



T.C.

TOKAT GAZIOSMANPAŞA UNIVERSITY

GRADUATE SCHOOL

DEPARTMENT OF HORTICULTURE

Ph.D. OF SCIENCE PROGRAM

Effect of Different Calcium Doses and Salinity Levels on Yield, Quality, and Blossom End Rot in Tomato (*Solanum lycopersicum* L)

Ph.D. THESIS

ZUHER RASHID SHAKIR

Supervisor: Prof. Dr. Naif GEBOLOĞLU

TOKAT- 2023

ETHICS CONTRACT

According to the thesis writing guide of Tokat Gaziosmanpaşa University Graduate Education Institute, an original version of the Ph.D. thesis titled “**Effect of Different Calcium Doses and Salinity Levels on Yield, Quality, and Blossom End Rot in Tomato (*Solanum lycopersicum* L)**”. Which I prepared under the supervision of Prof. Dr. Naif GEBOLOĞLU. I declare that I will accept all kinds of legal sanctions if it is determined that the work is in accordance with the rules and scientific ethical values



/ /2023

Zuher Rashid SHAKIR

ACKNOWLEDGMENT

First of all, I want to express my gratitude and thanks to the Almighty and Merciful (God) for providing me with the capability to complete this work.

I wish to express my sincere and deepest gratitude to my supervisor Prof. Dr. Naif GEBOLOĞLU for supervisor and for providing the required facilities during the achievement of this work.

Many thanks and gratitude to Prof. Dr. Şebnem KUŞVURAN and Prof. Dr. Sezer ŞAHİN for providing me with assistance and support.

I would like to express my thanks to every member, especially to Hakan KARTAL, Nurullah BAYRAM, Emine POLAT, Abdırızak MOHAMED SHEIKH, Ibrahim KARATAŞ and Zehra SEZER

I am very grateful to my Father and Mother who supported me on the road to success.

My deepest thanks to my Wife.

Zuher Rashid SHAKIR

ÖZET

Farklı Kalsiyum Dozları ve Tuz Seviyelerinin Domateste (*Solanum lycopersicum* L.)
Verim, Kalite ve Çiçek Burnu Çürüklüğüne Etkisi

Zuher Rashid SHAKIR
Ph.D

Tokat Gaziosmanpaşa Üniversitesi Lisansüstü Eğitim Enstitüsü
Bahçe Bitkileri Anabilim Dalı

Tez Danışmanı: Prof. Dr. Naif GEBOLOĞLU

Domates yetiştiriciliğinde karşılaşılan en önemli sorunlardan biri tuz stresidir. Domates tuz stresine orta derecede hassas türlerden biridir ve tuz stresinin olduğu durumlarda önemli verim ve kalite kayıpları meydana gelmektedir. Tuz stresinin önemli etkilerinden biri de domates meyvelerinde çiçek burnu çürüklüğüne neden olmasıdır. Tuz stresi altındaki domates bitkilerinin kalsiyum alımının azalması sonucunda çiçek burnu çürüklüğü ortaya çıkmaktadır. Kalsiyum, domates bitkilerinde tuz stresinin olumsuz etkilerini azaltmada etkili besin elementlerinden biridir.

Bu çalışma, 01 Mayıs - 10 Aralık 2021 ve 10 Mayıs - 30 Kasım 2022 tarihleri arasında Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, Tokat/Türkiye'de bir serada gerçekleştirilmiştir. Bitkiler topraksız kültürde yetiştirilmiştir. Yetiştirme ortamı olarak cocopeat + perlit karışımı (2:1 oranında) kullanılmıştır. Ufuk F1 indeterminate domates çeşidi ve LA442 domates hattı kullanılmıştır. Çalışmada, farklı kalsiyum dozları ve tuz seviyeleri arasındaki ilişkiler incelenmiştir. Dört farklı kalsiyum oxide dozu (0, 50, 100 ve 200 ppm) ve üç tuzluluk seviyesi (2.0, 4.0 ve 6.0 dS/m) kullanılmıştır. Bitkiler düzenli olarak tuz ve kalsiyum içeren sulama suyu ile sulanmıştır. Kalsiyum içeren sulama suyu saat 08.00'de, tuz içeren sulama suyu ise saat 16.00'da verilmiştir.

Sonuçlar, 2021 ve 2022 yıllarında LA442 ve Ufuk F1 genotipleri için, 0 ila 200 ppm arasında artan kalsiyum dozlarının hem tuzlu hem de tuzsuz koşullarda pazarlanabilir meyve verimini, pazarlanabilir meyve ağırlığını, toplam verimi ve meyve sayısını önemli ölçüde artırdığını göstermiştir. Pazarlanabilir verim, toplam verim ve pazarlanabilir meyve ağırlığı, her iki yılda ve iki çeşitte de yüksek tuz konsantrasyonunda 200 ppm kalsiyum uygulamasında maksimum seviyeye ulaşmıştır. Besin çözeltisinin tuzluluğu arttıkça, çiçek burnu çürüklüğü insidansı artmış ve Ca dozu arttıkça bu oran azalmıştır. Yüksek tuz konsantrasyonunda Ca dozunun artırılması, çiçek burnu çürüklüğünde önemli bir azalma ile sonuçlanmıştır. Artan tuz konsantrasyonu meyvede Brix'in artmasına neden olmuş, Ca dozları ile Brix arasında önemli bir fark bulunmamıştır. Tuz stresi yaprak klorofil içeriğinde azalmaya neden olurken, Ca dozları arttıkça klorofil içeriği miktarı da artmıştır. Domates yapraklarının Fe ve Mn içeriği tuz ve Ca'daki artışa bağlı olarak azalmıştır. Yaprak Fe içeriği tuzluluk ve Ca dozları arttıkça azalmıştır. P ve K yüksek tuzlulukta azalırken, yaprak P

ve K içeriđi ile kalsiyum dozları arasında bir ilişki bulunmamıştır. Yaprak Na içeriđi artan tuz ile artarken, Ca dozları ile önemli bir ilişki bulunmamıştır. Domates meyvelerinde, yaprakta ve ayrıca meyve ucundaki Ca miktarı tuz arttıkça azalmış ve kalsiyum arttıkça artmıştır. Meyvelerdeki C vitamini tuz stresinden olumsuz etkilenmiş ve Ca dozları arttıkça artmıştır. Tuzluluk meyve enzim aktivitesini etkilemiştir. Meyvede MDA, APX, CAT ve POX aktiviteleri tuz stresi altında artarken, yüksek Ca dozu bazı uygulamalarda azalmaya neden olmuş veya değışmemiştir.

Sonuç olarak, domateste tuz stresi bitki gelişimi, verim ve kalite parametrelerinde önemli bir düşüşe neden olmuş, ancak tuz stresi altındaki bitkilere yüksek konsantrasyonlarda Ca dozları tuz stresinin etkisini önemli ölçüde azaltmıştır. Verim ve kalite kaybının önemli bir kısmı meyvelerdeki çiçek burnu çürüklüğünden kaynaklanmıştır. Tuz stresinde çiçek burnu çürüklüğü artarken, stres altındaki bitkilere yüksek dozda Ca verilmesi çiçek burnu çürüklüğünü önemli bir ölçüde azaltmıştır.

ANAHTAR KELİMELELER:

Besin elementi, Antioksidan, Enzim, Vitamin C, Klorofil.

ABSTRACT

Effect of Different Calcium Doses and Salinity Levels on Yield, Quality, and Blossom End Rot in Tomato (*Solanum lycopersicum* L.)

Zuher Rashid SHAKIR
Ph.D

Tokat Gaziosmanpasa University Institute of Graduate Studies
Department of Horticulture

Supervisor: Prof. Dr. Naif GEBOLOĞLU

Salinity is one of the most important problem in tomato production. Tomato is moderately salt-sensitive crops, and significant yield and quality losses occur under salt stress. One of the most important effect of salt stress is that it causes blossom end rot in tomato fruit. The reduced uptake of calcium by tomato plants under salt stress leads to the development of blossom end rot. Calcium is one of the effective nutrients in reducing the negative effects of salt stress in tomato plants.

This study was carried out in a greenhouse at the Gaziosmanpaşa University, Agricultural Faculty, Department of Horticulture, Tokat/Türkiye, from 01 May to 10 December 2021 and from 10 May to 30 November 2022. Plants were grown in soilless culture. Cocopeat + perlite mixture (2:1 ratio) was used as growing media. Ufuk F1 indeterminate tomato variety and LA442 tomato line were used. In the experiment, interactions between different calcium doses and salt levels were tested. Four different calcium oxide doses (0, 50, 100, and 200 ppm) and three salinity levels (2.0, 4.0, and 6.0 dS/m) were used. The plants were regularly watered with irrigation water containing salt and calcium. Irrigation water containing calcium was given at 08.00, while, irrigation water containing salt was given at 16.00.

The results showed that in the years 2021 and 2022 for the LA442 and Ufuk F1 genotypes, increasing calcium doses from 0 to 200 ppm significantly increased marketable fruit yield, marketable fruit weight, total yield and fruit number in both saline and non-saline conditions. Marketable yield, total yield and marketable fruit weight were maximized at 200 ppm calcium application in both years and two varieties at high salt concentration. As the salinity of the nutrient solution increased, the incidence of blossom end rot increased, and as the Ca dose increased, the rate decreased. Increasing the Ca dose at high salt concentration resulted in a significant decrease in blossom end rot. Increasing salt concentration caused an increase in Brix in the fruit, and no significant relationship was found between Ca doses and Brix. While salt stress caused a decrease in leaf chlorophyll content, the amount of chlorophyll content increased as the Ca doses increased. Fe and Mn content of tomato leaves decreased due to increase in salt and Ca. Leaf Fe content decreased as salinity and Ca doses increased. While P and K decreased in high salinity, no relationship was found between leaf P and K content with calcium doses. While leaf Na content increased with increasing salt, no significant relationship was found with Ca doses. The amount of Ca

in tomato fruits, Ca of leaf and also in the tip of the fruit decreased as salt increased and increased as calcium increased. Vitamin C in fruit was negatively affected by salt stress, and the increase in Ca doses increased. Salinity effected fruit enzyme activity. While MDA, APX, CAT and POX activities in fruit increased under salt stress, high Ca dose caused a decrease or did not change in some applications.

As a result, salt stress in tomato caused a significant decrease in plant development, yield and quality parameters, but high concentrations of Ca doses to plants under salt stress significantly reduced the effect of salt stress. A significant portion of the yield and quality loss was caused by blossom end rot in fruits. While blossom end rot increased in salt stress, giving high doses of Ca to plants under stress significantly reduced blossom end rot.

KEYWORDS:

Nutrient Element, Antioxidant, Enzyme, Vitamin C, Chlorophyll.

TABLE OF CONTENTS

	Pages
ÖZET	I
ABSTRACT	III
TABLE OF CONTENTS	V
LIST OF TABLES	VIII
LIST OF FIGURES	IX
1. INTRODUCTION	1
2. LITERATURE REVIEW	6
2.1. Tomato.....	6
2.2. Role of plant nutrients in tomato.....	8
2.3. The importance of calcium and its role in vegetable crops.....	10
2.4. The role of Calcium in tomato production.....	11
2.5. The importance of calcium and its role.....	13
2.6. Effect of calcium on the yield and Blossom end rot of tomato.....	15
2.7. Salinity.....	17
2.8. Effect of salinity on vegetable crops.....	19
2.9. Effect of salinity on the quality and yield of tomato.....	20
2.10. Effect of calcium and salinity on the yield and quality of tomato.....	28
2.11. Interaction between calcium and macro nutrition.....	33
2.11.1. Interaction between calcium and nitrogen.....	33
2.11.2. Interaction between calcium and potassium.....	36
2.11.3. Interaction between calcium and phosphors.....	38
2.11.4. Interaction between calcium and magnesium.....	40
2.12. Interaction between calcium and micro nutrition.....	42
2.13. Reactive Oxygen Species.....	45
3. MATERIALS AND METHODS	48
3.1. Materials.....	48
3.1.1. Description of the experiment.....	48
3.1.2. Plant material.....	49
3.2. Method	50
3.2.1. Experimental design and statistical analysis.....	53
3.3. Experimental Parameters.....	53
3.3.1. Marketable yield	53
3.3.2. Average fruit weight (g).....	54
3.3.3. Total yield.....	54
3.3.4. Fruit dry weight (%).....	54
3.3.5. Leaf dry weight (%).....	54
3.3.6. Blossom end rot	54
3.3.7. Total soluble solids of fruit juice (%).....	55
3.3.8. Electrical conductivity of fruit juice (EC dS/m).....	55
3.3.9. pH of fruit juice	56
3.3.10. Titratable acidity of fruit juice (TA).....	56
3.3.11. Leaf chlorophyll content (SPAD).....	56
3.3.12. Nutrient analysis in fruit and leaf.....	57
3.3.13. Calcium analysis in fruit parts.....	57
3.3.14. Fruit firmness.....	58

3.3.15. Ascorbic acid (Vitamin C).....	59
3.3.16. Fruit skin color.....	59
3.3.17. Antioxidative Enzyme Analysis.....	59
3.3.18. Catalase Activity (CAT).....	60
3.3.19. Peroxidase Enzyme Activity.....	61
3.3.20. Ascorbate Peroxidase (APX) Activity.....	61
3.3.21. Glutathione Reductase (GR) Activity.....	62
3.3.22. Determination of Lipid Peroxidation Amount (MDA).....	62
4. RESULTS AND DISCUSSION.....	64
4.1. Effect of Salinity and Ca Doses on Marketable Yield.....	64
4.1.1. Marketable fruit yield.....	64
4.1.2. Fruit number.....	64
4.2. Effect of salinity and Ca doses on marketable fruit weight.....	66
4.3. Effect of salinity and Ca doses on total yield.....	69
4.3.1. Total yield (ton/ha).....	69
4.3.2. Fruit number.....	69
4.4. Effect of salinity and Ca doses on fruit dry weight.....	71
4.5. Effect of salinity and Ca doses on the leaf dry weight.....	73
4.6. Effect of salinity and Ca doses on rate of blossom end rot.....	74
4.7. Effect of salinity and Ca doses on Brix of tomato variety.....	79
4.8. Effect of salinity and Ca doses on electrical conductivity of fruits.....	80
4.9. Effect of salinity and Ca doses pH of tomato variety.....	81
4.10. Effect of salinity and Ca doses on fruit titratable acidity of tomato fruit....	82
4.11. Effect of salinity and Ca doses on leaf chlorophyll (SPAD).....	84
4.12. Effect of salinity and Ca doses on leaf micronutrients content.....	86
4.12.1. Iron content in leaf	86
4.12.2. Copper content in leaf	87
4.12.3. Zinc content in leaf	89
4.12.4. Manganese content in leaf.....	91
4.13. Effect of salinity and Ca doses on leaf macronutrients content.....	92
4.13.1. Phosphorus content in leaf.....	92
4.13.2. Potassium content in leaf.....	94
4.13.3. Calcium content in leaf.....	96
4.13.4. Magnesium content in leaf.....	97
4.13.5. Sodium content in leaf.....	99
4.14. Effect of salinity and Ca doses on fruit micronutrients content.....	101
4.14.1. Iron content in fruit.....	101
4.14.2. Copper content in fruit.....	103
4.14.3. Zinc content in fruit.....	105
4.14.4. Manganese content in fruit.....	106
4.15. Effect of salinity and Ca doses on fruit macronutrients content.....	108
4.15.1. Phosphorus content in fruit.....	108
4.15.2. Potassium content in fruit.....	109
4.15.3. Calcium content in fruit.....	110
4.15.4. Magnesium content in fruit.....	113
4.15.5. Sodium content in fruit.....	114
4.15.6. Calcium content in fruit tip.....	116
4.16. Effect of salinity and Ca doses on fruit firmness.....	117

4.17. Effect of salinity and Ca doses on fruit ascorbic acid (Vitamin C).....	119
4.18. Colour parameters of tomato fruits.....	121
4.19. Catalase Activity (CAT).....	124
4.20. Peroxidase Enzyme Activity.....	125
4.21. Ascorbate Peroxidase (APX) Activity.....	127
4.22. Glutathione Reductase (GR) Activity.....	128
4.23. Determination of Lipid Peroxidation Amount (MDA).....	129
5. CONCLUSIONS AND RECOMMENDATIONS.....	132
6. REFERENCES.....	136



LIST OF TABLES

Pages

Table 2.1. Dry matter components in tomato fruit	7
Table 2.2. Tomato production of some important countries	8
Table 3.1. Macro and micronutrients used in the study.....	53
Table 4.1. Effect of salinity and Ca doses on marketable yield.....	65
Table 4.2. Effect of salinity and Ca doses on marketable fruit number.....	67
Table 4.3. Effect of salinity and Ca doses on marketable fruit weight (g).....	68
Table 4.4. Effect of salinity and Ca doses on total yield (ton/ha).....	70
Table 4.5. Effect of salinity and Ca doses on total yield (fruit number).....	72
Table 4.6. Effect of salinity and Ca doses on fruit dry weight.....	73
Table 4.7. Effect of salinity and Ca doses on leaf dry weight.....	75
Table 4.8. Effect of salinity and Ca doses on rate of blossom end rot.....	76
Table 4.9. Effect of salinity and Ca doses on Brix of tomato variety.....	80
Table 4.10. Effect of salinity and Ca doses on electrical conductivity of fruits.....	82
Table 4.11. Effect of salinity and Ca doses on pH of tomato variety.....	83
Table 4.12. Effect of salinity and Ca doses on titratable acidity of tomato fruit.....	84
Table 4.13. Effect of salinity and Ca doses on leaf chlorophyll (SPAD).....	86
Table 4.14. Effect of salinity and Ca doses on leaf Fe content.....	88
Table 4.15. Effect of salinity and Ca doses on leaf Cu content.....	89
Table 4.16. Effect of salinity and Ca doses on leaf Zn content.....	90
Table 4.17. Effect of salinity and Ca doses on leaf Mn content.....	92
Table 4.18. Effect of salinity and Ca doses on leaf P content.....	94
Table 4.19. Effect of salinity and Ca doses on leaf K content.....	96
Table 4.20. Effect of salinity and Ca doses on leaf calcium content.....	98
Table 4.21. Effect of salinity and Ca doses on leaf Mg content.....	100
Table 4.22. Effect of salinity and Ca doses on leaf Na content.....	101
Table 4.23. Effect of salinity and Ca doses on fruit Fe content.....	103
Table 4.24. Effect of salinity and Ca doses on fruit Cu content.....	104
Table 4.25. Effect of salinity and Ca doses on fruit Zn content.....	106
Table 4.26. Effect of salinity and Ca doses on fruit Mn content.....	107
Table 4.27. Effect of salinity and Ca doses on fruit P content.....	109
Table 4.28. Effect of salinity and Ca doses on fruit K content.....	111
Table 4.29. Effect of salinity and Ca doses on fruit Ca content.....	112
Table 4.30. Effect of salinity and Ca doses on fruit Mg content.....	114
Table 4.31. Effect of salinity and Ca doses on fruit Na content.....	116
Table 4.32. Effect of salinity and Ca doses on Ca of Fruit tip.....	118
Table 4.33. Effect of salinity and Ca doses on fruit firmness.....	119
Table 4.34. Effect of salinity and Ca doses on fruit ascorbic acid.....	121

LIST OF FIGURES	Pages
Figure 3.1. Tomato cultivated pot.....	48
Figure 3.2. Fruit of tomato used in the study.....	49
Figure 3.3. Preparing of solutions and first apply to pots.....	50
Figure 3.4. Seedling planting, irrigation and harvest.....	51
Figure 3.5. Irrigation of plants.....	51
Figure 3.6. Electrical conductivity and pH measurement in drainage solution.....	52
Figure 3.7. Symptoms of blossom end rot in fruits.....	55
Figure 3.8. Determining of chlorophyll index in tomato leaves.....	57
Figure 3.9. Stages of reading nutrient elements.....	58
Figure 3.10. Measuring of fruit firmness	60
Figure 3.11. Measuring of fruit skin color.....	60
Figure 3.12. Catalase Activity a. Preparing sample b. reading of sample.....	61
Figure 3.13. Peroxidase Enzyme Activity reading by spectrometer.....	62
Figure 3.14. Ascorbate Peroxidase (APX) Activity reading by spectrometer.....	62
Figure 3.15. Glutathione Reductase (GR) Activity reading by spectrometer.....	62
Fig. 4.1. Effect of different salt concentrations on BER at 0 and 50 ppm Ca doses..	77
Fig. 4.2. Effect of different salt concentrations on BER at 100 and 200 ppm Ca doses.....	78
Fig. 4.3. Effect of salinity and Ca treatments on colour parameters of tomato fruits corresponding to years and genotypes.....	123
Fig. 4.4. Effect of salinity and Ca treatments on CAT of tomato fruits corresponding to years and genotypes.....	125
Fig. 4.5. Effect of salinity and Ca treatments on pox of tomato fruits corresponding to years and genotypes.....	126
Fig. 4.6. Effect of salinity and Ca treatments on APX of tomato fruits corresponding to years and genotypes.....	128
Fig. 4.7. Effect of salinity and Ca treatments on GR of tomato fruits corresponding to years and genotypes.....	129
Fig. 4.8. Effect of salinity and Ca treatments on GR of tomato fruits corresponding to years and genotypes.....	131

1. INTRODUCTION

One of the most significant vegetable crops grown worldwide is the tomato, also known as *Lycopersicon esculentum* Mill. This plant, a member of the Solanaceae family, is not only one of the most important items in terms of production, consumption, and trade, but it is also a vital product for human nutrition. As of 2021, the total global production of tomato is estimated at 189.13 million tonnes. China leads the production with a total of 67.63 million tonnes, followed by India in second place, Türkiye in third place with 13.09 million tonnes, and the United States of America in fourth place with 10.47 million tonnes. China, producing more tomato than any other country globally, accounts for 35 percent of the overall global production. The production of tomato in Türkiye dropped from 13.2 million tonnes in 2020 to 13.1 million tonnes in 2021 (Anonim, 2021). Despite the fact that, this plant can be found in many parts of the world, one of the most important countries in the world for tomato production is Türkiye. This is attributed to Türkiye has favorable climatic conditions (Keskin, 2013). Tomato contain concentrations of various nutrients: carotenoids, lipids, organic acids (citric acid and malic acid), 93–95 percent water, alcohol-insoluble solids (including proteins, cellulose, pectin, and polysaccharides), and 5-7% inorganic chemicals. (Minoia et al., 2010; Petro-Turza, 1986).

