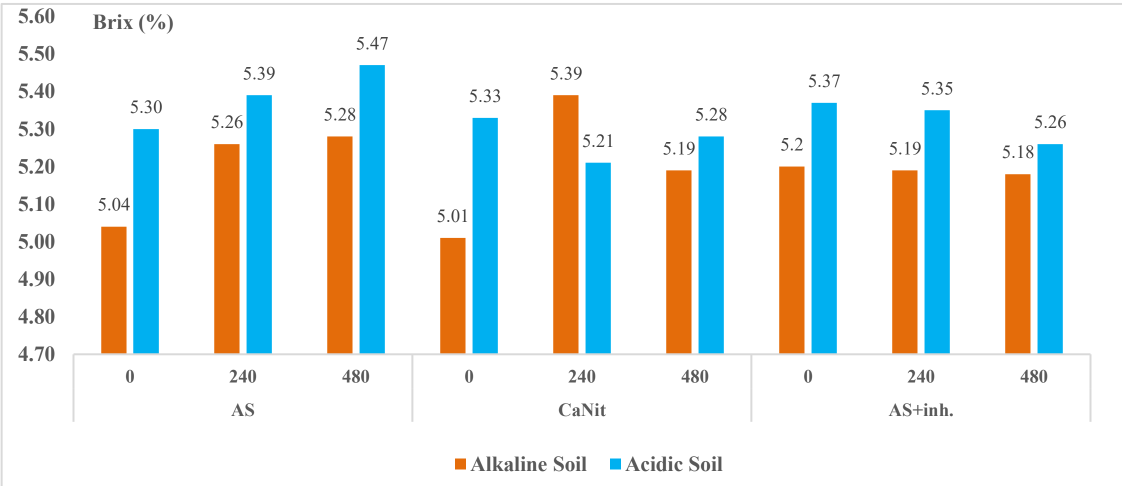


Figure 9. Effects of different nitrogenous sources and potassium doses on Fruit brix (dry matter) tomato plants grown in alkaline and acidic soils

in alkaline soil showed that the highest brix (5.28%) was obtained with a dose of 240 mg K_2O kg^{-1}. The control treatment of AS yielded the lowest brix (5.30%) in acidic soil, while the 'AS x K_{480}' interaction resulted in the highest brix (5.47%). The AS fertilizer yielded the highest brix (5.39%) among the nitrogen fertilizers applied to acidic soil. High brix (water-soluble dry matter) is necessary for tomato flavor and tomato paste yield. FAO (1992) reported that tomato brix values are between 5 and 8%. Our results on brix in tomato fruit are similar to the results of some researchers. Yağmur et al. (2004) obtained tomato brix values between 4.32 and 5.02% with potassium applied at different doses (0, 120, 240, and 360 kg K_2O ha^{-1}). Similarly, in another study, the highest brix (5.25%) was obtained with increasing potassium levels (150, 300, and 450 mg K L^{-1}) at a 450 mg K L^{-1} dose (Öktüren Asri and Sönmez, 2010). Fandi et al. (2010) observed that the brix values of tomatoes varied between 5.6 and 6.4%. Şahin et al. (1998) investigated the effects of different growing media on yield, quality, and plant growth of tomato plants and found that brix values in tomatoes varied between 4.1 and 5.65%. Javaria et al. (2012) reported that brix values in tomatoes varied between 5.0 and 6.97% and found the highest brix value (6.97%) at a dose of 375 mg K kg^{-1}. Şahin et al. (2016) also reported that tomato brix values varied between 5.05 and 5.65%.

Table 4. The effect of various nitrogenous sources and potassium dosages on the yield and yield components of tomato plants grown on different soil types