Tomato is processed in various ways, including the production of soup, juice, ketchup, puree, paste, and even in dried and powdered forms. In addition, Pickled tomato and preserves can also be made from green tomatoes (Jayaramaiah et al., 2018). Tomato is commonly consumed as fresh vegetable around the world due to their abundance of essential nutrients and phytochemicals that are rich in antioxidants, tomato includes several nutrients, such as minerals, vitamins, proteins, essential amino acids and carotenoids like lycopene. Lycopene is the primary carotenoid found in tomato and tomato-based products. Consuming lycopene has been shown to decrease the likelihood of developing cancer, cardiovascular disease, and other significant illnesses (Ali et al., 2020). It is now generally accepted that the tomato possesses the world has most potent natural antioxidant. Additionally, the tomato is considered the most significant food item due to it is exceptional nutritional content, making it one of the most protective foods (Shankar et al., 2013).

When it comes to maintaining their growth and development, plants greatly rely on the nutrients they receive. Calcium is one of the essential nutrients. Ca^{2+} an ion form of calcium, is absorbed by the plant and is a vital component for the development of plants in general as well as the fruits that they produce. Calcium also plays an important role in the resistance of plants to diseases as well as the protection of the cell wall. Calcium, on the other hand, plays a major role in the growth and development of cells, also in the permeability of membranes, protection of cell walls, and the defense of tissues (Marschner, 2011). Typically, higher plants contain around 0.5% calcium on a dry matter basis. Calcium is a mineral with limited mobility in plants; it moves from the roots to the upper leaves as levels of transpiration and water intake increase. Inside greenhouses, plants consume less water compared to those in open fields, yet yields are projected to be greater in greenhouses. Consequently, greenhouse plants require more nutrients than those grown in open fields (Cakmak and Romheld, 1997; Ishii et al., 2001).

The absorption of water by the leaf occurs solely in the xylem vessels, whereas the absorption of water by the fruit occurs in both the phloem and xylem vascular tissues. The tissue in the fruit that is most susceptible to calcium deficiency disorders is BER, primarily due to its significantly low calcium concentration (White, 2001). Cell plasmolysis and the water-soaked look of BER are the first signs that indicate a calcium deficiency in fruit. These symptoms start turning dark brown as a result of the death of the cells (Suzuki et al., 2003). In addition, increased transpiration and growth rates can decrease water potential while simultaneously increasing tissue strength by acting as sinks for xylem calcium (De Freitas et al., 2010). The distribution of calcium that occurs when it moves from the roots to the leaves and fruit will be determined by the amount of calcium present in the xylem sap (Ho and White, 2005). The middle lamella of cell walls is closely linked with calcium, and it plays a significant role in the growth and development of cells (Wu et al., 2002). BER, water-soaked dark spot at the end of the fruit, has been linked to a local plant nutritional disorder. This disorder is characterised by increased permeability and deterioration of fruit cell membranes, which, in turn, leads to a loss of turgor and the leakage of cell liquids into the cellular space (Saure, 2001; 2014). BER develops during the fruit development stage, approximately two to four weeks after anthesis, in tomato and pepper species belonging to the family

Solenacea, resulting in quality and yield reductions and, consequently, financial losses. BER has been demonstrated to cause losses of between 23 and 37% in every part of the world where tomato are grown (Aişe et al., 2014). However, BER can also develop internally within the fruit, without showing any signs on the outside of the fruit. This might result in black seeds or black pulp (Ho et al., 1999). A sufficient amount of potassium, magnesium, and calcium in the nutrition solution has the potential to increase the yield and improve the fruit quality.

Blotchy ripening, cat facing, fruit cracking, and BER are examples of some of the physiological disorders that can develop despite adequate fertilizer management and that, to some extent, can be connected with these plant nutrients, when it comes to BER, which is capable of resulting in significant economic losses (Taylor and Locascio, 2004). The depletion of magnesium in crops grown in arid regions that have a high Ca/Mg ratio may be due to the fact that the method of absorption changes depending on the relative amounts of calcium and magnesium in the solution (Yan and Ying , 2018). The nutrient solution is impact on BER, the presence of gold specks in fruits, and plant Ca and K absorption with raising K/Ca ratios in the nutritional solution, the occurrence of BER increased but the incidence of gold specks decreased, As the K/Ca ratios in the nutrient solution increased, there was a corresponding rise in the occurrence of BER, while the presence of gold spots decreased (Nukaya et al., 1995). The incidence of BER was found to be high when the fertiliser contained high levels of nitrogen (N), sulphur (S), magnesium (Mg), potassium (K), and chloride (Cl), and also low levels of calcium (Ca) (Raleigh et al., 1944).

Calcium may not be useful to plants under certain situations, despite its presence in the soil. Particularly the fertilizer containing calcium dissolved with phosphorus, which produces sedimentation, salinity, and plant water intake issues, impedes plant calcium uptake significantly. Even if calcium is present in the soil, it is incapable of being retransformed for the fruit in some plants, causing deficient symptoms. Also, In the event that there is a lack of boron, it prevents the creation of flowers and fruits. A lack of calcium causes BER, which can result in a considerable reduction in production (Karaman et al., 2012). Calcium is absorbed by the roots from the soil solution, and subsequently, it is transported to the shoot through the xylem. Through the cytoplasm of cells connected by plasmodesmata (the symplast) or through the gaps between cells, it

can flow through the root. It is uncertain how much the apoplastic and symplastic pathways contributed to the transfer of calcium to the xylem (White, 2001). It is generally accepted that the extremely low levels of calcium in the phloem sap are a result of calcium buildup in the cells that surround the phloem. All plant organs, which receive the majority of their nutrients from the phloem sap, have a comparatively low calcium content as a direct result of the low calcium levels in the phloem (Mengel and Kirkby, 2001).

One of the many environmental stresses that causes significant variations in the growth, physiology, and metabolism of plants and poses a threat to the cultivation of plants all over the world is salinity (Jaleel et al., 2007). Ionic stress, osmotic stress, and secondary stresses, mainly oxidative stress, are all caused in plants by salt stress (Yang and Guo, 2018). The salinity of the soil has increased as a result of inefficient methods of irrigation, incorrect application of fertilizers, and contamination from industrial sources (Ouhibi et al., 2014). Salt stress has a detrimental impact on plant growth and development by creating osmotic and ionic stress; the specific nature of these effects is dependent on the type of salt that was given to the plant, the genotype and developmental stage of the plant at the time of exposure to the stress, and salt has a negative effect on tomato fruit size, overall yield, and photosynthesis. (Çiçek and Çakırlar, 2002). In most cases, high salinity is caused by high concentrations of sodium and chloride ions in the soil solution. This, in turn, leads to hyperosmotic and hyperionic conditions, both of which inhibit the ability of plants to absorb water and nutrients from the soil (Ismail et al., 2014).

The high salinity induced by NaCl led to issues such as the external osmotic pressure solution exceeding the osmotic pressure of plant cells, requiring the regulation of osmotic pressure to prevent dehydration in plant cells, the absorption of nutrient ions like potassium and calcium, overabundance of sodium would be problematic, enzymes and membrane systems would be directly hurt by high concentrations of Na and Cl (Horie et al., 2012). One of the impacts of salt stress is a decline in photosynthetic activity, which leads to a decrease in chlorophyll a and chlorophyll b as well as a reduction in both the capacity for photosynthetic activity and the amount of carbon dioxide that can be taken up by the plant (Francois and maas, 1993).

Plants are able to tolerate higher levels of salt when they are grown in soils that have been amended with large quantities of calcium. One of the straightforward applications involves adding calcium to the nutritional solution in order to reduce the consequences of salt stress, this approach of soilless culture increased useable growth and also an improvement in fruit quantity and quality (Binti ahmad, 2018). Plants have to make adjustments to their physiological and biochemical processes when they are subjected to salt stress. These mechanisms are involved in controlling ion and osmotic homeostasis, as well as stress damage control and repairing (Zhu, 2002). To reduce the detrimental effects of salinity on plants and circumvent this stress, one of the methods involves enhancing the nutritional content of the substrate used for plant growth by applying exogenous nitrogen, potassium, calcium, magnesium, or phosphorus (Ebert et al., 2002; Kaya et al., 2003).

The aim of this study is to determine the effect of different calcium doses on yield, quality and percentage of BER in tomato fruits under salinity stress. In the study, effect of different calcium doses and salinity levels on uptake of macro and micro nutrients, antioxidant activity, fruit quality parameters such as vitamin C, titratable acidity, electrical conductivity, etc.

2. LITERATURE REVIEW

2.1. Tomato

Tomato is a highly consumed and widely cultivated vegetable globally. It is thought that the wild type of tomato species originated from the regions of South America, particularly in Peru. These regions are believed to be the original habitat of the wild-type tomato plant (Faostat, 2017). Tomato is categorized into two species: *Lycopersicon pimpinellifolium* and *Lycopersicon esculentum* (Taylor, 1986). Tomato plants are classified based on their growth determinate, semi-determinate, or indeterminate. The classification "determinate" refers specifically to the pattern of growth displayed by the plant. Determinate tomato plants are typically grown outside. These plants have a limited growth capacity, typically reaching a height of 1 to 1.5 m. After reaching their maximum height, they produce fruit and then gradually decrease in growth. Many of the early-ripening tomato varieties belong to the determinate category. The main stem terminates with a cluster of flowers, causing the development of secondary shoots. The branches of the plant stop growing at approximately the same distance from the main stem, resulting in a compact and symmetrical circular shape. On the other hand, indeterminate tomato plants have a dominant main stem, which hinders the growth of secondary shoots, resulting in a sprawling growth pattern (Madhavi and Salunkhe, 1998).

The fruit of the tomato plant is an edible berry that is typically bright red in color, due to the accumulation of the lycopene. In wild plants, the fruit has a diameter of 1 to 2 centimeters, but it is much larger in cultivated varieties. The shape of the fruit can vary greatly, ranging from a flat round to a true round, square round, oblong, pear, oxheart, and many other variations. Botanically, the fruit is referred to as a fleshy berry or a swollen ovule, with the body of the fruit being derived from the ovary wall that encompasses and protects the seeds, also known as the pericarp (Gillaspy et al., 1993). Tomato, a crop that growth in warm weather, are highly sensitive to frost during all stages of growth. The recommended temperature range for tomato production during the day is between 21°C and 27°C, tomato plants can withstand temperatures exceeding 38°C, but excessively high temperatures can negatively impact the maturing fruit.

During the night, temperatures should be between 15°C and 18°C. However, low night temperatures below 12°C can impede the formation of pollen and hinder fruit development (Bielinski et al., 2014).

Tomato grow in different soil textures, although commercial growers typically favor sandy soils. Sandy soils have superior drainage and warm up more quickly compared to loam and clay loam soils. However, denser soil types can still be utilized for tomato cultivation as long as proper irrigation and effective drainage systems are in place (Bielinski et al., 2014).

Tomato plants have a wide tolerance for humidity levels, but it is important for optimal fruit quality that humidity does not experience significant fluctuations within a short period of time. Different production guides for greenhouse tomato provide varying recommendations for the ideal relative humidity levels, ranging from 60% to 85%. While higher humidity levels can contribute to better fruit sets up to a certain extent, they also create a favorable environment for the development of diseases. The most favorable relative humidity for pollination is around 70%. When humidity exceeds 80%, pollen grains tend to clump together, reducing their dispersal and lowering pollination rates. The stickiness of pollen decreases as humidity levels decrease. When relative humidity drops below 60%, the stigma, a part of the flower, may dry out, leading to decreased rates of pollination (Langenhoven, 2018).

Table 2.1.Dry matter components in tomato fruit (Petro-Turza, 1987; Yılmaz, 2001).

Components	(%)
Fructose	25.0
Glucose	22.0
Sucrose	1.0
Citric acid	9.0
malic acid	4.0
Protein	8.0
dicarboxylic amino acid	2.0
Pectins	7.0
Cellulose	6.0
Hemicellulose	4.0
Minerals	8.0
Oils	2.0
Ascorbic acid	0.4
Colors	0.5
Others (amino acids, vitamins, polyphenols)	1.0
volatile compounds	0.1

Table 2.2. Tomato production in some important countries (Anonymous, 2021)

Countries	Area harvested (1000 ha)	Yield (ton/ha)	Production (1000 tons)
China	1.144,82	59,08	67.636,72
India	845,00	25,07	21.181,00
Türkiye	165,20	79,22	13.095,26
USA	109,23	95,90	10.475,27
Iraq	32,74	22,73	744,17
World	5.167,39	36,60	189.133,40

2.2. Role of plant nutrients in tomato

Tomato necessitate a minimum of twelve essential nutrients for their proper growth and reproductive processes. These nutrients include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), boron (B), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), and molybdenum (Mo). Macronutrients, like N, P, K, Ca, and Mg, are needed in large amounts for tomato production to be at its best. Other nutrients, like B, Fe, Mn, Cu, Zn, and Mo (also called micronutrients), are needed in small amounts because tomato already have a lot of them. Because the earth can't provide enough N, P, and K for tomato to grow and produce at their best, these nutrients are added to the soil as manures and fertilizers. Ca and Mg are added to soils when they are limed. Most of the time, N, P, and K fertilizers provide sulphur because many of these fertilizers have S compounds in them. Most of the time, the earth gives plants enough micronutrients, unless the plant needs more (Sainju et al., 2003).

Nitrogen is a crucial element found in various compounds, such as proteins, amino acids, and enzymes, which play a vital role in driving biochemical processes during the growth of tomato (Winsor, 1973). When the soil lacks nitrogen, tomato plants may exhibit stunted and weak growth, along with yellowing of leaves at the base. Younger leaves tend to stay small and pale green, and in severe instances, older leaves turn yellow and wither prematurely. Nitrogen deficiency can negatively impact fruit production, reducing the quantity, size, storage quality, color, and taste of tomato. Nitrogen is an essential component of proteins and amino acids, which are crucial for

vital functions in plant growth and reproduction. Without an adequate supply of nitrogen, these fundamental processes would be impaired (Needham, 1973).

Phosphorus plays a vital role in stimulating root growth in tomato plants, which helps with their initial establishment after transplanting or seeding. To promote early root development and establishment in the soil, tomato plants are typically provided with a starter solution containing a high concentration of phosphorus a few days after transplanting. Having an excess of phosphorus in the soil is generally not detrimental to tomato. However, it can reduce the accessibility of certain micronutrients like iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) by decreasing their solubility in the soil and limiting their movement within the plant (Zhu et al., 2018).

Tomato has a high demand for potassium (K) as they absorb it in significant quantities, resulting in higher concentrations compared to other nutrients. Potassium plays a crucial role in promoting robust growth in tomato and contributes to early flowering and fruit set, ultimately leading to an increased yield and number of tomato per plant (Varis and George, 1985). Potassium is essential for regulating water through stomatal movement in plants. It plays a vital role in activating enzymes and is necessary for various metabolic processes, including carbohydrate metabolism, translocation, nitrogen metabolism, protein synthesis, and the regulation of cell sap concentration (Mengel and Kirkby, 2001).

Tomato require a substantial amount of calcium (Ca) due to its higher concentration in various parts of the plant. Fortunately, most soils naturally provide sufficient levels of calcium for tomato growth. Calcium deficiency may occur when the soil pH falls below 4.5. The ideal pH range for optimal tomato growth is typically between 5.5 and 7.0. However, excessive liming should be avoided, as it can lead to a deficiency of micronutrients like iron (Fe) and manganese (Mn) (Ganeshamurthy et al., 2016).

Boron is highly important for the pollination and reproductive development of tomato, as it directly affects the production of flowers and fruits. Boron deficiency is a commonly observed nutritional disorder in commercial tomato farming. It often arises in soilless compost and sandy soils with high levels of calcium. This deficiency is characterized by the yellowing of green leaflets, which become fragile and display brown pigmentation along the veins. In more severe instances, leaf chlorosis, distortion, and the formation of later points can also occur (Fouda et al., 2020).

Magnesium is an essential element found in chlorophyll, pectin, organic acids, and coferments. The application of magnesium fertilizer greatly enhances the production of tomato fruits. Greenhouse-grown tomato commonly experience magnesium deficiency, which is evident through interveinal chlorosis initially observed in the lower leaves and gradually spreading upwards(Sainju et al., 2003).

2.3. The importance of calcium and its role in vegetable crops

Symptoms of calcium deficiency may manifest in various parts of the plant, depending on the specific species, such as tomato, pepper, watermelon and cucumber. Watermelon, cucumber and pepper plants experiencing a calcium deficiency exhibit symptoms that closely resemble those seen in tomato fruits, commonly known as BER. These symptoms typically appear in the initial stages of fruit growth and development. Initially, water-soaked tissues emerge in the BER region of the pepper fruit, which later progress to a brown coloration with necrotic areas (Charles and Shomakher, 2005). The fruit tissue near the affected area of BER in peppers tends to undergo a more rapid loss of green color compared to the unaffected parts of the pepper. Furthermore, the presence of BER creates favorable conditions for the infection of the affected tissue by saprophytic fungi and bacteria that contribute to the development of a rot-like appearance (Hochmuth and Hochmuth, 2009).

In leafy vegetables, the symptoms of calcium deficiency commonly occur at the tips of young and covered leaves, which have low transpiration rates resulting in limited calcium accumulation. Moreover, a high occurrence of tipburn is typically linked to environmental conditions that promote plant growth, this symptoms appear in lettuce, cauliflower and celery (Khan et al., 2017).

Lettuce, when affected by calcium deficiency disorder known as tip burn, displays distinct characteristics such as the presence of dark brown lesions and necrosis on the edges of developing leaf tips. In certain varieties, tipburn initially appears on the small veins along the leaf margin. Typically, inner and younger leaves are more prone to tip burn compared to outer and older leaves, celery plants experiencing calcium deficiency exhibit a disorder called blackheart, which is characterized by the presence of light to dark brown speckles, lesions, and necrosis on the edges of developing leaf tips in the

central growth region. As the plant grows, the black heart symptoms can darken and spread outward from the inner tissues of the plant (Koike and Smith, 2010). In cauliflower, a condition known as tip burn, which is associated with calcium deficiency, is characterized by the development of light brown discoloration and necrosis at the tips of the young inner wrapper leaves that surround the cauliflower head (Masarirambi et al., 2011).

2.4. The role of Calcium in tomato production

More than a century ago, reports in the scientific literature documented the signs and symptoms of calcium deficiency disorders in various crop species (Brooks, 1914). Initially referred to simply as disorders with unknown physiological disorders causes, it was later suggested that these disorders were caused by infection from pathogens, toxicity, and stress in plants (Atanasoff, 1934; Carne and Martin, 1934). Subsequent research focused on the nutrient requirements of plants uncovered that growing plants in environments with different levels of calcium could lead to either an increase or decrease, respectively, in the occurrence of these disorders. As a result, these disorders were renamed "calcium deficiency disorders"(Chiu and Bould, 1977).

Calcium is necessary for the construction of the cell wall, and the middle lamella of the cell wall contains calcium pectate. This pectate regulates the influx of nutrients into the plant, making certain that the nutrients avoid causing harm to the plant in any way. The presence of calcium pectate in the middle lamella helps to maintain the overall health of the plant by controlling the entry of non-toxic nutrients (Tejashvini, 2018). Calcium is a necessary macronutrient, and the calcium levels in tomato fruits range from 3.08 to 16.42 mg 100/g (Anjum et al., 2020).

A shortage of calcium results in the emergence of recognizable symptoms such as the darkening and deformation of the edges of younger leaves, as well as a reduction in the growth of meristematic tissue. These visual symptoms are a direct consequence of calcium deficiency (Morard et al., 1996). Calcium also has a role in extending the shelf life of harvested tomato by preventing post-harvest degradation, which is a process that occurs after the harvest, calcium plays a role in maintaining the integrity of the membrane in two distinct manners: firstly, by slowing down the alterations in lipids that

occur during the aging process, and secondly, by enhancing the process of restructuring (Sati & Qubbaj, 2021). Calcium deficiency is almost always caused by a decrease in calcium uptake and transport within the plant, which can occur in soilless culture when there are disturbances in the water supply or when there is an excess of salt in the water (Adams and Ho, 1993).

According to Bhattarai and Gautam, (2006) the weight loss of tomato fruits decreased by up to 19% when 0.25% CaCl_2 was applied, leading to increased firmness during storage. Michailidis et al., (2020) found that applying 0.5% CaCl_2 to sweet cherries through foliar application resulted in a higher concentration of Calcium in the fruits and alterations in primary and secondary metabolites. Senevirathna et al., (2010) discovered that the application of CaCl_2 can delay the development of fruit color in tomato by reducing the production of ethylene and slowing down the respiration rate. This, in turn, increases the shelf life of the fruits. Wills and Tirmazi, (1979) found that raising the calcium in tomato fruits from 0.11 mg. g^{-1} to 40 mg. g^{-1} can delay their ripening.

Hao and Papadopoulos, (2003) observed that having high calcium concentrations (7.5 mM) in the nutrient solution leads to higher yields, bigger fruits, and a greater percentage of marketable fruits compared to low calcium concentrations (3.5 mM). Sajid et al., (2020) evaluated the impact of foliar application of calcium at different concentrations (0, 0.5, 1.0, and 1.5%) on four tomato cultivars. The results showed that foliar application of calcium at 1.5% significantly increased the plant height, number of branches, total yield, fruit firmness, TSS content, and reduced the incidence of fruit infestation in the cultivar Rio grand compared to the untreated plants of cultivar Roma VF. It was concluded that to achieve better growth and yield, the tomato cultivar Rio Grand should be sprayed with 1.5% calcium. Boone et al., (1997) investigated the impact of calcium nutrition on six tomato cultivars grown hydroponically, using (60, 120, or 185 mg.L^{-1}) calcium levels. The results showed that leaf calcium content ranged from increased to $54,000 \text{ } \mu\text{g.g}^{-1}$ dry weight. The marketable yield was not impacted by the medium or calcium treatment either. However, there was a significant difference in marketable yield between cultivars, with 'Trust' having the highest yield of 2.7 kg per plant, compared to 'Celebrity' at 1.6 kg per plant. The study implies that the use of a cheaper medium (pine bark) and lower calcium levels may be appropriate for fall tomato production.

2.5. The importance of calcium and its role

Calcium plays a critical role in the functioning of cells and maintaining their structural integrity. It is involved in the maintenance of the salt balance within plant cells and regulates the opening and closing of stomata, which is essential for water transport in the plant. Additionally, calcium promotes pollen germination, regulates various enzyme systems, and has a positive effect on the growth and well-being of cells and conductive tissues. Furthermore, calcium is particularly important for the quality of tomato fruits, especially in preventing a common issue known as BER (Krishna et al., 2019).

Calcium is a vital factor in the regulation of growth and development in plants. The range of processes in which this ion is involved is extensive and continues to expand, touching upon nearly all aspects of plant development (Hirschi, 2004). Furthermore, calcium is not only critical for the cell wall and membrane but is also recognized as a key intracellular secondary messenger (Poovaiah and Reddy, 1993). The process of cellular calcium influx begins with the uptake of Ca^{2+} ions through various mechanisms at the plasma membrane. This is followed by the absorption of these ions by the mitochondria and endoplasmic reticulum. Finally, there is a connection between the calcium stores and the nucleus. Scientific studies have shown that the fluctuation of Ca^{2+} in the endoplasmic reticulum plays a critical role in cell proliferation. If there is a depletion of Ca^{2+} in the endoplasmic reticulum, this triggers an influx of Ca^{2+} across the plasma membrane in a phenomenon known as store-operated calcium entries (SOCEs). This process is crucial in regulating cellular processes and maintaining the overall health and function of plant cells (Pinto et al., 2015).

Calcium serves a crucial function in stress signaling by acting as a secondary messenger. The perception of salt stress leads to a cytosolic calcium signal that activates a calcium sensor protein called SOS_3 . Once activated, SOS_3 binds to and stimulates the activity of SOS_2 , a serine/threonine protein kinase. The activated SOS_2 kinase then regulates the functions of SOS_1 , a plasma membrane Na^+/H^+ antiporter, and NHX1 , a tonoplast Na^+/H^+ antiporter. These activities result in either the removal of Na^+ from the cytosol or its compartmentation within the vacuole. This process is crucial in regulating the response of plant cells to stress and promoting the overall health and survival of the plant (Hadi and Karimi, 2012).

The regulation of various cell functions in plants is controlled by the concentration of free calcium in the cytosol. This evidence supports the idea that calcium serves as a messenger in transmitting external stimuli to the plant cells. This signaling often involves the use of plasma membrane-associated protein kinases, phosphatidylinositol pathways, or a combination of both. These findings highlight the important role of calcium in regulating cellular processes and responding to external signals in plants (Poovaiah and Reddy, 1987). Calcium plays a significant part in the cytosolic signal transduction pathways that are involved in the cell's responses to a wide variety of abiotic and biotic factors (Scrase-Field and Knight, 2003).

The presence of abiotic stress typically results in an increase of free calcium in the cytoplasm of the cells. This, in turn, triggers gene expression, which in turn stimulates biochemical responses that permit the plant to adapt to a variety of adverse conditions. Therefore, calcium plays a role in the regulatory mechanisms that enable the plant to adapt to adverse situations such as high temperature, low temperature, water stress, and high salinity (El Habbasha and Ibrahim, 2015). Calcium participates in various cellular functions in plant cells that are influenced by fluctuations in the amount of Ca^{2+} in the cytoplasm, such as maintaining ion balance, controlling gene expression, and carbohydrate metabolism (Bush, 1995). The calcium concentration in the cytosol needs to be subjected to stringent biochemical and physiological regulation. After cytosolic oscillations, the resting state of cytosolic calcium is reset by the activity of Ca-ATPases and H^+/Ca exchangers, which are proteins that transfer calcium from the cytosol into the apoplast or storage organelles inside the cell. Calcium is required to be present in high quantities within cellular organelles for it to be loaded into the cytosol during signaling responses. Calcium is also required to serve as a counterion to both inorganic and organic anions(White and Broadley, 2003). Calcium is a non-toxic mineral nutrient. Plant cells are able to withstand large quantities of calcium in their extracellular (Palta and Lee-Stadelmann, 1983).

2.6. Effect of calcium on the yield and Blossom end rot (BER) of tomato

Calcium is to be a beneficial treatment for addressing physiological disorders such as BER, enhancing fruit firmness, delaying the ripening process, and reducing ethylene production in tomato (Abbasi, 2021). Numerous other researchers concur that BER incidence peaks roughly two weeks after anthesis (Saure, 2001). Hagassou et al., (2019) proposed that there are three theories to explain the onset of BER. The first theory attributes the cause to a decrease in root uptake and abnormal regulation of calcium cellular partitioning. The second theory suggests that an increased vulnerability to various stresses due to elevated levels of active gibberellins (GAs) and reduced Ca^{2+} , leads to heightened cell membrane permeability and thirst theory suggests that abiotic stresses, or elevated NH_4 levels, which result in the production of reactive oxygen species and eventual breakdown of membranes and loss of cell turgor, play a primary role.

According to Saure, (2014) BER occurs in tomato and pepper fruits. Interestingly, the depletion of water-soluble Ca^{2+} in the fruit's apoplastic pool has only been obtained after BER symptoms become visible. In contrast, In the initial phases of BER formation in fruits, the distribution and concentration of Ca^{2+} remain similar to that of healthy fruit. The main causes of BER are the effects of abiotic stress factors, such as salinity, drought, light intensity, heat, and ammonia nutrition. These factors lead to an increase in reactive oxygen species (ROS), resulting in elevated oxidative stress and ultimately cell death. The cell death process involves the breakdown of the plasma membrane, tonoplast, and endoplasmic reticulum, which occurs before the leakage of ions, including Ca^{2+} , and the loss of turgor. Reitz et al., (2021) studied the effect of different levels of calcium chloride on processing tomato plants that were highly susceptible to BER. The study applied four levels of calcium chloride (0 ppm, 10 ppm, 100 ppm, and 500 ppm) daily to the plants, starting from the first flowering stage. The fruit was then harvested 21 to 22 days after pollination. The results showed that the 10 ppm treatment had the lowest occurrence and riskiness of BER. In contrast, the highest incidence of BER was observed in the 0 ppm treatment, and the severity was significantly higher in the 500 ppm and 0 ppm treatments compared to the 10 ppm CaCl_2 treatment. Nonami et al., (1995) found that more levels of calcium were found in tomato affected by BER

compared to normal fruit. This suggests that the reason for the occurrence of BER is due to genetic differences between cultivars, rather than a difference in calcium nutrition.

Mazumder et al., (2021) conducted a study on the impact of different concentrations of CaCl_2 on four tomato varieties, named MT-1, MT-3, 303, and 105. The tomato plants were sprayed with CaCl_2 solutions at concentrations of 0.0%, 1.0%, 1.5%, and 2.0% (w/v). They found that spraying with 2% CaCl_2 improved the control of physiological disorders such as BER and reduced weight loss. Furthermore, the highest concentration of CaCl_2 (2%) raised the total ascorbic acid (AA), lycopene content, total phenolic content (TPC), and antioxidant activity (DPPH) compared to the lesser doses and control tomato. Among the four tomato varieties, MT-3 showed the best response to higher doses of CaCl_2 (2%) in terms of growth, yield, disease and insect resistance, quality, and shelf-life performance, compared to the other varieties and CaCl_2 treatment combinations. Hadi et al., (1996) studied different doses of CaCl_2 on the incidence of (BER) in three tomato cultivars, named Mountain Supreme, Celebrity, and Sunrise. Three levels of CaCl_2 were applied, representing very deficient (20 ppm), normal (200 ppm), and very high (1000 ppm) levels of calcium. The results showed that Yield and average fruit weight were significantly different amongst cultivars, but not BER or leaf calcium content. The incidence of BER was 95% higher in the low calcium treatment compared to the medium calcium treatment. However, there was no significant difference in BER between the medium and high calcium treatments.

Borkowski, (1983) the study was carried out to determine the calcium level of tomato fruits in their various stages of growth. The results showed that the highest content of calcium was in the smallest and youngest fruits, averaging 317 mg Ca/kg. The calcium content of fruits 15 and 65 days old was slightly lower, while the lowest level of calcium was found in fruits 35 days old, at 244 mg Ca/kg. These findings suggest that calcium uptake by tomato fruits is permanent during ripening, but during rapid growth, calcium uptake may be lesser than fruit growth, causing a decrease in calcium content. This stage of development may also result in increased susceptibility to BER. The study also showed that sprays of fruits with 0.5% calcium chloride ($\text{CaCl}_2 \times 2\text{H}_2\text{O}$) or calcium nitrogen can control BER appearance. These sprays decreased the number of fruits

affected by BER by about six times and increased the calcium content of the fruits by as much as two times.

Vinh et al., (2018) conducted a study on different tomato cultivars of varying fruit sizes, comparing 'Momotaro Fight' and 'Cindy Sweet' in four growing seasons. During the spring and summer, BER incidence was higher in 'Momotaro Fight' (60%) compared to 'Cindy Sweet' (10%) when plants were fed low calcium. BER was rarely observed when water-soluble calcium was above $0.30 \mu\text{mol}\cdot\text{g}^{-1}$ FW, and both cultivars had an increase in BER incidence with decreasing water-soluble calcium concentration. The fruit growth rate was more robust in 'Momotaro Fight' than in 'Cindy Sweet', particularly in the summer. Sturiao et al., (2020) examined the effect of different calcium concentrations (0.5, 1.5, 3.0, 6.0 and 10.0 mmol L^{-1}) at different time intervals (57, 84, 97 and 115 days after sowing) on cherry tomato cultivar Iracema. They found that the optimal calcium concentration for the best growth and yield of Iracema was between 6.0 and 7.0 mmol L^{-1} . Additionally, they discovered that a calcium deficiency does not always result in BER symptoms. Dorais et al., (1998) emphasized that applying calcium bi-weekly is crucial in preventing BER.

2.7. Salinity

Various salts present in the soil provide essential nutrients to plants. However, an excess of salt in the soil can disrupt water absorption. Saline or salty soils can arise from different sources of salt ions. Sodium chloride (NaCl) is an example of a salt that hinders the ability of plant roots to absorb water from the soil. Each salt molecule consists of a positively charged sodium ion and a negatively charged chlorine ion. On the other hand, water is composed of two hydrogen atoms and one oxygen atom, forming a polar molecule with positive and negative ends. Similarly, salt molecules and water molecules are polar and can bind together, with multiple water molecules binding to one salt molecule. When salt comes into contact with water in the soil, the negatively charged ions of the salt, such as chloride, attract the positively charged hydrogen of the water, while the positively charged side of the salt attracts the negatively charged oxygen of the water. Plant roots need to absorb water from the soil, but when there is an excess of salt in the soil, much of the water becomes bound to the salt, making it

unavailable for the roots to utilize. This can ultimately lead to the death of the plant. Salt toxicity has both osmotic and ionic components, which can severely affect the growth of roots and shoots.

The uptake of sodium ions (Na^+) across the plasma membrane happens rapidly, resulting in physiological effects on both extracellular and intracellular sites. Sodium reduces the binding of calcium ions (Ca^{2+}) to the plasma membrane, inhibits the influx of Ca^{2+} while increasing its efflux, and depletes the internal stores of Ca^{2+} from endomembranes. These changes in cellular Ca^{2+} homeostasis are considered the primary responses of root cells to salt stress. Salt rapidly reduces the transfer of Ca^{2+} to leaf cells, leading to a decrease in Ca^{2+} activity and an increase in Na^+ activity in the apoplast of leaf cells. This reduction in Ca^{2+} serves as a signal that is transported to the leaves, potentially preceding or coinciding with the signal of limited water supply (Warrence et al., 2002).

The addition of supplemental calcium has ameliorative effects on salt stress by preventing Na^+ -related changes in cellular Ca^{2+} homeostasis. Due to inadequate irrigation and excessive use of chemicals on soil, soil salinity has risen over the years. As a result, it is projected that by 2050, more than half of the land currently available for agriculture will be lost to salinity, as stated in a study by (Hasanuzzaman et al., 2014). Many types of tomato varieties are sensitive to medium levels of salinity (Singh et al., 2012). Tomato varieties cultivated under 200 mM NaCl stress exhibited notable differences in the dry weights of shoots and roots. Nonetheless, there were no significant correlations observed between the dry weight of the shoot root and the evaluated scale classes, Na concentration, or ion ratios (Dasgan et al., 2002).

Plants respond to salinity in distinctive ways, categorizing them into glycophytes or halophytes. Halophytes, like *Seidlitzia rosmarinus*, are capable of tolerating high levels of sodium chloride (NaCl) and can survive in soils that are over two times more saline than seawater. High levels of NaCl can directly impact nutrient absorption in plants, such as reducing the uptake of calcium and nitrate by sodium and chloride ions, respectively. Salinity impedes plant growth mainly through three mechanisms: ion toxicity, osmotic stress, and nutritional imbalance (Patel et al., 2010).

2.8. Effect of salinity on vegetable crops

The growth and development of pepper plants are negatively impacted by the use of highly salty water for irrigation. This affects their ability to produce photosynthetic pigments and total phenols, resulting in decreased yields and quality (Hussein et al., 2012). Yasar and Uzal, (2020) reported that, increasing of Ca amount in water solution under salt stress reduced the the negative effects of salt. The presence of salt stress reduces the production of watermelon seedlings and decreases their growth, biomass, and overall quality (Sousa et al., 2023).

Cauliflower growth is primarily impacted by salinity when introduced during the early growth stage. The decrease in growth is primarily influenced by the specific ions present, although minor nutrient imbalances due to the antagonistic effects of Na^+ and Cl^- are also observed (Giuffrida et al., 2017).

Turhan et al., (2015) suggested that higher salinity levels negatively affect cucumber yield. Fruit weight, diameter, length, and water content remain unaffected by irrigation water salinity up to 1.7 and 2.7 dS m^{-1} . Soluble solids content improves with salinity up to 3.7 dS m^{-1} , but decreases with higher salinity levels. Soil salinity has a negative linear relationship with evapotranspiration. Optimal water use and irrigation water use efficiency are achieved at salinity levels of 0.3 and 1.7 dS m^{-1} . Cucumbers can be grown using irrigation water with a salinity level of up to 1.47 dS m^{-1} . In their study, Çiçek and Çakırlar (2002) found that exposure to salt stress led to a notable reduction in shoot length, fresh and dry weights of the shoot, as well as the leaf area of both maize cultivars. As the level of stress increased, these negative effects became more pronounced.

In a study conducted by Saberi, (2011) the impact of salinity and irrigation frequency on two forage sorghum varieties, Speedfeed and KFS4, was investigated. The sorghum plants were subjected to different salinity levels (0, 5, 10, and 15 dS/m) and varying irrigation frequencies. The results indicated that salinity, irrigation frequency, and variety all had a significant influence on the number of ratoon tillers. As salinity levels increased and irrigation frequency decreased, the number of tillers decreased. Additionally, the Speedfeed variety displayed a higher number of tillers compared to the KFS4 variety.

2.9. Effect of salinity on the quality and yield of tomato

The presence of salt in the soil is one of the most significant problems faced by horticultural producers, such as those who grow tomatoes. Salinity is becoming a growing concern for irrigated agriculture in tropical and subtropical regions. The intrusion of saltwater is on the rise worldwide, which poses a threat to coastal communities by polluting groundwater and decreasing its usefulness for consumption (Safi et al., 2018).

Tabatabaie et al., (2004) observed that a nutritional solution with a high EC (6 dS/m) will cause a rise in blossom, end rot (BER). The study conducted by Ehret and Ho, (1986) also reported that the tomato plant did not experience any significant reduction in crop yield at salinity levels above 7 dS/m. This could be due to the low intensity of light and high relative humidity levels that were present during the experiments, which could have had a positive impact on the plant's ability to withstand the high salinity levels. However, when salinity is applied during the day or in the spring or summer season, the resulting yield reductions are more severe than during the night or in autumn cultivation.

Johnson et al., (1992) found that in the summer, lower relative humidity and higher illumination and temperatures can lead to a decrease in water potential in the plant due to faster transpiration. In addition to this, high salinity can also decrease the water potential in the plant, resulting in a decrease in water flow into the fruit and a reduction in the rate of fruit expansion. These factors could further exacerbate the impact of high salinity levels on tomato yield, especially during the summer season.

Cuartero and Soria, (1997) observed that the yield of tomatoes can be adversely affected either by a decrease in the average weight of the fruit or by a decrease in the number of fruits produced by the plant. When the electrical conductivity levels are relatively low, the yield reduction is primarily caused by a decrease in the average fruit weight, while the number of fruits produced remains unaffected. However, as the EC levels increase, the decline in the number of fruits produced becomes the main reason for the reduction in yield. Pasternak et al., (1979) reported that the presence of salt can cause a decrease in the flowering of tomato plants. Cruz and Cuartero, (1990) investigated the effect of salinity on the number of fruits produced by tomato plants under different levels of

salinity. Their observations indicated that salinity had a negative impact on the number of fruits produced by each plant. As the level of salt increased, the number of fruits produced by each plant gradually decreased.

Cruz et al., (1990) found that salinity stress hurts tomato plants, leading to a decrease in shoot dry weight. This is commonly used as an indicator of salt tolerance in tomato studies. Cuartero and Fernandez, (1999) investigated the effects of NaCl salinity stress on the growth of tomato plants. They reported that the stress resulted in lower fresh and dry weights of the plants.

According to a study by Rafat and Rafiq, (2009) increase in salinity levels up to 0.4% sea salt solution ($\text{EC } 5.4 \text{ dSm}^{-1}$) led to a proportional decrease in the total chlorophyll content in tomato plants. This indicates that salinity has a negative impact on the plant's photosynthetic process. Another study by Agius et al., (2022) showed that higher salinity levels of 17 and 34 mM led to a decline in yield of cherry tomato. However, interestingly, the quality of the tomato actually improved with higher levels of salinity. This was evidenced by the higher levels of total soluble solids, fructose, and glucose in the fruit. These results suggest that although high levels of salinity can negatively impact the yield of cherry tomatoes, it can also have a positive effect on the fruit's quality.

According to Beckles, (2012) there is a relationship between the electrical conductivity (EC) of soil and the sugar concentration of fruits. In particular, the application of a high ionic solution or a reduction in watering, both of which can increase the EC of soil, can lead to an increase in the sugar concentration per fruit. The study aimed to uncover the mechanism responsible for this increase in soluble sugar content under saline water irrigation.