Soil	N Sources	K doses	Yield (g pot^{-1})	Stem Diameter (mm)	Plant height (cm)	Number of fruits (fruit $plant^{-1}$)	Fruit diameter (mm)	Average Fruit weight (g)
Alkaline Soil	AS	0	482.90 b	12.75 n.s	51.00 e	7.750 bc	59.06 ab	92.65 n.s
		240	542.20 a	11.50 n.s	58.67 d	8.25 bc	54.32 cd	72.53 n.s
		480	537.10 a	12.00 n.s	58.83 d	8.33 b	53.59 d	80.95 n.s
	Mean		**520.70 A**	**12.08 A**	**56.17 C**	**8.11 B**	**55.66 B**	**82.04 A**
	CaNit	0	407.00 c	10.75 n.s	60.67 d	6.25 c	60.64 a	97.76 n.s
		240	394.50 c	9.25 n.s	77.25 a	8.00 bc	54.57 cd	75.59 n.s
		480	396.90 c	10.25 n.s	71.67 b	8.75 ab	57.17 bc	85.72 n.s
	Mean		**399.50 C**	**10.08 B**	**69.86 A**	**7.67 B**	**57.46 A**	**86.35 A**
	AS+inh.	0	334.10 d	11.25 n.s	49.50 e	9.25 ab	54.88 cd	70.95 n.s
		240	470.60 b	10.75 n.s	71.00 b	8.00 bc	57.23 bc	72.95 n.s
		480	549.00 a	10.75 n.s	68.33 c	10.50 a	55.20 cd	74.75 n.s
	Mean		**451.20 B**	**10.92 B**	**62.94 B**	**9.25 A**	**55.77 B**	**72.88 B**
	K0		408.00 C	11.58 a	53.72 C	7.75 b	58.19 A	87.12 A
	K_{240}		469.10 B	10.50 ab	68.97 A	8.10 b	55.37 B	73.69 B
	K_{480}		494.30 A	11.00 b	66.28 C	9.20 a	55.32 B	80.47 AB
	ANOVA							
	N Sources		**	**	**	**	**	**
	K doses		**	*	**	*	**	**
	N sour. x K doses		**	N.S	**	**	**	N.S
Acidic Soil	AS	0	487.50 f	13.25 ab	75.17 a	10.00 ab	57.81 ab	85.11 de
		240	620.10 d	12.33 b	68.67 c	8.33 bc	52.86 c	123.98 b
		480	589.90 e	13.00 ab	75.50 a	11.00 a	56.03 b	98.32 c
	Mean		**565.80 C**	**12.86 b**	**73.11 A**	**9.78 n.s**	**55.57 B**	**102.47 B**
	CaNit	0	408.80 g	14.67 a	63.00 d	7.00 c	57.15 ab	81.76 e
		240	747.70 a	13.33 ab	76.00 a	10.68 ab	58.64 ab	140.78 a
		480	706.30 b	13.50 ab	74.00 ab	12.33 a	58.80 ab	100.91 c
	Mean		**621.00 B**	**13.83 a**	**71.00 B**	**10.00 n.s**	**58.20 A**	**107.82 A**
	AS+inh.	0	615.20 de	12.50 b	65.67 d	11.50 a	59.43 a	85.86 de
		240	684.00 bc	14.25 ab	65.67 d	11.75 a	57.85 ab	96.88 c
		480	668.60 c	13.50 ab	72.25 b	9.75 ab	59.17 ab	95.52 cd
	Mean		**656.00 A**	**13.42 ab**	**67.86 C**	**11.00 n.s**	**58.82 A**	**92.75 C**
	K0		503.80 C	13.47 n.s	67.95 C	9.50 B	58.13 A	84.24 C
	K_{240}		683.90 A	13.31 n.s	70.11 B	10.25 AB	56.45 B	120.55 A
	K_{480}		655.00 B	13.33 n.s	73.92 A	11.03 A	58.00 A	98.25 B
	ANOVA							
	N Sources		**	*	**	N.S	**	**
	K doses		**	N.S	**	**	**	**
	N souc. x K doses		**	**	**	**	**	**

*****: p<0.01, *: p<0.05, N.S: Not Significant***

Table 5. The effect of different nitrogenous sources and potassium doses on some fruit quality of tomato plants grown in alkaline and acidic soils