According to Bolarin et al., (1993) all stages of tomato plant growth, including seed germination, vegetative growth, and reproduction, are sensitive to salt stress. This sensitivity results in a reduction of economic yield when plants are exposed to salt stress. Adams and Ho, (1989) conducted three different experiments at different times. They found that both high salinity levels and long salinization periods reduced the number of clusters per plant in tomato. In other words, salinity negatively affected the plant's ability to produce a high number of clusters, which is crucial for achieving a desirable yield. These findings emphasize the importance of managing salinity levels

and exposure time during tomato cultivation to achieve maximum economic yield. Hajer et al., (2006) conducted two separate experiments on tomato grown under saline conditions and found that increased salinity resulted in a decrease in fruit yield in both cases. In other words, the higher the salinity levels, the lower the fruit yield.

According to Fawzy et al., (2019) while salinity is generally thought to have a negative impact on the yield of tomato crops, it has also been found to have positive effects on the flavor of the fruit. Salinity has been reported to have positive effects on the growth of many vegetable crops. Despite the adverse impact of salt stress on the yield traits of tomato, it appears that there is a beneficial and positive effect on the flavor of the fruit.

Zhang et al., (2016) found that salinity has a negative impact on tomato plant growth and development. Specifically, they observed that salinity reduces the rate of root elongation and lateral root growth, which is caused by restrictions in root cell growth and increased root lesions. Salinity stress also leads to reductions in tomato leaf size, shoot height, and stem diameter due to a decrease in photosynthesis, tissue expansion, and cell division. Additionally, salinity causes a decrease in leaf chlorophyll content, stomata resistance, and photosynthetic activities. As salinity increases to 5 dS m⁻¹ and beyond, there is a significant reduction in tomato yield, with a 7.2% decrease per unit increase in salinity. The osmotic effect of salinity can also reduce root water uptake, leading to water stress in the plant. However, it is worth noting that fruit quality is the only factor that appears to benefit from increased salinity.

Shalhevet and Yaron, (1973) discovered that an increase in salinity led to a corresponding increase in the total soluble solids content, which helped offset the decrease in yield to some extent. The reduction in water uptake due to soil salinity had a direct correlation with the reduction in fruit yield. Santos et al., (2017) proposed that an increase in salinity caused a rise in the levels of sodium and chlorine, while simultaneously leading to a decrease in the concentrations of potassium and nitrogen in the leaf tissue.

Zhang et al., (2017) investigated the effects of salinity stress on tomato plants by subjecting them to six different salinity levels, (0.78, 0.91, 1.10, 1.26, 1.41 and 1.58 dS m⁻¹). The study found that as salinity levels increased to 1.58 dS m⁻¹, plant fresh weight, leaf chlorophyll, and dry weight were all significantly impacted. Salinity stress also had a significant effect on tomato yield when the electrical conductivity (EC)

reached 1.41 dS m^{-1} , with yield being more sensitive to salinity stress than growth variables. Interestingly, the study also found that fruit quality improved with increasing salinity, indicating a positive correlation between salinity and fruit quality. Leaf chlorophyll was identified as the most sensitive indicator for salinity stress, and the salinity threshold for achieving higher fruit quality and yield was determined to be 1.41 dS m^{-1} .

Turhan, (2020) conducted a study that found that salinity levels greater than 2.6 dS m^{-1} had a significant negative impact on the marketable and paste yield of tomato plants. In terms of tomato fruit characteristics, the study showed that at 6.6 dS m^{-1} , the levels of soluble solids content and total sugar content increased significantly, whereas the water content and lycopene content increased significantly at 4.6 dS m^{-1} . However, these values decreased significantly once the salinity levels exceeded the aforementioned levels. Furthermore, the study identified a positive correlation between the total acid contents of the tomato fruit and the salinity levels, meaning that the total acid values of the fruit increased as the salt concentrations increased. In a study conducted by Sridevi, (2020) observed that an increase in salt concentration in saline irrigation water resulted in a decrease in yield. The study found that the maximum salinity tolerance for the crops being tested was 2 dS m^{-1} , meaning that any concentration of salt in the irrigation water above this level would result in a significant reduction in yield.

Shao and Chen, (2013) use of saline water with an electrical conductivity as low as 4 dS/m can result in a significant increase in BER in crops. The study also found that there is a positive correlation between the salinity of irrigation water and the incidence of BER, meaning that as the salinity of the water increases, so does the likelihood of BER occurring. Specifically, the study observed that irrigation water with a salinity level of $4\text{-}5.5 \text{ dS/m}$ resulted in an increase in the occurrence of BER. Tüzel et al., (2000) found that raising the EC levels of the nutrient solution led to a decrease in both the crop yield and fruit size, while also causing an increase in the occurrence of BER. Nevertheless, the fruit's EC, total soluble solids, TA, and DM (dry matter) contents exhibited an upward trend with the increasing EC levels.

Zhai et al., (2015) tomato productivity was significantly reduced in 2013 when irrigation water with a salinity level above 4.5 dS/m was used. The same trend was observed in 2012 and 2014, with the most significant reduction in yield occurring at a

salinity level of 5.5 dS/m, resulting in a 32.3% lower yield compared to the control. Mitchell et al., (1991) studied the effects of irrigation with saline water and water deficit on the growth and quality of fruit. They found that irrigation with saline water did not have a significant impact on the total yield of fresh fruit or the concentration of hexose, a type of sugar, but it did slightly reduce the water content of the fruit. As a result, the concentration of inorganic ions increased in the fruit. Neither irrigation practice affected fruit set or marketable soluble solids, which is the product of marketable red fruit yield and percent soluble solids. Water deficit and salinity, however, increased the concentration of starch during early fruit development. Nonetheless, at maturity, the concentration of starch decreased to less than 1%, regardless of treatment. Water deficit irrigation and irrigation with saline water also led to higher concentrations of fruit acids compared to the control.

Zhang et al., (2017) conducted a study to investigate the effects of short-term salinity stress on tomato growth, water use efficiency (WUE), yield, and fruit quality. The researchers found that salinity stress lasting less than 21 days during any growth stage did not have a significant impact on tomato growth or WUE. In addition, salinity stress during the vegetative stage did not affect the yield of tomato plants. However, salinity stress during the flowering and fruiting stages led to a decrease in tomato yield. This reduction in yield was primarily caused by a decrease in the number of fruits produced, rather than a decrease in the size of individual fruits. Interestingly, the study also found that exposure to salt during the fruiting stage actually resulted in an improvement in fruit quality.

Habibi et al., (2021) conducted a study to investigate the effects of four different salt treatments (50, 100, 150, and 200 mM) as well as a control group with no sodium chloride. In the initial experiment, the researchers found that saline conditions significantly reduced the germination rate, shoot length, and root length of the plants. In the second experiment, the seeds were first grown in vermiculite before being transplanted into a hydroponic system where they were exposed to different salt treatments. The study found that salinity, at the levels tested, had a negative impact on several aspects of plant growth including plant height, root length, the number of flowers, photosynthetic rate, transpiration rate, and stomatal conductance. In a study conducted by Mizrahi, (1982) plants were treated with 3 to 6 grams of NaCl per liter at

the anthesis stage. The results showed that salinity had a significant impact on the development of fruits, shortening their development time by 4 to 15%. Despite the smaller size of the fruits from salt-treated plants, they had a better taste than those from the control group. The fruits from the salt-treated plants also had a higher percentage of dry weight, total soluble solids, and titratable acidity, as well as a higher content of reducing sugars, Cl, Na, and various pericarp pigments. In addition, the electrical conductivity of the juice was higher in fruits from salt-treated plants compared to those from the control group, while the pH was lesser.

Sakamoto et al., (1999) conducted an experiment where tomatoes were exposed to two levels of salinity (EC) 5.0 dS m^{-1} and 8.0 dS m^{-1} at two different stages of fruit ripening: immature green stage and decolouring stage. The study found that increasing salinity during the immature green stage led to a greater improvement in fruit quality than increasing salinity during the decolouring stage, but it also resulted in a decrease in fruit yield. The decrease in yield was attributed to a reduction in fruit weight but not in fruit number. Salinity was found to increase the concentration of soluble solids, citrate, and ascorbic acid in the tomato. Singh et al., (2012) conducted a study using ten genetically diverse tomato genotypes, and exposed them to three different salinity levels (control, 1.0% NaCl, and 3.0% NaCl) using Hoagland's solution. The researchers found that as the salt concentration increased, the growth and development of tomato plants were negatively affected. Specifically, higher salt levels led to a decrease in seed germination and a longer time required for germination. Additionally, the root-to-shoot dry weight ratio increased, and the Na^+ content increased while the K^+ content decreased. The highest salinity level (4 dS m^{-1}) had the most detrimental effect on the germination of tomato varieties. However, among the different genotypes, Sel-7, Arka Vikas, and their crosses were found to be the more tolerant genotypes.

Adilu and Gebre, (2021) conducted an experiment using four tomato varieties (Sirinka, Weyno, ARP D2, and Roma VF) and five different salinity levels (1 dS m^{-1} , 2 dS m^{-1} , 3 dS m^{-1} , 4 dS m^{-1} , and control) to observe their effects on germination. The results showed that ARP D2 variety had the shortest mean germination time, highest mean germination rate, and highest speed of germination in the control treatment. The variety also had the lowest first and last days of germination, and the lowest uncertainty of germination. However, as the salinity levels increased, the days of germination and the

uncertainty of germination increased, while the germination index and total germination percentage decreased across all varieties.

Rahman et al., (2018) conducted a study on five different varieties of tomato plants from the Bangladesh Agricultural Research Institute (BARI-T 1, BARI-T 2, BARI-T 3, BARI-T 4, and BARI-T 5) to observe the effect of NaCl-salinity levels (2, 4, 6, and 8 dS/m) on their morphological properties and yield. The plants were irrigated with saline water, and their number of leaves, leaf length, leaf width, number of days to flowering, number of flowers, and number of branches were recorded. The study found that increasing NaCl salinity levels had a significant impact on the morphological properties of all the tomato plants, except for the number of days to flowering. Furthermore, the yield of the tomato plants was significantly reduced when compared to the control group that was irrigated with tap water (0.043 dS/m). Cuartero and Fernandez-Munoz, (1998) have put forward the suggestion that the yield of plants can be significantly reduced when grown using a nutrient solution that has an electrical conductivity (EC) of 2.5 dS/m or higher. They found that when the EC increased above 3.0 dS/m, there was a $9\pm 10\%$ reduction in yield for every increase of 1 dS/m. When the EC levels are relatively low, the reduction in yield is primarily due to a decrease in the average fruit weight, while the decline in the number of fruits produced explains most of the yield reduction at higher EC levels. It has been observed that small-sized tomatoes are less affected by salt-induced reductions in fruit weight, and hence, they can be grown at moderate salinity levels. Kayees et al., (2016) conducted a study on the effects of different salinity levels on the growth and development of tomato seedlings. The researchers used five different salinity levels, including a control group with no salt and levels of 4, 8, 12, and 16 dS m⁻¹. The results showed that increasing salinity negatively impacted the emergence percentage, radicle length, and plumule length of the seedlings. As salinity levels increased, the Na⁺ content of the plants increased, while the K⁺ content decreased.

Kada et al., (2022) also conducted a study to examine the effects of salt stress and salinity treatments on tomato plants. The study used four different levels of NaCl, including a control group with no salt, as well as levels of 75 mM, 145 mM, and 200 mM. The results showed that all treatments had a significant impact on the measured parameters, with the effects being more pronounced at higher salt concentrations,

particularly at 200 mM. The study found that tomato plants exhibit different modes of adaptation to saline stress, including morphological adaptations such as a decrease in leaf area, physiological adaptations such as a reduction in net CO₂ assimilation rate, stomatal conductance, transpiration, and Rwc, as well as biochemical adaptations such as a decrease in chlorophyll content.

In their study, Ahmed et al., (2017) investigated the effects of different salinity levels on tomato plants. The treatments included irrigation with fresh water (control) and four levels of salinity: 4 dS m⁻¹, 6 dS m⁻¹, 8 dS m⁻¹, and 10 dS m⁻¹. They found that the plants irrigated with fresh water had the highest fruit yield per plant (1.52 kg) while the lowest yield (0.667 kg) was obtained from the highest level of saline water treatment (10 dS m⁻¹). Moreover, the effective treatment for the highest total fruit yield (36.57 t ha⁻¹) was the control treatment (irrigation with fresh water), while the lowest fruit yield (21.87 t ha⁻¹) was observed in the treatment with the highest salinity level (10 dS m⁻¹). The different salinity levels also significantly affected the total soluble solid content with the highest level (2.53) observed in the treatment the highest salinity level (10 dS m⁻¹), and the lowest level (2.00) in the control.

Rani et al., (2017) conducted a study on the effects of salinity on tomato plants, where four different levels of salinity (2, 4, 6, and 8 dS/m) were tested along with a control group. The results showed that as the level of salinity increased from 0 to 8 dS/m, there was a decrease in plant height, chlorophyll content, and photochemical efficiency of the tomato plants. Interestingly, the plants that were salinized with sulphate had better vegetative growth compared to those that were salinized with chloride. Additionally, the total chlorophyll concentration in the leaves of the tomato plants was significantly reduced under salt stress.

El-Mogy et al., (2018) investigated the impact of different levels of sodium chloride (NaCl) on the genes of cherry tomato (*Solanum lycopersicum* L), cv. west Virginia 106, grown in a glasshouse. The plants were irrigated with various concentrations of NaCl, including 0, 25, 50, 75, 100, and 150 mM. The results showed that the plants treated with 75, 100, and 150 mM NaCl had shorter heights, reduced stem width, lower plant dry weight, fewer flowers, and smaller leaf area, which led to decreased yield. Furthermore, the fruit weight and number were negatively affected by the treatments with 50 mM NaCl or higher. However, the salinity treatment resulted in fruit with an

improved taste, including increased total soluble solids, titratable acidity, and firmness. The study found that cherry tomato plants treated with 25 mM NaCl produced higher quality fruit without compromising the yield, while the improved fruit quality at 50 and 75 mM NaCl was accompanied by a reduction in yield.

Cuartero & Fernandez-Munoz, (1998) conducted a study on three cultivars of tomato, namely Dart, Robin, and Tomito, to investigate the effect of salinity on fruit yield and quality. The three cultivars were grown under three different salinity levels, including 0.5, and 4 and 8 dS m⁻¹, respectively. The results showed that Robin had a lower salinity tolerance, as it exhibited a greater decrease in fruit mean weight compared to the other two cultivars, which had smaller fruits. Furthermore, an increase in fruit dry matter and total soluble solids was observed with an increase in salinity. BER increased in Tomito and Robin from 0.5% under control conditions to 7.7% under 8 dS m⁻¹ salinity, but the difference was not statistically significant. In contrast, Dart, a cultivar with elongated fruit, showed a significant increase in BER, from 0.8% under control conditions to 19.5% under 8 dS m⁻¹ salinity.

2.10. Effect of calcium and salinity on the yield and quality of tomato

Supplementary calcium was found to counteract the harmful impacts of sodium on the membranes of root cells. The negative effects of salinity were observed to have a greater effect on the integrity of the cell membrane as opposed to the root hydraulic conductance. Therefore, it can be inferred that salinity, along with additional calcium, primarily impacts the symplastic water transport pathway, rather than the apoplastic water transport pathway (Azaizeh et al., 1992).

The primary function of calcium in enhancing the ability of plants to tolerate high levels of salt is connected to its capacity to limit the movement of sodium into the xylem, resulting in a reduction of the concentration of sodium in the plant's shoot (Husain et al., 2004).

Plant growth and survival under conditions of high salinity can be protected by the presence of calcium (Davenport et al., 2005). The optimal range for external Ca²⁺ concentration required for maximum growth in saline environments typically falls

between 5 and 10 mM Ca^{2+} , with some variation depending on both the salinity level and the specific genotype of the plant (Cramer, 2002).

In a study conducted by Lolaei et al., (2012) used four different levels of NaCl (0, 50, 100, and 150 mM) and four levels of CaCl_2 (0, 100, 200, and 300 mg L^{-1}) were examined. The findings revealed that salinity stress led to a decline in fruit yield, whereas an increase in the concentration of Ca^{2+} in the nutrient solution resulted in higher fruit yield. Furthermore, under conditions of salinity stress, leaf content of Ca^{2+} , K, and N declined. Overall, the experiment demonstrated that exposure to salinity stress had a substantial negative impact on plant growth, leaf count, and fruit weight. In their study, Parvin et al., (2015) investigated the effects of five different salinity levels (0, 2, 4, 6 and 8 dS m^{-1}) and three levels of Ca^{2+} (0, 5 and 10 mM). The application of calcium to salinized plants led to a modest improvement in tomato fruit production in the presence of salinity stress. Thus, this experiment suggests that Calcium can be an effective means of mitigating the detrimental effects of Na^+ stress on tomato cultivation. The highest number of fruits per plant (34.65) was observed in the 10 mM Ca treatment, while the lowest value (33.15) was recorded for the 5 mM Ca treatment. Moreover, an increase in calcium concentration was associated with an increase in the number of fruits produced by tomato plants. The study also revealed that salinity stress significantly reduced plant growth, leaf count, and fruit weight.

Rab et al., (2017) conducted an experiment in which tomato plants were exposed to three different levels of salinity (0, 75, and 150 mM), and foliar application of calcium solutions at six different concentrations (0.0, 0.25, 0.50, 0.75, 1.0 and 1.25%). The results of the study showed that the interaction between salinity and calcium had a significant impact on the yield and incidence of BER in tomato fruits. Specifically, the yield of tomato plants decreased with an increase in salinity levels, but this decrease was less pronounced when foliar calcium application was used. Additionally, while salinity increased the incidence of BER in tomato plants, the increase in BER was lower in plants that received calcium application compared to the control plants. These findings suggest that foliar calcium application can be an effective means of mitigating the negative impact of salinity on tomato yield and BER incidence. Küçükçelik, (2013) suggested that applied solutions of calcium nitrate ($\text{Ca}(\text{NO}_3)_2$) to the fruits of two different tomato cultivars, Alsancak F_1 and Swanson F_1 , using concentrations of 0.00%,

0.25%, and 0.75% (w/v). The results showed that the use of Swanson F₁ with perlite medium was ideal for achieving early growth, while Alsancak F₁ was better for reducing BER and the number of cracked fruits, as well as decreasing the percentage of BER in terms of numbers. Growing Alsancak F₁ in perlite was found to be the most effective for achieving a higher percentage of marketable yield in terms of weight. Interestingly, the effects of different calcium levels on preventing BER and cracked fruits were not found to be statistically significant. Ehret, (1986) reported that the reason for the increase in BER incidence (BER) in tomatoes under high soil salinity is due to the difficulty that calcium faces in moving from the root of the tomato plant to the fruit. Soria et al., (2000) conducted a study in two growing seasons, winter and spring-summer, using two concentrations of NaCl and three concentrations of CaCl₂. The results showed that tomato yield was reduced more by NaCl in the spring-summer season (70%) than in the winter season (55%). While increased Ca fertilization did not affect the yield of NaCl-treated plants in winter, a 60% increase in yield was observed in spring-summer by increasing Ca from 4 to 6 mM. This increase in yield was due to the larger size of fruits, but not to a higher number of fruits. The study found a significant increase in °Brix with NaCl treatments, with a higher increase in spring-summer (60%) than in winter (30%). In the winter season, no BER symptoms were observed, but in spring-summer, NaCl-treated plants showed a significant increase in BER.

In a study by Tanveer et al., (2020) tomato seeds and seedlings were treated with 100 mM NaCl and two different concentrations of calcium (5 and 10 mM). The results showed that the application of calcium significantly reduced the negative impact of salinity on both germination and growth. Increasing the concentration of calcium led to a significant increase in growth and germination, both in the salt-affected and control plants. In particular, 10 mM calcium was found to be the most effective, increasing the promptness index by 20.7%, seedling length, and improving root and shoot fresh and dry weight, relative water content, and leaf area. Similarly, 5 mM calcium also increased plant height and membrane stability index. These findings suggest that the application of Ca²⁺ can enhance the growth of tomato plants under saline conditions. Nizam et al., (2019) conducted an experiment in which they applied five different levels of salinity (measured by Na⁺ concentration) ranging from 0 to 8 dS m⁻¹ and three levels

of Ca^{2+} ranging from 0 to 10 mM. The findings of the study revealed that the application of Ca^{2+} significantly enhanced the yield and yield-contributing characteristics of tomato in both saline and non-saline conditions. The highest number of fruits per plant (50.8) and the highest yield per plant (3.88 kg) were obtained from plants grown in $0 \text{ dS m}^{-1} \text{ Na} \times 10 \text{ mM Ca}^{2+}$, whereas the lowest yields were obtained from plants grown in $8 \text{ dS m}^{-1} \times 0 \text{ mM Ca}^{2+}$. These results suggest that the addition of Ca^{2+} can effectively reduce the harmful effects of salt stress on tomato plants.

Tabatabaeian, (2014) conducted an experiment to investigate the effect of sodium chloride and calcium chloride concentrations on various growth parameters of plants. Four different levels of sodium chloride concentration (0, 30, 60 and 90 mmol) and four different levels of calcium chloride concentration (0, 10, 20 and 30 mmol) were used. The results showed that increasing salinity had a negative impact on the relative water content of tissues, cytoplasmic membrane stability, and chlorophyll concentration in leaves. The dry weight of roots and shoots also decreased with increasing salinity levels, and the worst performance was observed in the 90 mmol concentration of sodium chloride. The findings suggested that the growth of plants treated with calcium chloride or a combination of calcium and chloride solutions was better than those treated with sodium chloride. The 10 mmol concentration of calcium chloride was found to have a significant positive effect on mitigating the damage caused by salinity.

Ahmad, (2018) conducted a study using two cultivars, Pearl and MT1, in a soilless culture system with three different levels of NaCl (0, 70, and 140 mM) and three concentrations of calcium sulphate (0, 2.5 and 10 mM). The results showed that the addition of calcium significantly improved the growth of Pearl in terms of plant height, total leaf area, shoot and root dry weight, and shoot to root ratio, throughout the experiment. The concentration of potassium and calcium in the leaves of Pearl was also improved after the addition of calcium, which reduced the membrane permeability to Na and Cl. Fruit yield, total soluble solids, titratable acidity, ascorbic acid, and BER were all significantly improved at 10 mM CaSO_4 . Additionally, the supplementation of calcium was effective in reducing the accumulation of proline and MDA content by improving the activity of antioxidants. The study suggests that adding calcium to the nutrient solution can alleviate the negative effects of salt stress and improve the growth, yield, and quality of fruits in a soilless culture system.

Montesano and van Iersel, (2006) suggested that the decrease in leaf size and elongation rate caused by NaCl was due to osmotic effects rather than the presence of Na^+ . Extra Ca^{2+} in the nutrient solution did not prevent these effects. The negative correlation between plant dry mass and solution electrical conductivity indicates an osmotic effect. The study found that leaf area development, which was inhibited by high EC, was more important for dry matter accumulation than leaf photosynthesis, which was inhibited by high Na^+ . When 20 mM Ca^{2+} was added to the 70 mM NaCl solution, the Na^+ concentration in the leaf decreased from 79 to 24 $\text{mg}\cdot\text{g}^{-1}$, which may explain how Ca^{2+} alleviates Na^+ toxicity.

According to Vitart et al., (2001) increased concentrations of Ca^{2+} have the ability to decrease the permeability of the plasma membrane to Na^+ and alter the properties of the cell wall. This results in a decrease in the accumulation of Na^+ by passive influx. Forghani et al., (2021) discovered that the combination of 40 mM NaCl with $\text{Ca}(\text{NO}_3)_2$ led to a 23% reduction in Na^+ content compared to plants treated with 40 mM NaCl alone. The results indicated that the application of $\text{Ca}(\text{NO}_3)_2$ could potentially enhance the chlorophyll content, dry weight, and balance the ion distribution, thereby minimizing the negative impact of salt stress on tomato plants.

According to Tuna et al., (2007) suggested that adding calcium sulfate as a supplement to the nutrient solution that contains salt had a significant positive impact on the growth and physiological factors of tomato plants that were affected by salt stress. This included an increase in plant growth, fruit yield, and membrane permeability, as well as an increase in leaf potassium, calcium, and nitrogen levels. Additionally, the use of supplemental CaSO_4 helped to maintain membrane permeability, raise the concentration of Ca^{2+} , N, and K^+ while reducing the concentration of Na^+ in leaves. These effects resulted from cation competition in the root zone and could potentially provide a straightforward and cost-effective solution to the problems associated with tomato crop production that is caused by high salinity.

Adams, (1990) discovered that salinity from arsenic had a greater effect on reducing the calcium content of the distal tissue of the fruit compared to the other parts. Additionally, the ratio of sodium to calcium increased more quickly in the distal tissue. In the leaves, sodium accumulation was primarily concentrated in the petioles. As a result, the ratio of sodium to calcium increased more significantly in the petioles compared to the laminae

as the sodium levels increased. Manivannan et al., (2007) found that calcium has a beneficial effect in mitigating the negative impact of salt stress on plants. Specifically, calcium was found to increase the total dry weight of the plant by promoting vegetative growth El-Enany, (2001) reported that the beneficial effect of calcium in counteracting the harmful effects of sodium chloride (NaCl) on plants may be due to a reduction in the uptake of sodium and an increase in the water content of hypocotyls and cotyledonary cultures under a combination of Na and Ca.

Alam, (1999) reported that in specific saline soils, ion toxicity can have a more damaging effect under an alkaline pH. Manaa et al., (2013) Noted that the study found a significant positive effect of calcium on enhancing the salt tolerance of tomato plants. As a result, there is a need for further research into protein trafficking, calcium signal transduction, and molecular signaling in order to gain a better understanding of the metabolic processes that occur during fruit development and ripening under conditions of salt stress.

2.11. Interaction between calcium and macro nutrition

2.11.1. Interaction between calcium and Nitrogen

Calcium and nitrogen play an important role in the growth and development of tomato plants. Calcium is crucial for the formation of strong cell walls, while nitrogen is needed for the production of chlorophyll, which is essential for photosynthesis. A balance between these two elements is necessary for optimal growth, as an excess of nitrogen can lead to reduced calcium uptake, resulting in weak cell walls and poor fruit development. Conversely, a lack of nitrogen can cause stunted growth and chlorophyll deficiencies. Maintaining a balanced ratio of calcium to nitrogen is therefore essential for healthy tomato plant growth. The increased pH level in the soil caused by its calcium carbonate content limits the availability of micronutrients such as zinc, copper, and the total amount of nitrogen in the most distal part of the fruit. (Sturiao et al., 2020). In plants with an excessive amount of N, the roots have the greatest amount of Ca, which stays in the roots and does not move to the shoots. The balance of ions can be crucial for plant nutrition, as an increase in anion uptake can lead to an increase in

cation uptake and vice versa. This effect on nutrient uptake in plants based on ionic balance was seen in tomato (Mengel and Kirkby, 1978).

Bonomelli et al., (2021) used of excessive nitrogen fertilizers could cause an imbalance with other nutrients and negatively impact plant development and yield. The results indicate that an excess of ammonium has a damaging effect on plant growth and results in a lack of calcium. Additionally, a calcium deficiency not only affects calcium levels, but also restricts nitrogen uptake and decreases nitrogen concentration in the plant. Oversupply of ammonium has a significant inhibiting effect on calcium absorption. In addition, Gunes et al., (1998) could not discover any evidence that raising Ca levels had a detrimental impact on the amount of nitrogen found in the leaves, reported that Ca may strongly interact with NH_4 , causing a local Ca deficiency in fruit and indirectly stimulating BER induction, leading to a localized calcium deficiency in the fruit and indirectly causing the induction of BER. Sandoval-Villa et al., (2001) Found that The BER in a greenhouse increased linearly as the $\text{NH}_4^+:\text{NO}_3^-$ ratio increased.

Nukaya et al., (1994) the study investigated the effect of various levels of $\text{NH}_4\text{-N}$ (0, 0.7, 1.3, and 2.0 m/l) in the nutrient solution on calcium uptake and the incidence of two fruit disorders, BER and gold specks on tow cultivars June pink' and Momotaro. As the NH_4N concentration increased, the occurrence of BER increased while the presence of gold specks decreased. The percentage of fruits affected by both BER and gold specks was higher in the cultivar 'June pink' compared to 'Momotaro'. The Ca uptake by the plants tended to decrease as the NH_4N concentration in the nutrient solution increased in both cultivars. However, a higher occurrence of gold specks was observed to be correlated with higher Ca uptake by the plants.

Hartman et al., (1986) noted that as the ratio of NH_4^+ to NO_3^- in the nutrient solution increased, the occurrence of BER increased and the fruit size decreased greatly, however the proportion of Ca^{2+} in the fruit wasn't affected by NH_4^+ additions. Experiments conducted by Vielemeyer and Weissert in 1990 showed that the use of N fertilizers containing NH_4^+ N led to the greatest occurrence of BER. Nevertheless, the fruits' uptake of Ca was not hindered. Barker and Ready, (1994) found the Ca content in the fruit of plants grown with NH_4^+ was found to be lower than those grown with NO_3^- , but there was no variation in the percentage of Ca based on the levels of NH_4^+ and

There was no discernible change in the amount of Ca present in fruit with or without BER.

Gholamnejad et al., (2000) conducted an experiment to grow tomato fruits using different nitrogen ratios (1:0, 3:1, 1:1 and 1:3) and three different calcium concentrations (2, 4, and 8 mmol/l). According to the findings, the application of calcium led to an increase in the amount of calcium found in the fruits, as well as an increase in yield, total amino acid, and auxin hormone levels. The fruits that were subjected to the 1:0 and 3:1 treatments each had a nitrate and ammonium content that was significantly higher than that of the other fruits. The calcium levels increased and nitrate accumulation decreased in the presence of 8 mmol/L calcium and a 100:0 ratio of NO_3 to NH_4 .

Gunes et al., (1998) Reported that Calcium application was found to increase the concentrations of Ca and N while decreasing the amounts of P, Mg, Fe, Zn, and Mn. Abdelhameed et al., (2018) suggested that the greatest nitrogen content in tomato leaves was recorded through the use of calcium application via a foliar method, and the increase in nitrogen content was the greatest when less calcium was applied through foliar application. Assunção et al., (2020) discovered that the addition of calcium and ammonium nitrate produced stronger fruits.

Dekock et al., (1979) when ammonium nitrogen was used, there was a high rate of BER. When ammonium nitrate or urea was used, the incidence of BER was intermediate. Ammonium nitrogen caused a high rate of BER. The condition improved in proportion to the amount of calcium present. An analysis of the blossom-end of tomatoes suffering from BER and those that were healthy showed that in the BER tissues, the amounts of calcium and iron were decreased, but the quantities of potassium, phosphorus, and the potassium ratio were increased.

In a study conducted by Wilcox et al., (1973) the authors proposed that the addition of ammonium-nitrogen ($\text{NH}_4\text{-N}$) can negatively impact calcium (Ca) absorption, leading to a deficiency of calcium in the plant. This calcium deficiency, in turn, results in the development of BER in tomato fruits. The study found that the addition of 112 ppm N or 224 ppm N of $\text{NH}_4\text{-N}$ during the fruiting stage rapidly induced the development of BER in the tomato fruit. In other words, the researchers found that the presence of high

levels of ammonium-nitrogen in the plant environment can negatively affect the calcium levels, causing BER to develop in the tomato fruit.

2.11.2. Interaction between calcium and potassium

In tomato plants, calcium and potassium can have an antagonistic relationship, meaning that the uptake and utilization of one mineral can affect the availability and uptake of the other. High levels of potassium can reduce the absorption of calcium in the plant, leading to a calcium deficiency, while high levels of calcium can limit the uptake of potassium, leading to a potassium deficiency. These imbalances can result in problems such as BER in tomato and other symptoms such as stunted growth, yellowing leaves, and poor fruit development. To achieve optimal growth and health, tomato plants need to have a balanced supply of both calcium and potassium (Taylor et al., 2004).

Potassium and calcium are the two most prevalent inorganic substances found in plant water cellular environments. K is the second most essential nutrient in leaf biomass after nitrogen, which emphasizes its crucial role and unavoidable significance in the functioning of plants. At the community level of plants, K^+ also plays a limiting factor in the growth of the community (Tripler et al., 2009).

In a study conducted by Peyvast et al., (2009) different amounts of calcium nitrate (4, 6, and 8 mmolL⁻¹) and potassium phosphate (2, 4, and 6 mmolL⁻¹) were applied to tomato crops. The results showed that the tomato plants fertilized with 6 mmolL⁻¹ of calcium nitrate and 4 mmolL⁻¹ of potassium phosphate had a higher quality compared to the other treatments. Sardans and Peñuelas, (2015) reported that the movement of calcium (Ca^{2+}) ions is impacted by the presence of high levels of potassium (K^+) ions, not only in the soil but also within the plants themselves. The high concentration of K^+ ions can affect the distribution of calcium and worsen calcium deficiencies.

According to a study conducted by Voogt, (1998) found that high levels of potassium present in the root zone can negatively impact the ability of plants to absorb calcium. This interference can potentially lead to decreased calcium uptake. Also, reported that if the potassium-to-calcium ratio is very low, it can potentially have a negative impact on the yield of tomatoes. This could lead to reduced production of tomatoes in areas where the soil has a low K:Ca ratio.

According to a study conducted by Ananthanarayana and Hanumantharaju, (1992) it was suggested that if the amount of calcium is optimal, it can lead to an increase in the availability of interchangeable and water-soluble potassium. This could result in better uptake and utilization of potassium by plants, potentially leading to increased plant growth and yield.

Paiva et al., (1998) reported that when there is an excessive amount of calcium in the soil, it can lead to decreased potassium absorption because of competition between the two ions. Bar-Tal & Pressman, (1996) found that Raising the K concentration from 5.0 to 10 mmol/L resulted in a decreased marketable yield because of a rise in the frequency of BER. When the roots were restricted, the K concentration and K/Ca ratio in the tomato plant parts decreased, but it did not impact the rate of K uptake per unit of root fresh weight. By raising the K concentration from 2.5 to 10 mmol/L, the K concentration in the plant parts and the rate of K uptake increased, but the Calcium concentration decreased. On the other hand, increasing the Calcium concentration in the solution had no impact on either the K concentration in plant parts or the K uptake rate. The frequency of BER had a strong correlation with the K/Ca concentration ratio in the leaves, but a weak correlation was seen with the K/Ca concentration ratio in ripe fruit. Lucas, (2015) reported that Excessive moisture in the soil intensified the disorder likely due to the faster movement of potassium ions compared to the slower movement of calcium ions. Vegetable calcium deficiencies are frequently linked to potassium nutrition. Some vegetable disorders related to potassium nutrition include blossom end-rot in tomato and peppers.

Tadesse & Nichols, (2003) suggested that an effort was made to reduce BER by adding 10.0 mS cm⁻¹ substituted calcium in place of some of the potassium in the nutrient solution. The incidence of BER was reduced by incorporating additional calcium in the nutrient solution. According to the study by Dorais et al., (2001) fruit quality can be enhanced and the incidence of BER can be averted by properly regulating the ratios of different cations. The authors found a correlation between high BER and high potassium to calcium ratios in leaves, but not in mature fruit. When the calcium ratio is low compared to potassium, the plant becomes susceptible to BER due to high levels of organic acids in the fruit. These high concentrations of organic acids decrease the absorption and accessibility of calcium. Islam et al., (2019); Armstrong & Kirkby,

(1979) the findings showed that a rise in potassium levels led to a decrease in calcium content, which could be the result of the unfavorable interaction between potassium and calcium in tomato.

Rajabipour et al., (2004) reported that the best skin strength was achieved when 160 kilograms per hectare of potassium (K) and calcium (Ca) were applied every two weeks as recommended. However, using double the recommended levels of K and Ca, or just doubling K without any Ca, led to weaker skin. Yoshida et al., (2014) investigation was conducted to study the impact of the Ca/K ratio (ranging from 4/12 to 12/4 in meL^{-1}) in nutrient solutions and the Ca concentration in fractions in the immature tomato fruits before the onset of BER symptoms. The study was conducted over three seasons and found that the incidence of BER increased as the Ca/K ratio in the supplied solutions decreased during the summer and spring, but there was little variation in winter. The Ca concentration was highest during winter and lowest during summer, and it decreased with a decrease in the Ca/K ratio of the solutions in the fractions.

Nukaya et al., (1994) investigated the impact of four potassium-to-calcium ratios (0.5, 1.0, 1.5 and 2.0 millimoles per liter) in the nutrient solution on the occurrence of BER and gold speckles on fruits of two tomato cultivars, 'Momotaro' and 'June pink,' and the uptake of calcium and potassium by the plants. As the potassium-to-calcium ratio in the nutrient solution increased, the prevalence of BER increased and the presence of gold speckles decreased. More fruits of the cultivar 'June pink' showed symptoms of BER and gold speckles compared to the cultivar 'Momotaro.' Within the same cultivar, the occurrence of BER and gold speckles showed an inverse relationship. The total calcium uptake at a potassium to calcium ratio of 2.0 millimoles per liter reduced to one-third at 'Momotaro' and one-half at 'June pink' in comparison to the uptake at a ratio of 0.5. The potassium uptake was also influenced by the potassium-to-calcium ratios, but to a lesser degree than the calcium uptake.

2.11.3. Interaction between calcium and phosphors

Phosphorus and calcium play important roles in the growth and development of tomato plants. Adequate levels of these nutrients in the soil can lead to improved yield and fruit quality, while insufficient levels can result in reduced yield and other problems. High

levels of calcium and an increased pH can decrease the uptake of phosphorus. Phosphorus uptake is inhibited at 9 pH, which is due to the increased addition of calcium, leading to a phosphorus deficiency (Lopez-Bucio et al., 2000).

Wissuwa et al., (2005) reported that the improvement in the reduction of BER as a result of phosphorus application may be due to the promotion of root growth and the enhancement of lateral root development and the development of fibrous rootlets. This increased growth in roots enhances the plant's ability to absorb water and nutrients, which may contribute to the positive effect of P application.

Farahani et al., (2009) study observed that when the amount of phosphorus fertilizer was increased, the yield, length, and dry weight of the primary roots of coriander plants also increased. Additionally, this improvement in root growth and function, as a result of P application, resulted in an increase in calcium concentration. The improved calcium uptake found in this study may have a positive impact on fruit growth and reduce the incidence of BER. Ghoname et al., (2012) have stated that the use of phosphorus has had a significant impact on decreasing BER, likely due to its improvement in water uptake and calcium absorption.

Kazemi, (2014) found that the beneficial effects of both phosphorus (P) and calcium (Ca) on tomato growth can be attributed to several factors, including improved cell division, better hormonal balance, more efficient photosynthetic activities, and optimized carbohydrate metabolism. These improvements led to an increase in the accumulation of dry matter and a general increase in the growth of plant tissues.

Niu et al., (2018) suggested that the application of calcium to the leaves increased the accumulation of calcium and phosphorus in the plants. AL-Bayati & Majeed, (2022) the use of an organic fertilizer containing both phosphorus and calcium, applied at a concentration of 2 ml/L and 2.5 ml/L respectively, both individually and in combination, led to significant improvements in various growth traits and fruit yield in a tomato hybrid. Nzanza, (2008) reported that The amount of phosphorus in tomato leaves fell as the amount of calcium in the nutrient solution increased, and the amount of phosphorus in the fruit reduced as the amount of calcium in the nutrient solution increased at higher rates. Also when plants are deficient in calcium, they tend to have a lower capacity to absorb anions such as phosphate, which can result in reduced growth.

Jakobsen et al., (1979) suggested that during root respiration, hydrogen carbonate ions can prevent calcium ions from reaching the root growing points. To ensure that calcium is effectively taken up and supplied, it is necessary for phosphate to be taken up and transported from the soil to the growing points. If calcium ions accumulate at the root surfaces, they may precipitate phosphates, which can hinder the uptake not only of phosphate, but also of calcium for a brief period. This sequence of events can have significant consequences, as once calcium is taken up, it is not retranslocated within the plant.

2.11.4. Interaction between calcium and magnesium

Magnesium, which is a fundamental component of cell walls, plays a crucial role in the process of photosynthesis and, as a result, is essential for the overall survival of the plant (Bergmann, 1992). The primary role of magnesium in plants is related to its ability to form bonds with strongly nucleophilic ligands through ionic bonding, as well as to function as a bridging element to create complexes of varying stability (Mengel and Kirkby, 2001). An increase in magnesium concentration in the nutrient solution has been shown to lower the osmotic potential of leaves, according to research by (Carvajal et al., 1999). In addition, elevated magnesium levels in the nutrient solution lead to higher levels of magnesium in the plant, and reduced dry matter in fruit, according to a study by (Gunes et al., 1998). Calcium is a strong competitor with magnesium, and the bonding sites on the root plasma membrane have been observed to have less attraction to the highly hydrated Mg^{2+} than to Ca^{2+} , as suggested by (Grabarek, 2011).

According to Papadopoulos, (2003) reported a reciprocal relationship between the uptake of magnesium and calcium. The presence of high levels of external calcium leads to reduced magnesium uptake, which can be attributed to cationic antagonism or interactions. Additionally, Gransee and Führs, (2013) suggested that the decrease in magnesium levels may also be due to the withdrawal of magnesium from the nutrient solution to maintain cationic balance against increasing calcium levels. The high activity of calcium counteracts the function of magnesium. Ananthanarayana and Hanumantharaju, (1992) found that magnesium has a more significant inhibitory effect on calcium uptake than calcium levels have on magnesium uptake.

According to research conducted by Paiva et al., (1998); Li et al., (2019) when the concentration of calcium in the nutrient solution is increased, it can lead to an increase in the amount of calcium taken up by the plant while reducing the uptake of magnesium. This relationship between calcium and magnesium is antagonistic, meaning that an increase in one can reduce the uptake of the other. During periods of calcium stress, the plant may increase its uptake of magnesium to compensate for the lack of calcium. Morard et al., (1996) observed that when plants are deficient in calcium, this antagonistic relationship between calcium and magnesium is especially strong in the leaves, which suggests that calcium plays an important role in the translocation of magnesium from the roots to the above-ground parts of the plant.