Soil	N Sources	K doses	*Fruit hardness ($kg.cm^{-2}$)*	*Fruit pH*	*Brix (%)*
Alkaline Soil	**AS**	**0**	2.82 g	4.18 cd	5.04 d
		240	3.43 e	4.07 e	5.26 b
		480	3.39 ef	4.20 bc	5.28 b
	Mean		**3.25 C**	**4.15 B**	**5.20 n.s**
	CaNit	**0**	4.26 a	4.31 a	5.01 d
		240	4.15 b	4.10 e	5.39 a
		480	3.59 d	4.21 bc	5.19 c
	Mean		**4.00 A**	**4.21 A**	**5.20 n.s**
	AS+inh.	**0**	3.62 d	4.22 b	5.20 c
		240	3.90 c	4.23 b	5.19 c
		480	3.35 f	4.15 d	5.18 c
	Mean		**3.62 B**	**4.19 A**	**5.19 n.s**
	K_0		3.57 B	4.23 A	5.08 C
	K_{240}		3.83 A	4.13 C	5.28 A
	K_{480}		3.45 C	4.18 B	5.22 B
			ANOVA		
	N Sources		**	**	N.S
	K doses		**	**	**
	N Sources x K doses		**	**	**
Acidic Soil	**AS**	**0**	2.79 g	4.35 a	5.30 d
		240	4.10 b	4.35 a	5.39 b
		480	3.76 c	4.32 b	5.47 a
	Mean		**3.54 B**	**4.34 A**	**5.39 A**
	CaNit	**0**	4.34 a	4.36 a	5.33 cd
		240	3.66 d	4.27 c	5.21 f
		480	2.89 f	4.25 d	5.28 de
	Mean		**3.63 A**	**4.29 B**	**5.27 C**
	AS+inh.	**0**	3.69 cd	4.26 cd	5.37 bc
		240	3.10 e	4.17 e	5.35 c
		480	3.78 c	4.34 a	5.26 e
	Mean		**3.53 B**	**4.26 C**	**5.33 B**
	K_0		3.61 A	4.33 A	5.33 n.s
	K_{240}		3.60 A	4.26 C	5.32 n.s
	K_{480}		3.48 B	4.30 B	5.34 n.s
			ANOVA		
	N Sources		**	**	**
	K doses		**	**	NS
	N Sources x K doses		**	**	**

***: p<0.01, *: p<0.05, N.S: Not Significant*

4. Conclusions

According to the study results, the effects of different nitrogenous sources and potassium doses on tomato yield, yield components, and some fruit quality parameters in different soils were statistically significant (P<0.01, P<0.05). In the alkaline soil, the highest tomato yield (549.00 g pot^{-1}) was obtained from the 'inh. AS x K_{480}' interaction. According to the average yield results for different nitrogen fertilizers applied into alkaline soil, the highest tomato yield (520.70 g pot^{-1}) was found in AS application, and tomato yield increased with increasing potassium doses from 0 mg K_2O kg^{-1} dose to 480 mg K_2O kg^{-1} dose. In the acidic soil, the highest tomato yield (747.70 g pot^{-1}) was obtained from the 'CaNit x K_{240}' interaction. According to the average yield results of different nitrogen fertilizers applied to acid soils, the highest tomato yield (656.00 g pot^{-1}) was obtained from the inh. AS fertilizer application and based on the average yield results of the potassium doses, the highest tomato yield (683.90 g pot) was obtained from the 240 mg K_2O kg^{-1} dose. The relationship between potassium (K) and nitrogen (N) is essential for the growth and development of tomatoes, since it affects numerous physiological and biochemical processes. Potassium is vital for various plant processes, such as enzyme activation, photosynthesis, and nutrient transport, whereas nitrogen is a crucial constituent of amino acids and proteins. The simultaneous administration of these nutrients can substantially influence tomato growth, yield, and quality. Potassium substantially influences tomato growth and quality; yet its relationship with nitrogen is complex and demands careful management in order to maximize advantages. Maintaining an equilibrium among these nutrients is crucial for optimizing productivity and quality while reducing adverse environmental effects. Nonetheless, excessive application may result in diminishing results and possible environmental harm, underscoring the necessity of targeted nutrient management measurements.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Zengin, M., Gezgin, S.; Design: Zengin, M., Yılmaz, F.; Data Collection or Processing: Nazzal, M., Uzun, F.; Statistical Analyses: Nazzal, M., Uzun, F.; Literature Search: Nazzal, M.; Writing, Review and Editing: Zengin, M., Nazzal, M.

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