Wills & Tirmazi, (1979) Suggested that the ability to inhibit ripening was not unique to calcium, since other divalent metal ions, such as manganese, cobalt, and magnesium, had similar effects. reported that a low Ca:Mg ratio in the growing medium or soil could impact nitrogen metabolism, leading to limitations in protein synthesis. Buczek and Leonowicz-Babiak, (1971) proposed that when the ratio of Ca: Mg changed in the soil or medium from 3:1 to 3:30, with all other components remaining constant except for magnesium, it can lead to the growth of dwarfed plant forms, reduced dry weight gain, and decreased protein content.

Yan and Hou, (2018) propose that when the concentration of soluble magnesium and calcium is 20 mmol/L or more, and the plant is fully transpiring, magnesium absorption becomes completely independent of energy. As a result, the ratio of absorbed Ca/Mg by the plant is similar to that in the solution. This is because both calcium and magnesium are passively absorbed at this concentration. Therefore, for soils that are frequently leached, the Ca/Mg ratio has a negligible impact on crop uptake of magnesium as long as the concentration of magnesium in the solution is sufficient and not too high to result in passive absorption.

Hao and Papadopoulos, (2002) observed that the accumulation of high levels of Ca and Mg in closed hydroponic systems could be advantageous for tomato growth. In line with this, Sonneveld and Voogt, (1985) reported a significant reduction in yield for eggplant fruits due to low Mg levels, while the yield of cucumbers was somewhat affected by a low Ca supply. Calcium was found to strongly affect the uptake of Mg.

Papadopoulos, (2003) conducted an experiment in the fall using two different concentrations of calcium (150 and 300 mg L⁻¹) in combination with four different concentrations of magnesium (20, 50, 80, and 110 mg L⁻¹). The incidence of BER increased linearly with increasing magnesium concentration in the early growth stage when the calcium level was low. However, at high levels of calcium, the incidence of BER was not affected by magnesium concentration. At high levels of calcium, the concentration of magnesium only affected fruit firmness late in the season; the firmness of fruit was higher at 80 mg L⁻¹ magnesium compared to 50 mg L⁻¹ magnesium. Suggested that the optimal calcium to magnesium concentration ratio for tomato production is estimated to be 300/50-80 mg L⁻¹.

Hao & Papadopoulos, (2004) found that the occurrence of BER increased in a linear pattern with the increase of Mg concentration when the Ca concentration was at 150 mg.L⁻¹, but was not influenced by Mg concentration when the Ca concentration was at 300 mg.L⁻¹. Ilyas et al., (2021) conducted a study using four different levels of Calcium chloride as a calcium source (0%, 0.15%, 0.30%, and 0.45%) and four levels of magnesium sulphate as a magnesium source (0%, 0.04%, 0.08%, and 0.12%), with 15-day intervals after transplantation for a period of three months. The study found that a combination of 0.30% calcium and 0.08% magnesium with a 15-day interval after transplantation significantly increased crop yield and growth under the specific agro-climatic and soil conditions of Peshawar valley.

Kumar et al., (2021) also reported that using calcium and magnesium at rates of 0.6% and 0.2%, respectively, in tomato crops can improve the quality of the crop by increasing nutrient content and uptake of primary and secondary nutrients. Aghofack-Nguemezi et al., (2010) concluded that calcium and magnesium are important elements in fertilizers, as they delay the ripening of mature-green tomato fruits and increase the shelf-life of red-ripe ones.

2.12. Interaction between calcium and micro nutrition

Boron is an essential micronutrient that plays a crucial role in plant growth and development. It is involved in many physiological processes, including cell division, cell elongation, and the formation and maintenance of cell walls. Additionally, boron is

necessary for the proper formation of flowers, fruits, and seeds, as well as the transfer of sugars and starches within the plant. Boron deficiency can result in stunted growth, reduced yields, and deformities in the structure of flowers, leaves, and stems (Cakmak and Romheld, 1977).

Boron is believed to have a positive impact on the intake of cations, especially calcium, and to slow down the intake of anions. Additionally, boron is considered to play an important role in carbohydrate and nitrogen metabolism (Batey, 1971). The relationship between calcium and boron is particularly noteworthy due to the similarity in their functions to other plant nutrients. Both elements are essential for cell wall metabolism and the process of auxin transport (Dela-Fuente et al., 1986).

In addition to a lack of boron, calcium deficiency is often observed in acidic soils. Calcium is closely relationship with boron in both the soil and the plant. This increases the plants' need for boron due to their similar functions, but it also reduces the availability of boron in the soil because of the formation of calcium-borate complex and the antagonistic relationship between calcium and boron (Tsadilas et al., 2005). Liming causes notable modifications in soil properties, which affect the way boron is adsorbed and desorbed in the soil (Sarkar et al., 2015).

Yamauchi et al., (1986) suggested that a lack of boron can impede the movement of calcium and lead to irregular alterations in calcium metabolism within the cell wall. Boron has the tendency to maintain calcium in a dissolved state within the plant. The findings of Ramon et al., (1990) also indicate that boron deficiency has a distinct impact on the transport of calcium and its conversion into an insoluble form, such as cell wall constituents.

Kabata-Pendias and Pendias, (1992) have established that the harmful impact of boron can be alleviated or avoided by introducing calcium into the soil. Additionally, Bramlage and Weis, (2004) have observed that boron works in conjunction with calcium ions, resulting in an enhancement of calcium concentration in fruits. This, in turn, may augment the calcium content of leaves and fruits in plants that have been fertilized with boron.

According to Milagres, (2019) boron has a positive effect on the uptake of calcium, and this can lead to an increase in the amount of vitamin C present in the fruit. This is achieved by improving the integrity of the membranes, reducing biosynthesis, and

reducing respiration in cherry tomato. Additionally, Loomis and Durst, (1992) found that a suitable level of boron can encourage the absorption of calcium by the roots of tomato plants, resulting in greater biomass accumulation.

Korkmaz & Aşkın, (2013) have proposed that the highest yield of 38.338 kg/tree was obtained by applying 2% calcium nitrate, while the lowest yield was observed when 1.5% boron was used, which resulted in a yield of 20.764 kg/tree. In contrast, Tejashvini and Subbarayappa, (2021) discovered that a significantly greater number of fruits per plant and fruit yield were achieved by using calcium at a rate of 10 kg/ha and boron at a rate of 2.2 kg/ha. However, the uptake of boron was not significantly influenced by the application of calcium.

Islam et al., (2016) conducted a study to investigate the impact of the foliar application of boron and calcium on the characteristics of cherry tomato. Their research indicated that the firmness of the tomato fruit was improved and maintained during the storage period when treated with both boron and calcium. Additionally, the tomato fruits treated with boron and calcium had the least amount of weight loss and the best shelf life. Moreover, the vitamin C content of the tomato fruits treated with boron and calcium was higher compared to the control group.

Barman et al., (2014) stated that the occurrence of CaCO_3 in soils leads to an increase in B fixation by means of increased soil pH and adsorption, which can result in reduced B uptake and subsequent B deficiency in the plant. Moreover, excessive amounts of calcium in the plant can result in the precipitation of boron, rendering it unavailable for the plant. A lack of B causes abnormal changes in cell wall metabolism. However, in the case of tomato, B deficiency slightly increased the uptake of Ca but prevented its translocation to the upper leaves.

Anil et al., (2020) have proposed that the use of calcium at a rate of 2/3 LR or 1 LR can lead to a significant increase in tomato biomass yield, with a 21% and 16% rise observed respectively, compared to the control group. Increasing the rate of boron application resulted in a reduction of calcium availability in the post-harvest soil from 513 to 476 mg/kg. There was a significant interaction between the effects of calcium and boron on the available calcium content in the soil. When calcium was applied at a rate of 2/3 LR and boron was added at a rate of 1.5 mg/kg, this significantly improved

biomass yield, nutrient uptake, and soil pH, along with increased availability of calcium.

Lavanya and Bahadur, (2021) reported that increasing levels of foliar-applied calcium and boron, ranging from 0% to 0.6%, resulted in a significant increase in the morphological and yield attributes of cherry tomato plants. The application of 0.6% calcium and 0.6% boron showed the highest net returns and B:C ratio due to increased yield. Similarly,

Ashraf et al., (2018) found that a solution containing 0.2% boric acid and 0.3% calcium chloride resulted in better results than the control in terms of vegetative growth, flowering, and yield components. Ekinici et al., (2015) proposed that the application of Ca and B humate nutrients could be a practical and economical solution for tomato and cucumber plants that do not suffer from calcium and boron deficiencies during their growth phase.

Plese et al., (1998) recommended that applying 1 g of boron and 0.6% CaCl_2 every 14 days or 0.6% CaCl_2 every 7 days, in the absence of boron, are good options for obtaining higher tomato production and reducing the number of fruits affected by BER. Meanwhile, Liebisch et al., (2009) found no significant effect of additional applications of Ca and B on the total fruit yield of tomato. However, they did observe differences in the non-marketable fraction of fruit yield between treatments and cultivars. The cultivar KK2 was highly susceptible to both BER and fruit cracking and therefore produced fewer marketable fruits compared to the FMTT cultivar. Although the Ca and B sprays reduced the incidence of BER, they increased fruit cracking at the same time.

2.13. Reactive Oxygen Species

During the initial phases of BER development, the distribution and concentration of Calcium in the affected fruit remain comparable to those in healthy fruit. The underlying causes of BER are linked to the impacts of abiotic stress, which triggers an elevation in reactive oxygen species (ROS), leading to heightened oxidative stress and eventual cell death. The breakdown of cellular structures, including the plasma membrane, tonoplast, and endoplasmic reticulum, occurs as a result of cell death. This process precedes, rather than follows, the leakage of ions, including Calcium, and the

loss of turgor (Saure, 2014). In the presence of salinity, oxygen radicals and hydrogen peroxide production, as well as NAD(P)H oxidase activity, were intensified during the most vulnerable developmental stage. These findings indicate that oxygen-free radicals might contribute to the BER symptoms (Aktas et al., 2005).

When plants are faced with various stressors, including high salinity, one significant response of plants is to minimize the presence of reactive oxygen species (ROS) by inhibiting photosynthesis while also enhancing their removal through scavenging mechanisms (Zhu et al., 2001).

Exposure of plants to stress results in an accumulation of ROS within their cells, causing oxidative stress on the crops (Hadi & Karimi, 2012). Mestre et al., (2012) investigated the association between oxidative metabolism and BER, we observed that a deficiency of calcium resulted in decreased activity of key enzymes involved in the detoxification of reactive oxygen species (ROS). It was found that the activity of the ascorbate-glutathione enzymes, responsible for ROS detoxification, was significantly affected by the lack of calcium. This deficiency also led to the inhibition of other enzymes responsible for hydrogen peroxide (H₂O₂) detoxification, consequently leading to an increase in lipid peroxidation. As a result, we define BER as the visible symptom of a significant event of lipid peroxidation caused by the disruption of cellular glutathione homeostasis.

Freitas et al., (2012) it is proposed that the combined impact of calcium and reactive oxygen species (ROS) on calcium deficiency disorders may be compartmentalized within the apoplast, which is the extracellular space in plant tissues. In such a scenario, calcium deficiency disorders may only occur if the levels of Calcium in the apoplast are insufficient to counterbalance the effects of ROS on the peroxidation of membrane lipids.

Reitz and Mitcham, (2021) conducted a study to examine the potential involvement of lignification, hydrogen peroxide content, catalase activity, and peroxidase activity in BER affected fruit. They measured these factors in the top, bottom, and BER-affected tissue of BER-affected fruit and in the top and bottom in good physical shape fruit. To determine the lignin content, the researchers used histochemical staining, autofluorescence, and thioglycolic acid degradation methods. The findings suggested that hydrogen peroxide content was higher in the BER-affected and adjacent tissues

compared to healthy fruit and the top of the Fruit was impacted by BER. Catalase activity was significantly reduced and ferulic acid peroxidase activity was increased in the BER-affected and unaffected tissue at the bottom of the Fruit was impacted by BER compared to the bottom of normal fruit. The analysis of lignin showed that lignin content was higher in the BER-affected tissue compared to tissue from the bottom of healthy fruit.



3. MATERIALS AND METHODS

This study was carried out in a greenhouse at the Gaziosmanpaşa University, Agricultural Faculty, Department of Horticulture, Tokat/Türkiye (Latitude 39°51' to 40°55' North, Longitude 35°27' to 37°39' East elevation. It is 623 meters above sea), from 01 May to 10 December 2021 and from 10 May to 30 November 2022.

3.1. Materials

3.1.1. Description of the experiment

Plants were grown in soilless culture. Cocopeat+perlite mixture (2:1 ratio) was used as growing media. Seedlings were planted in pots, which had 21cm height, 25 cm width, 75 cm length and 26 L volume (Figure 3.1). Three plants were planted in a pot. The nutrient solution was balanced using water soluble fertilizers (18:18:18, 10:52:10, 16:8:24 and magnesium nitrate. Micro elements obtained from commercial combi micronutrients including water soluble Fe, Cu, B, Zn, Mn and Mo. Nitric acid was used to regulate the pH of the nutrient solution to 5.8 ± 2 . Irrigation water was diluted before use. The EC value of the irrigation water used in the experiment is 0.020 dS/m



Figure 3.1. Tomato cultivated pot.

3.1.2. Plant material

In the experiment *Ufuk F₁* variety and LA4442 tomato line were used. The characteristics of these genotypes used in the experiment are provided below:

Ufuk F₁:

Ufuk F₁ has high resistance to Vd, Va, Fol 0-1, For Ma, Mi, Mj, ToMV, TYLCV and TSWV. Fruit shape is oval, average fruit weight is about 220 g, and cultivation is suitable for greenhouses.

LA4442:

Name of variety is *S. lycopersicum* or *L. esculentum*, it is known as a wild tomato in South America. Cluster fruits are oval-shaped and have small leaves. Has a high resistance to Fusarium and TSWV. Commercial name is Florida 8516. (Figure 3.2).



Ufuk F₁



LA4442

Figure 3.2. Fruit of tomato used in the study

3.2. Method

In the experiment, different calcium and salt levels were tested as interactions. Four different calcium oxide doses (0, 50, 100 and 200 ppm) and 3 different salinity levels (2.0, 4.0 and 6.0 dS/m) were used. An EC dose of 2.0 dS/m was used as control treatment, and EC levels of 4.0 and 6.0 dS/m were used to induce salt stress. The EC value of the nutrient solution was adjusted to 2.0 dS/m, and NaCl was added to the nutrient solution for EC levels of 4.0 and 6.0 dS/m. In calcium applications, the above mentioned calcium doses were added to the diluted irrigation water (EC 0.020 dS/m) (Figure 3.3). 100 liter solution tanks were used for calcium and salt applications. Calcium and salt concentrations were prepared Daily using 100 liters tanks (Figure 3.3)



Figure 3.3. Preparing of solutions and first apply to pots

Tomato seedlings were grown in our commercial seedling production greenhouse. Plug trays were used to grow tomato seedlings. A tray had 216 cells. Growth medium was the mixture of peat and perlite in the ratio of 3:1, respectively. Tomato seedlings were planted when they had 5-6 true leaves (six weeks old). Seedlings were planted 0.4 m apart in row with rows 1.2 m apart. Plants were grown as a single stem, and the fruits are harvested upon reaching ripeness. (Figure 3.4)



Figure 3.4. Seedling planting, irrigation and harvest

The plants were regularly watered with irrigation water containing salt and calcium. While irrigation water containing calcium was given in the morning, irrigation water containing salt was given in the evening (Figure 3.5).



Figure 3.5. Irrigation of plants

The amount of irrigation water was adjusted so that 20% of the given water was drained. Drainage water was collected daily and the EC and pH of the water were measured regularly. When the EC concentration in the drainage water exceeds 8 dS/m, or the pH reaches 8, a solution with an EC concentration of 1 dS/m is prepared and applied once. (Figure 3.6)



Figure 3.6. Electirictical codictivity and pH measurement in drainage solution

The nutrient solution was prepared by modifying Hoagland and Arnon, (1950). Macro and micronutrients and their amounts used in the preparation of the nutrient solution are given in Table 3.1.

Table 3.1. Macro and micronutrients used in the study

Macronutrients (ppm)					
N	P	K	Ca	Mg	S
210	60	300	*	50	50
Micronutrients (ppm)					
Fe	Cu	Zn	B	Mn	Mo
3.0	0.03	0.05	0.5	0.5	0.01

3.2.1. Experimental design and statistical analysis

The experiment was conducted as a split-plot design with three replications. Salinity levels were placed in the main plots and calcium doses were placed in the sub-plots. Each replication involved six plants. Accordingly, in the study, 3 salinity levels, 4 calcium doses and 2 varieties were evaluated in both years, a totally 72 treatments and 432 plants.

All data were statistically analyzed by ANOVA using the SPSS software package (IBM SPSS Statistics 20). Differences between means were compared using the Duncan's multiple range test ($P < 0.05$).

3.3. Experimental Parameters

3.3.1. Marketable yield

Marketable fruits collected at each harvest were recorded as fruit number and weight for each treatment, and marketable yield was calculated as the number of fruits per plant and yield per hectare.

3.3.2. Average fruit weight (g)

The average fruit weight was calculated in grams by dividing the weight of marketable fruits collected in each harvest by the number of fruits. Fruit weight recorded as gram per fruit.

3.3.3. Total yield

All of the marketable and unmarketable fruits harvested in each plot were measured and recorded as fruit number and weight, and unmarketable yield was calculated as the number of fruits per plant and yield per hectare.

3.3.4. Fruit dry weight (%)

Fruit samples were collected during the third and sixth harvests, and weights were measured by sensitive balance (0.01g). Fruit samples were dried at 65°C until its weight stabilized and the dry weights recorded. The ratio of fruit dry weight to fruit fresh weight was calculated as % fruit dry weight.

3.3.5. Leaf dry weight (%)

In each treatment, the fourth and sixth leaves from the bottom were taken from each plant and weights were measured by sensitive balance (0.01). Leaf samples were dried at 65°C until their weight stabilized and the dry weights were recorded. The ratio of leaf dry weight to leaf fresh weight was calculated as % leaf dry weight.

3.3.6 Blossom end rot (BER)

Fruits with BER at each harvest were recorded as number. Thus, the number of fruits with BER was calculated. The number of fruits with BER in each treatment was proportioned to the total number of fruits, and the number of fruits with BER was calculated proportionally. In the LA4442 genotype, BER is seen on the outer shell of

the fruit, sometime calcium deficiency is not seen outside the fruit, it can also be seen as BER inside of the fruit. For this reason, 10 fruits were cut, and BER in the fruit was evaluated in each harvest. The damage pattern and symptoms of BER on the outside and inside of the tomato fruits are seen in Figure 7.



Figure 3.7. Symptoms of blossom end rot in fruits

3.3.7. Total soluble solids of fruit juice (%)

The fruit juice was extracted and filtered from the fruits harvested in the third and sixth harvests and total soluble solid (brix) was determined by digital refractometer (Hanna HI 96801 Dijital Refraktometre)

3.3.8. Electrical conductivity of fruit juice (EC) (dS/m)

After the harvest begins, the fruits that were harvested during the third and sixth harvests were undergo juice extraction and filtration, and the electrical conductivity of the juice was measured with the EC meter (Hanna HI-9812-5N, America).

3.3.9. pH of fruit juice

After the harvest has started, in the third and sixth harvests, the juice of the fruits taken from each of the treatment was extracted, and the pH value of the fruit juice was measured using a pH meter (Hanna HI-9812-5N, America).

3.3.10. Titratable acidity of fruit juice (TA)

Titretable acidity was determined by titrimetric method. After the harvest has started, in the third and sixth harvests, the juice of the fruits taken from each of the treatment was extracted, after filtration, without delay, a 10 ml sample was taken and 2-3 drops of phenolphthalein was added into it. The samples were titrated with 0.1 N sodium hydroxide (NaOH). Sodium hydroxide was added until it begins to change color and when the color changes, the amount of sodium hydroxide consumed was recorded. Then the titratable acidity was calculated in terms of citric acid using the following method.

$$\text{Titratable Acidity(\%)} = \frac{V \times N \times E \times 100}{M}$$

V= volume of standard using for titration

N= Normality of NaOH (0.1)

E= Acid equivalent of 1 mL 0.1 N NaOH (g)

M = sample size in milliliter

3.3.11. Leaf chlorophyll (SPAD)

Leaf chlorophyll content was measured two times, on the fourth and sixth leaves from the bottom, using a hand-held SPAD-502 Plus Chlorophyll Meter. SPAD was measured in 6 plants for each replication, and in 3 different positions for a leaf (Figure 3.8).



Figure 3.8. Determining of chlorophyll index in tomato leaves

3.3.12. Nutrient analysis in fruit and leaf

Nutrient element analyses (P, K, Ca, Mg, Na, Fe, Cu, Zn and Mn) were performed on fruit and leaf samples during the third and sixth harvest periods. 10 ripe fruits were taken from each treatment. Leaf samples were taken from the 5th and 6th branches of the plants. The leaves and fruits were dried in an oven at 70 °C until they reached a constant weight. Dried samples were grinded until they became powder. For reading macronutrients and micronutrients in samples, the powdered samples were undergo a process of dry-burning that involves the use of hydrochloric acid. And samples was filtered. Reading P, K, Ca, Mg, Na, Fe, Cu, Zn and Mn in the filter samples in the ICP-OES device according to Halvin and Soltanpour, (1980) (Figure 3.9).

3.3.13. Calcium analysis in fruit parts

Fruits were harvested during the green stage before turning red in the harvesting stage. Samples were collected by selecting visibly healthy tissue, and then the fruit was cut in the middle, between the top and the bottom. Fruit was dried in an oven at 70 °C until it reached a constant weight. Dried samples were grinded until they become powder. For reading Ca in samples, the powdered samples were undergo a process of dry-burning that involves the use of hydrochloric acid. Reading calcium in the filter sample in the ICP-OES device according to Halvin and Soltanpour, (1980).



Figure 3.9. Stages of reading nutrient elements

3.3.14. Fruit firmness

Flesh firmness was measured in fully ripened fruits in the third and sixth harvests. For measurement, 10 fruits from each treatment were used. The method used by Dilmaçunal et al., (2011); Gerçekcioğlu et al., (2019) was modified to measure firmness of tomato fruits. Measurements were taken with a dynamometer (PCE-FM 200 Force Gauge) and a test stand (Wheel Manual Test Stand, Model: SL J-B, S/N: 4K15C01961, Capacity: 500 N, Stroke: 150 mm, PCE Instruments). The head used had a diameter of 1.5 mm, a length of 2 mm, and up to 3 mm diameter. The piercing tip was inserted 10 mm into the fruit and the value was recorded (Figure 3.10).

3.3.15. Ascorbic Acid Determination

Tomato fruits were washed in water. The juices were extracted by cutting the fruits in half and squeezed with hand. Then 10 g juice was mixed with 50 ml of 6% metaphosphoric acid solution and transferred to a 100 mL volumetric conical flask and filled with 3% metaphosphoric acid to the required volume. The sample was filtered using Whatman filter paper. Ascorbic acid was determined volumetrically by 2,6-dichloroindophenol titration method (Rekha et.al., 2012; Thimmaiah, 1999). Ten ml of a 10% standard L-ascorbic acid solution was taken in a conical flask and 10 ml of 3% metaphosphoric acid were added. The content was titrated with dye until the pink-colored end point appeared. The millilitres of dye solution required to complete the titration were recorded and then dye factor was calculated. Ten ml of aliquot were titrated with dye. The ascorbic acid content of the samples was calculated by using the following formula: $\text{Ascorbic acid (mg/ml)} = [\text{Titre} \times \text{Dye factor} \times \text{Volume made up (ml)} \times 100] / [\text{Volume extract (ml)} \times \text{Weight of sample (g)}]$

3.3.16. Fruit skin color

Four times, at 15-day intervals, 10 ripe fruits was taken from each treatment in each harvest, used the CR 300, Minolta, Japan) device to measure the fruit skin color. And the results were calculated in terms of L* (Lightness), a* (Red/ Green) value and b* (Blue/Yellow) value. (Figure 3.11).

3.3.17. Antioxidative Enzyme Analysis

To detect changes in enzyme activity in plants under salinity stress, approximately 0.5 g of plant sample was crushed in porcelain mortars with liquid nitrogen. Then, 0.1 mM Na-EDTA found in the sample was homogenized with 10 ml of 50 mM phosphate buffer solution (pH: 7.6). After the homogenized samples have been centrifuged for 15 minutes at aturnover speed of 15000 rpm, the resulting centrifugates was used for enzyme analysis. The samples for enzyme analysis were placed in ice-containing cuvettes and stored at a temperature of $+4^{\circ}\text{C}$ until the analysis is performed.



Figure 3.10. Measuring of fruit firmness



Figure 3.11. Measuring of fruit skin color

3.3.18. Catalase Activity (CAT)

The degradation rate of H_2O_2 at 240 nm ($E=39.4 \text{ mM cm}^{-1}$) were measured. In this enzyme analysis, a reaction medium was prepared by adding 50 mM phosphate buffer containing 0.1 mM EDTA (pH: 7.6), 0.1 ml 100 mM H_2O_2 , and enzyme extract, so that the final volume is 1 ml (Cakmak and Marschner, 1992; Çakmak et al., 1994). Finger (3.12).

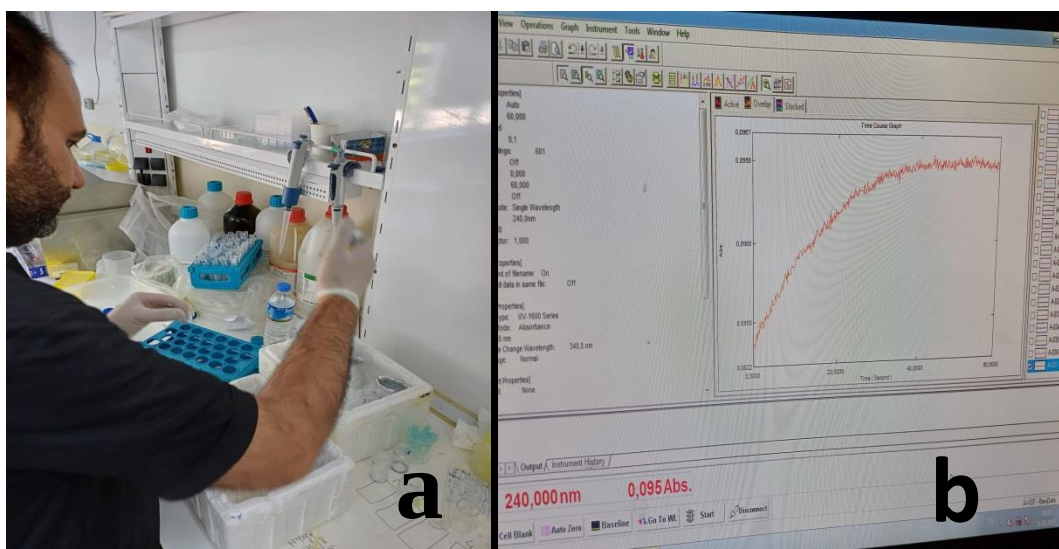


Figure 3.12. Catalase Activity a. Preparing sample b. reading of sample

3.3.19. Peroxidase Enzyme Activity (POX)

The peroxidase activity was determined according to the method described by Castillo et al., (1984). 3 mL of the reaction mixture containing 10 mM guaiacol, 50 mM H_2O_2 , 50 mM phosphate buffer (pH 6), and 50 μl enzyme extract was used. The absorbance was monitored at a wavelength of 470 nm for 5 minutes, and the increase in absorbance was recorded at 1-minute intervals at 25 °C. The amount of enzyme that increases the absorbance by 0.01 per minute is 1 enzyme unit, and the results was calculated in units of enzyme per gram of leaf (EU/g leaf). Figure (3.13)

3.3.20. Ascorbate Peroxidase (APX) Activity

Ascorbate Peroxidase (APX) Activity was determined by measuring the oxidation of ascorbate at 290 nm ($E=2.8 \text{ mM cm}^{-1}$) according to Cakmak and Marschner, (1992); Çakmak et al., (1994). Accordingly, the reaction medium adjusted to a final volume of 1 ml, 50 mM phosphorus buffer (pH: 7.6) containing 0.1 mM EDTA, 12 mM H_2O_2 containing 0.1 ml 10 mM EDTA, 0.1 ml of 0.25 mM L(-) ascorbic acid and enzyme extract was added and the ascorbate oxidation was read at 290 nm. Figure (3.14)



Figure 3.13. Peroxidase Enzyme Activity (POX) reading by spectrometer

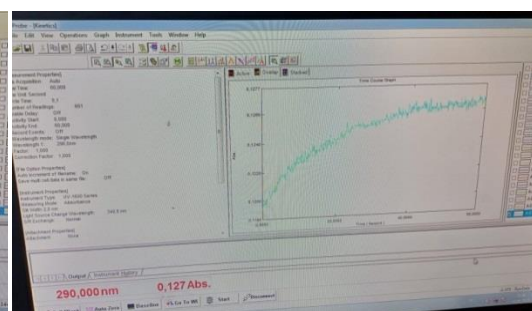


Figure 3.14. Ascorbate Peroxidase (APX) Activity reading by spectrometer

3.3.21. Glutathione Reductase (GR) Activity

Glutathione Reductase (GR) Activity was measured based on the oxidation of NADPH at 340 nm ($E=6.2 \text{ mM cm}^{-1}$) according to Cakmak and Marschner, (1992); Cakmak et al., (1994). Accordingly, NADPH oxidation was measured at 340 nm by adding 50 mM phosphorus buffer (pH= 7.6) containing 0.1 mM EDTA, 0.1 ml 0.5 mM oxidized glutathione (GSSG), 0.1 ml 0.12 mM NADPH and enzyme extract to the reaction medium adjusted to a final volume of 1 ml (Figure 3.15)

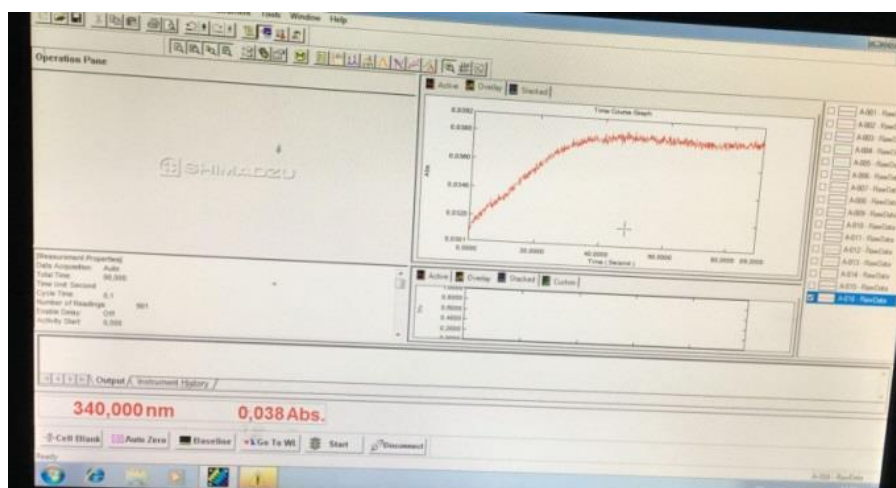


Figure 3.15. Glutathione Reductase (GR) Activity reading by spectrometer

3.3.22. Determination of Lipid Peroxidation Amount (MDA)

The measurement of lipid peroxidation was performed by following the method described by Lutts et al. (1996). 200 mg of leaf samples was weighed and 5 ml of 0.1%

trichloroacetic acid (TCA) was added on it. This mixture was centrifuged for 20 minutes at at aturnover speed of 12500 rpm. 3 ml of supernatant was taken from a 5 ml extract, 3 ml of 0.1% thiobarbutric acid (TBA) containing 20% TCA was added to the supernatant. The mixture was kept in a hot water bath at 95°C for 30 minutes. After that, absorbance values at A532 and A600 nm was read in the spectrophotometer. The obtained values was placed in the formula below and the amount of MDA (Malondialdehyde) was calculated.

MDA= (A 532- A 600) x Extraction volume (ml) / (155 mM/cm x Sample amount (mg))



4. RESULTS AND DISCUSSION

4.1. Effect of Salinity and Ca Doses on Marketable Yield

4.1.1. Marketable fruit yield

Different calcium doses and levels of salt stress significantly affect the marketable yield of the LA4442 variety. In both years 2021 and 2022, the highest values of marketable fruit yield (118.58 and 127.31 ton/ ha respectively) were recorded from interaction of 200 ppm calcium and EC 2.0 dS/m. Conversely, the lowest marketable fruit yield (24.4 and 25.92 ton/ ha respectively) were recorded from the interaction of calcium 0 ppm and EC 6.0 dS/m.

For the Ufuk F₁ variety in both 2021 and 2022, the peak marketable yield values were 278.22 and 286.95 ton/ha respectively, resulting from the combination of 200 ppm calcium and EC 2.0 dS/m. In contrast, the minimum marketable fruit yields for those years were 20.91 and 20.24 ton/ha respectively, observed from the pairing of 0 ppm calcium and EC 6.0 dS/m.

In both years for the LA4442 and Ufuk F₁ genotypes, the findings indicated that increasing calcium doses reduced the impact of salinity on the marketable fruit yield. These results were compatible with Lolaei et al., (2012) whose findings revealed that salinity stress led to a decline in fruit yield, whereas an increase in the concentration of calcium in the nutrient solution resulted in higher fruit yield. The impacts of the treatments on the marketable yield of tomato were found in Table 4.1.

4.1.2. Fruit number

The marketable fruit number of tomato showed significant variations in response to different levels of calcium and salinity. In 2021, the marketable fruit number of the LA4442 variety was significantly affected by calcium application. The highest value of fruit number/plant 125.24 was recorded from the interaction of 200 ppm calcium and EC 2.0 dS/m. Conversely, the lowest value of fruit number/plant 47.30 was recorded from the interaction of 0 ppm calcium with EC 6.0 dS/m.

Table 4.1. Effect of salinity and Ca doses on marketable yield

Treatments		Ton/ha			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	38.35±2.39 ^{fg}	34.16±1.28 ^g	39.52±0.43 ^{gh}	37.10±1.07 ^{gh}
	50	41.11±2.77 ^f	39.31±0.84 ^f	58.89±2.21 ^f	58.09±2.62 ^f
	100	50.95±4.76 ^{cd}	68.20±1.51 ^c	155.55±5.72 ^c	156.69±4.28 ^c
	200	118.58±5.88 ^a	127.31±7.96 ^a	278.22±7.13 ^a	286.95±9.89 ^a
4	0	32.29±1.51 ^h	29.17±0.73 ^h	34.86±1.17 ^{hi}	31.09±1.69 ^h
	50	41.13±3.06 ^f	33.22±1.12 ^g	44.32±1.91 ^g	44.05±2.32 ^g
	100	47.74±5.61 ^{de}	51.20±1.35 ^d	86.67±1.10 ^e	89.29±3.08 ^e
	200	68.13±1.17 ^b	84.37±5.13 ^b	185.58±5.65 ^b	191.99±9.01 ^b
6	0	24.45±1.63 ⁱ	25.92±0.55 ^h	20.91±1.41 ^j	20.24±0.60 ⁱ
	50	34.13±1.98 ^{gh}	28.18±1.58 ^h	32.83±0.53 ⁱ	32.27±0.64 ^h
	100	43.14±0.56 ^{ef}	46.39±1.21 ^e	59.24±1.70 ^f	66.92±6.56 ^f
	200	55.04±2.05 ^c	52.55±2.81 ^d	133.85±1.53 ^d	136.78±8.81 ^d
Means					
Salinity	2	62.25 ^a	67.25 ^a	133.05 ^a	134.71 ^a
	4	47.33 ^b	49.49 ^b	87.86 ^b	89.11 ^b
	6	39.19 ^c	38.26 ^c	61.71 ^c	64.05 ^c
Ca	0	31.70 ^d	29.75 ^d	31.76 ^d	29.48 ^d
	50	38.79 ^c	33.57 ^c	45.35 ^c	44.80 ^c
	100	47.28 ^b	55.26 ^b	100.49 ^b	104.30 ^b
	200	80.58 ^a	88.08 ^a	199.22 ^a	205.24 ^a
Significant differences					
Salinity		**	**	**	**
Ca		**	**	**	**
Salinity*Ca		**	**	**	**

Values followed by similar letters under the same column are not significantly different at $p \leq 0.05$.

** : Represent significance difference ($P \leq 0.01$).

In 2022, statistical analysis of the data showed that calcium concentration had a significant effect on marketable fruit number in the LA4442 variety, and their interactive effect was also found to be significant. The highest marketable fruit number 131.11 were obtained from the interaction between 200 ppm calcium and EC 2.0 dS/m. However, the lowest value of marketable fruit number 41.11 was noted from interaction between 0 ppm calcium and EC 6.0 dS/m. The results showed that increasing calcium from 0 ppm to 200 ppm led to an increase in marketable fruit numbers. Conversely, increasing the salinity from 2.0 dS/m to 6.0 dS/m resulted in a decline in marketable fruit number. In 2021 and 2022, it were noted that increased calcium reduced the effect

of salt on marketable fruit number. These findings were consistent with Agius et al., (2022) when they found that increased salt levels caused a decrease in the yield of cherry tomato. These findings were consistent with Parvin et al., (2015); Rab et al., (2017) when they mentioned to that the increase in calcium concentration was associated with an increase in the number of fruits produced by tomato.

The marketable yield of the Ufuk F₁ variety was significantly affected by calcium concentration and the interaction between salinity and calcium. In 2021, the maximum value of marketable fruit number 83.65 were recorded from the interaction of 200 ppm calcium and EC 2.0 dS/m. Conversely, the minimum value of marketable fruit number (12.86) were recorded from the interaction of 0 ppm calcium with EC 6.0 dS/m. These results were agreed with Nizam et al., (2019), who observed that calcium significantly increased the marketable yield of tomato in both saline and non-saline conditions. The minimum marketable yield values were observed at 8 dS/m, the highest number of fruits plant⁻¹ and the highest yield plant⁻¹ were recorded from the interaction between 0 dS/m Na and 10 mM calcium.

In 2022, the marketable fruit number of the Ufuk F₁ variety showed that, the maximum value of marketable fruit number 82.83 were recorded from the interaction of 200 ppm calcium and EC 2.0 dS/m. while, the minimum value of marketable fruit number (13.42) was recorded from the interaction of 0 ppm calcium with EC 6.0 dS/m.

It was observed that elevated calcium levels mitigated the impact of salt on the marketable fruit number. During 2021 and 2022, in both genotypes (Ufuk F₁ and LA4442), increased calcium led to an increase in marketable fruit number and a decrease in salt stress. The effects of the applications on the marketable fruit number of tomato were presented in Table 4.2.

4.2. Effect of salinity and Ca doses on marketable fruit weight

The marketable fruit weight of the LA4442 variety was notably influenced by the interaction between of salinity and calcium. In the years 2021 and 2022, the maximum marketable fruit weight (43.35g and 43.35g respectively) were obtained from the interaction of calcium 200 ppm and EC 2.0 dS/m. Conversely, the minimum marketable

fruit weight (23.63g and 22.76g respectively) were recorded from the interaction of 0 ppm calcium with EC 6.0 dS/m.

Table 4.2. Effect of salinity and Ca doses on marketable fruit number

Treatments		Number/plant			
Salinity	Ca	LA4442		Ufuk F ₁	
		2021	2022	2021	2022
2	0	60.32±4.56 ^{gh}	52.56±3.75 ^{gh}	24.13±1.20 ^h	26.17±1.09 ^g
	50	69.20±5.36 ^{ef}	63.67±2.00 ^f	31.11±0.72 ^f	32.50±0.87 ^f
	100	80.95±5.72 ^d	111.00±3.18 ^b	52.86±2.18 ^c	54.67±1.13 ^c
	200	125.24±6.55 ^a	131.11±5.17 ^a	83.65±1.98 ^a	82.83±1.04 ^a
4	0	52.70±4.12 ^{hi}	46.00±1.15 ^{hi}	17.62±0.48 ⁱ	15.67±0.38 ⁱ
	50	74.45±3.10 ^{de}	56.67±2.19 ^{fg}	27.46±0.99 ^g	26.83±0.80 ^g
	100	82.22±4.05 ^d	81.66±3.06 ^d	41.27±1.92 ^e	40.42±0.88 ^e
	200	108.73±3.82 ^b	108.22±8.70 ^b	60.79±0.73 ^b	63.42±1.01 ^b
6	0	47.30±3.37 ⁱ	41.11±3.42 ⁱ	12.86±0.48 ^j	13.42±0.38 ⁱ
	50	64.29±4.77 ^{fg}	53.67±2.61 ^g	24.29±0.48 ^h	19.58±0.38 ^h
	100	62.70±3.60 ^{fg}	72.44±6.18 ^e	31.74±0.73 ^f	33.25±0.66 ^f
	200	95.40±5.25 ^c	88.89±2.88 ^c	46.67±1.72 ^d	47.83±1.04 ^d
Means					
Salinity	2	83.93 ^a	89.58 ^a	47.94 ^a	49.04 ^a
	4	79.26 ^b	73.14 ^b	36.79 ^b	36.58 ^b
	6	67.42 ^c	64.03 ^c	28.89 ^c	28.52 ^c
Ca	0	53.44 ^d	46.55 ^d	18.20 ^d	18.42 ^d
	50	69.31 ^c	58.00 ^c	27.62 ^c	26.31 ^c
	100	75.29 ^b	88.37 ^b	41.96 ^b	42.78 ^b
	200	109.79 ^a	109.41 ^a	63.70 ^a	64.69 ^a
Significant differences					
Salinity		**	**	**	**
Ca		**	**	**	**
Salinity*Ca		**	**	**	**

Values followed by similar letters under the same column are not significantly different at $p \leq 0.05$.

** : Represent significance difference ($P \leq 0.01$).

For Ufuk F₁, the highest marketable fruit weight was obtained from the interaction of 200 ppm calcium and EC 2.0 dS/m at 204.45g and 202.29g in 2021 and 2022, respectively. However, the lowest values of marketable fruit weight (88,81g and 89,63g respectively) were obtained from the interaction of calcium 0 ppm with EC 6.0 dS/m.

In both years, for the LA4442 and Ufuk F₁ genotypes, the experiments showed a significant improvement in the weight of marketable fruit due to increased calcium

levels. This increase also helped mitigate the effects of salt stress, further enhancing the weight of the marketable fruit. These results were agreed with El-Mogy et al., (2018) whoes noted that both fruit weight was negatively affected by treatments with 50 mM NaCl or higher. These findings were consistent with Jonson et al., (1992) when they found that as salinity levels rose, the weight of individual fruits reduced. This is because heightened salinity reduces the plant has water potential, subsequently decreasing the water intake into the fruit and affecting its growth rate. The effects of the treatments on the marketable fruit weight were illustrated in Table 4.3.

Table 4.3. Effect of salinity and Ca doses on marketable fruit weight (g)

Treatments		fruit weight (g)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	27.89±0.66 ^e	27.48±0.65 ^{ef}	95.98±5.01 ^f	100.77±4.35 ^h
	50	31.64±0.35 ^d	31.78±0.50 ^d	122.07±3.22 ^d	123.55±4.89 ^f
	100	38.08±1.01 ^b	37.43±0.50 ^b	164.97±1.75 ^b	164.21±6.30 ^c
	200	43.35±1.49 ^a	43.35±2.17 ^a	204.45±7.72 ^a	202.29±9.39 ^a
4	0	26.33±0.69 ^f	26.40±1.02 ^f	97.08±0.80 ^f	98.60±4.39 ^h
	50	27.87±0.71 ^e	28.55±0.51 ^e	103.95±1.00 ^e	105.39±5.58 ^g
	100	34.07±0.16 ^c	34.33±1.00 ^c	127.24±1.03 ^d	128.20±7.12 ^e
	200	37.63±0.55 ^b	37.98±1.54 ^b	168.67±4.93 ^b	170.03±8.76 ^b
6	0	23.63±0.39 ^g	22.76±1.23 ^g	88.81±0.71 ^g	89.63±4.05 ⁱ
	50	25.57±0.33 ^f	25.87±0.83 ^f	95.97±2.97 ^f	97.92±3.61 ^h
	100	31.89±0.82 ^d	31.83±0.69 ^d	121.45±3.09 ^d	120.21±6.30 ^f
	200	34.55±0.51 ^c	34.32±1.25 ^c	133.97±3.32 ^c	134.12±8.12 ^d
Means					
Salinity	2	35.24 ^a	35.01 ^a	146.87 ^a	147.71 ^a
	4	31.47 ^b	31.82 ^b	124.23 ^b	125.56 ^b
	6	28.91 ^c	28.70 ^c	110.05 ^c	110.47 ^c
Ca	0	25.95 ^d	25.55 ^d	93.96 ^d	96.33 ^d
	50	28.36 ^c	28.74 ^c	107.33 ^c	108.95 ^c
	100	34.68 ^b	34.53 ^b	137.88 ^b	137.54 ^b
	200	38.51 ^a	38.55 ^a	169.03 ^a	168.81 ^a
Significant differences					
Salinity		**	*	**	**
Ca		**	**	**	**
Salinity*Ca		**	**	**	**

Values followed by similar letters under the same column are not significantly different at $p \leq 0.05$.
 ** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively.

4.3. Effect of salinity and Ca doses on total yield

4.3.1. Total yield (ton/ha)

The effect of salinity and calcium doses had a significant impact on total yield in 2021 and 2022 for the LA4442 variety. Using a combination of 200 ppm calcium and EC 2.0 dS/m, the total yield reached their highest at 118.97 and 127.73 ton/ha respectively. However, using 0 ppm calcium and 6.0 dS/m resulted in the minimum yields of 41.56 and 39.54 ton/ha respectively.

In 2021 and 2022, for the Ufuk F₁ variety, when combined with 200 ppm calcium and EC 2.0 dS/m, total yield peaked at 279.27 and 287.20 ton/ha respectively. In contrast, when paired with 0 ppm calcium and EC 6.0 dS/m, the total yield dropped to its lowest at 55.04 ton/ha. However, in 2022, the lowest values of total yield 46.16 ton/ha were recorded from the interaction between 0 ppm calcium and EC 6.0 dS/m.

In 2021 and 2022, for the LA4442 and Ufuk F₁ variety, increasing calcium concentration generally led to an increase in total yield across different salinity levels. The negative impact of increased salinity on yield was somewhat mitigated by higher calcium concentrations. These results were in agreement with Nizam et al., (2019) who found that as salinity increased, salt stress decreased both the yield metrics and overall yield of the tomato. Also, calcium significantly reduced the impact of salinity on both total yield and yield-contributing characteristics. These results agreed with Jonson et al., (1992) observed that increased salinity resulted in smaller fruit sizes. Raising the concentration of external calcium may positively influence tomato plants when they are subjected to NaCl stress Zhang et al., 2016). The impacts of the treatments on the total yield of tomato were presented in Table 4.4.

4.3.2. Fruit number

The interaction between salinity and calcium doses had a significant effect on total yield (fruit number). In 2021 and 2022, the LA4442 variety showed that increasing calcium from 0 to 200 ppm in both EC (2.0 dS/m and 4.0 dS/m) led to a gradual increase in fruit number. The highest fruit numbers (126.03 and 131.44 respectively) were obtained with

200 ppm calcium and EC 2.0. In contrast, lowest number of fruit in 2021 (83.97) was recorded from interaction between 100 ppm calcium and EC 6.0 dS/m, and in 2022 the minimum values of fruits/plant (77.69) were obtained from EC 2.0 dS/m with 0 ppm calcium. However, at EC 6.0 dS/m, calcium doses did not have a significant effect on a number of fruits.

Table 4.4. Effect of salinity and Ca doses on total yield (ton/ha)

Treatments		Ton/ha			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	50.25±2.00 ^{de}	46.06±3.16 ^{ef}	73.26±1.68 ^f	65.97±5.29 ^g
	50	46.94±3.86 ^{ef}	49.84±3.17 ^{de}	76.62±2.98 ^f	82.81±4.12 ^f
	100	56.11±5.27 ^{cd}	71.19±2.74 ^c	162.30±6.48 ^c	162.92±6.21 ^c
	200	118.97±5.93 ^a	127.73±3.94 ^a	279.27±6.29 ^a	287.20±9.66 ^a
4	0	42.52±2.03 ^f	42.63±0.75 ^{fg}	80.17±3.25 ^f	81.65±6.30 ^f
	50	49.04±4.42 ^e	49.62±1.53 ^{de}	65.66±1.12 ^g	71.20±6.85 ^{fg}
	100	55.62±3.57 ^{cd}	53.72±1.25 ^d	104.54±1.74 ^e	103.01±7.63 ^e
	200	69.12±2.82 ^b	84.82±5.19 ^b	188.21±4.84 ^b	193.11±9.10 ^b
6	0	41.56±3.19 ^f	39.54±1.43 ^g	60.19±3.62 ^{gh}	46.16±4.10 ^h
	50	41.61±3.49 ^f	46.56±2.60 ^{ef}	55.04±1.61 ^h	61.13±4.63 ^g
	100	50.19±2.01 ^{de}	53.12±1.02 ^d	80.38±5.16 ^f	79.84±5.60 ^f
	200	57.32±2.63 ^c	53.37±2.32 ^d	139.98±6.30 ^d	141.03±7.69 ^d
Means					
Salinity	2	68.07 ^a	73.70 ^a	147.86 ^a	149.72 ^a
	4	54.07 ^b	57.70 ^b	109.65 ^b	112.24 ^b
	6	47.67 ^c	48.15 ^c	83.90 ^c	82.04 ^c
Ca	0	44.78 ^c	42.74 ^d	71.21 ^c	64.59 ^d
	50	45.86 ^c	48.67 ^c	65.77 ^c	71.71 ^c
	100	53.97 ^b	59.34 ^b	115.74 ^b	115.25 ^b
	200	81.80 ^a	88.64 ^a	202.48 ^a	207.11 ^a
Significant differences					
Salinity		**	**	**	**
Ca		**	**	**	**
Salinity*Ca		**	**	**	**

Values followed by similar letters under the same column are not significantly different at $p \leq 0.05$.

** represent significance difference ($P \leq 0.01$).

These outcomes were congruent with Soria et al., (2000) who pointed out that increasing Ca from 4 to 6 mM. This increase in yield was due to the larger size of fruits,

but not to a higher number of fruits. Also, these results were in agreement Rab and Haq, (2012) who noticed that increased calcium doses from 0.3% to 0.6% let to increase the fruit number. In 2021 and 2022 years, for the Ufuk F₁ variety, the maximum fruit number was 83.98 and 83.06, respectively, observed from the interaction of 200 ppm calcium and EC 2.0 dS/m. In 2021, the lowest fruit number was 41.34, noted from the combination of 0 ppm calcium and EC 2.0 dS/m. However, in 2022, the minimum fruit number 41.47 was recorded from the interaction between 100 ppm calcium and 6.0 dS/m. the results showed that in both years calcium significant effect on number of fruit but salinity decline the number of fruit. These results match Zhang et al., (2017) who found that salinity stress during the flowering and fruiting stages led to a decrease in tomato yield. This reduction in yield was primarily caused by a decrease in the number of fruits produced. The effects of the applications on total yield (fruit number) of tomato were presented in Table 4.5.

4.4. Effect of salinity and Ca doses on fruit dry weight

In 2021, LA4442 variety data revealed that the highest dry fruit weight 6.16% was recorded from the interaction between 200 ppm calcium and EC 6.0 dS/m. In contrast, the lowest dry fruit weight of 4.80% was found from the interaction between 200 ppm Calcium and EC 2.0 dS/m. In 2022, the interaction between calcium and salinity had no significant effect on the dry fruit weight. These results align with those of Adams, (1990) who discovered that the fruit dry weight accumulation did not reduce consistently with rising salinity and calcium did not influence this accumulation.

In 2021 for the Ufuk F₁ variety, the maximum dry fruit weight 7.29% resulted from the combination of 50 ppm calcium and EC 6.0 dS/m. Conversely, the minimum dry fruit weight 5.86% was observed from the combination of 50 ppm calcium and EC 4.0 dS/m. These results particularly agree with Cuartero and Fernández-Muñoz, (1998) who discovered that the increase in fruit dry weight was observed with an increase in salinity.

Table 4.5. Effect of salinity and Ca doses on total yield (fruit number)

Treatments		Fruit/number			
		LA4442		Ufuk F ₁	
		2021	2022	2021	2022
Salinity	0	85.55±1.67 ^e	77.69±3.79 ^g	43.02±1.00 ^f	47.33±1.73 ^f
	50	84.60±2.77 ^e	80.40±2.34 ^{fg}	41.34±0.13 ^f	44.33±1.73 ^g
	100	85.71±5.97 ^e	115.27±3.79 ^b	57.30±1.67 ^c	58.67±3.81 ^c
	200	126.03±6.76 ^a	131.44±5.17 ^a	83.98±1.98 ^a	83.06±4.98 ^a
Ca	0	93.17±1.67 ^{de}	86.53±3.14 ^{def}	50.17±1.16 ^e	49.56±1.59 ^{ef}
	50	102.54±3.85 ^{bcd}	83.93±1.01 ^{efg}	50.02±1.09 ^e	50.72±1.41 ^e
	100	99.84±4.53 ^{cd}	98.66±3.13 ^c	49.27±1.59 ^e	47.86±1.49 ^{ef}
	200	110.32±3.70 ^b	109.22±9.00 ^b	61.35±0.72 ^b	63.75±2.12 ^b
Means	0	102.54±5.88 ^{bcd}	94.64±3.95 ^{cd}	50.86±1.28 ^{de}	53.75±1.61 ^d
	50	104.76±5.61 ^{bc}	92.47±2.96 ^{cd}	52.51±1.31 ^d	48.81±1.27 ^{ef}
	100	83.97±4.81 ^e	91.58±6.29 ^{cde}	43.41±0.32 ^f	41.47±1.06 ^h
	200	99.69±5.05 ^{cd}	92.49±2.95 ^{cd}	49.22±1.58 ^e	49.83±1.93 ^{ef}
Significant differences					
Salinity		*	**	**	**
Ca		**	**	**	**
Salinity*Ca		**	**	**	**

Values followed by similar letters under the same column are not significantly different at $p \leq 0.05$.

** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

In 2022, the maximum dry fruit weight 7.12% was derived from the pairing of 200 ppm calcium and EC 2.0 dS/m. Conversely, the interaction between of 0 ppm Calcium and EC 6.0 dS/m produced the lowest dry fruit weight 6.00%. These results were supported by Nizam et al., (2019) Who found that increase calcium let to decrease salt stress in tomato dry fruit. And, Posada and Rodriguez, (2009) reported that fruits of salt-stressed plants had reduced total dry matter. The effects of the treatments on the dry weight of the fruit were found in Table 4.6.

Table 4.6. Effect of salinity and Ca doses on fruit dry weight

Treatments		Fruit dry weight (%)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	5.33 ± 0.21 ^b	6.41±0.73	6.37±0,25 ^{bcd}	6.25±0.07 ^{de}
	50	5.23 ± 0.23 ^b	6.65±0.42	5.90±0,14 ^d	6.42±0.13 ^{cd}
	100	5.28 ± 0.32 ^b	6.47±0.23	6.17±0,24 ^{cd}	6.84±0.15 ^b
	200	5.08 ± 0.28 ^b	6.09±0.14	6.13±0,25 ^{cd}	7.12±0.07 ^a
4	0	5.36 ± 0.23 ^b	6.97±0.38	6.64±0,31 ^{bc}	6.05±0.11 ^{ef}
	50	5.37 ± 0.38 ^b	6.68±0.16	5.86±,024 ^d	6.23±0.10 ^{de}
	100	5.36 ± 0.05 ^b	6.20±0.22	6.52±0,21 ^{bcd}	6.24±0.06 ^{de}
	200	5.21 ± 0.49 ^b	6.28±0.26	6.83±0,27 ^{ab}	6.72±0.28 ^b
6	0	5.16 ± 0.30 ^b	7.77±0.72	6.95±0,16 ^{ab}	6.00±0.13 ^f
	50	5.55 ± 0.21 ^b	7.67±0.33	7.29±0,24 ^a	6.14±0.08 ^{ef}
	100	5.53 ± 0.22 ^b	6.72±0.51	6.86±0,26 ^{ab}	6.27±0.03 ^{de}
	200	6.16 ± 0.06 ^a	6.28±0.14	6.61±0,23 ^{bc}	6.49±0.05 ^c
Means					
Salinity	2	5.23 ^b	6.41 ^b	6.14 ^c	6.66 ^a
	4	5.32 ^b	6.53 ^b	6.46 ^b	6.31 ^b
	6	5.60 ^a	7.11 ^a	6.93 ^a	6.23 ^b
Ca	0	5.28	7.05 ^a	6.65	6.10 ^d
	50	5.38	7.00 ^a	6.35	6.27 ^c
	100	5.39	6.46 ^b	6.52	6.45 ^b
	200	5.48	6.22 ^b	6.52	6.77 ^a
Significant differences					
Salinity		**	**	*	**
Ca		n.s	**	n.s	**
Salinity*Ca		*	n.s	*	*

Values followed by similar letters under the same column are not significantly different at $p \leq 0.05$.

** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

ns: Not significant difference.

4.5. Effect of salinity and Ca doses on leaf dry weight

The interaction of calcium and salinity significantly affected the leaf dry weight in different parts of the tomato plant in LA4442 in 2021, the interaction between 200 ppm calcium and EC 6.0 dS/m resulted in the highest observed value of leaf dry weight, which was 10.52%. Conversely, the minimum value of leaf dry weight 7.20% was measured in the interaction between 0 ppm calcium and EC 2.0 dS/m. The results showed a significant effect of calcium on the salt stress in the leaf dry weight. Increased

calcium doses were due to the increase in leaf dry weight. These findings were line with Manivannan et al., (2007) calcium mitigates the effects of salt stress, leading to an increase in the plant's total dry weight by enhancing its vegetative growth.

In 2022, there were no significant deferent of effect calcium and salt on leaf dry weight. These findings were consistent with Adams, (1990) when they found that the accumulation of dry weight in the leaves was not progressively decreased by increasing salinity, and calcium had no effect on this accumulation.

The impact of various calcium doses and salt levels on the accumulation of dry weight in tomato plant leaves was examined in Ufuk F₁ variety in 2021. The highest leaf dry weight 11.16% was found with 200 ppm calcium and EC 4.0 dS/m. In contrast, 0 ppm calcium and EC 0 dS/m exhibited the lowest leaf weight 8.60%.

In 2022, the greatest value of leaf dry weight 10.96% was obtained from the interaction between 200 ppm calcium and EC 2.0 dS/m. However, the lowest leaf dry weight 7.88% was obtained from the interaction between 0 ppm calcium and EC 6.0 dS/m. These results totally agreed with Parvin et al., (2015); Tabatabaeian, (2014) when they found that increase salinity decreased leaf dry weight and increases calcium doses let to increase leaf dry weight. The impacts of the treatments on the leaf dry weight were presented in Table 4.7.

4.6. Effect of salinity and Ca doses on rate of blossom end rot

The occurrence of Blossom end rot was significantly influenced by the levels of salinity, the concentration of calcium, and the interaction between salinity and calcium (Figure 4.1, 2). In 2021 and 2022 for LA4442 variety, the interaction between 0 ppm calcium and EC 6.0 dS/m resulted in the highest percentages of blossom end rot, which were 53.89% and 56.61%, respectively. On the other hand, the minimal occurrences of blossom end rot, recorded at 0.62% and 0.25%, respectively, were noted when the calcium level was raised to 200 ppm and the EC was decreased to 2.0 dS/m.

During the years 2021 and 2022, the Ufuk F₁ variety exhibited varying degrees of BER due to different calcium and salinity interactions, BER peaked at 74.72% and 75.04%, respectively, in conditions where there was 0 ppm calcium and the salinity was at EC 6.0 dS/m. On the other hand, when 200 ppm of calcium was present and salinity was at

EC 2.0 dS/m, BER was significantly reduced, with recorded values of 0.40% and 0.27%, respectively.

Table 4.7. Effect of salinity and Ca doses on leaf dry weight

Treatments		Leaf dry weight (%)			
Salinity	Ca	LA4442		Ufuk F ₁	
		2021	2022	2021	2022
2	0	7.20 ± 0.24 ^g	8.52±0.44	8.60±0.49 ^e	10.79±0.61 ^a
	50	8.70 ± 0.06 ^{cd}	9.01±0.25	10.13±0.23 ^{bc}	10.45±0.52 ^a
	100	8.61 ± 0.71 ^{cde}	10.20±0.52	10.57±0.62 ^{ab}	10.63±0.88 ^a
	200	9.61 ± 0.26 ^b	9.71±0.26	10.36±0.27 ^{abc}	10.96±0.61 ^a
4	0	7.83 ± 0.09 ^{fg}	8.05±0.82	9.63±0.27 ^{cd}	7.90±0.66 ^d
	50	8.56 ± 0.18 ^{cde}	8.31±0.14	10.54±0.59 ^{ab}	8.97±0.27 ^c
	100	9.15 ± 0.55 ^{bc}	8.62±0.27	10.52±0.63 ^{ab}	9.44±0.52 ^{bc}
	200	9.61 ± 0.58 ^b	8.62±0.42	11.16±0.33 ^a	10.09±0.36 ^{ab}
6	0	8.19 ± 0.37 ^{def}	7.72±0.53	9.15±0.78 ^{de}	7.88±0.45 ^d
	50	7.94 ± 0.27 ^{ef}	7.80±0.07	10.51±0.32 ^{ab}	8.79±0.08 ^{cd}
	100	8.98 ± 0.59 ^{bc}	8.26±0.06	10.66±0.27 ^{ab}	8.95±0.44 ^c
	200	10.52 ± 0.15 ^a	8.74±0.18	10.42±0.33 ^{abc}	10.38±0.72 ^{ab}
Mean					
Salinity	2	8.53	9.36 ^a	9.92 ^b	10.71 ^a
	4	8.79	8.40 ^b	10.46 ^a	9.10 ^b
	6	8.91	8.13 ^b	10.18 ^{ab}	9.00 ^b
Ca	0	7.74 ^d	8.10 ^b	9.13 ^b	8.86 ^c
	50	8.40 ^c	8.38 ^b	10.39 ^a	9.41 ^b
	100	8.91 ^b	9.03 ^a	10.58 ^a	9.67 ^b
	200	9.92 ^a	9.02 ^a	10.64 ^a	10.48 ^a
Significant differences					
Salinity		n.s	**	*	**
Ca		**	**	**	**
Salinity*Ca		*	n.s	*	*

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

ns: Represent not significant difference.

The results showed that in 2021 and 2022 years, the LA4442 and Ufuk F₁ varieties, higher salinity levels led to an increased incidence of BER. Nevertheless, this effect was alleviated when calcium doses were raised. These results were compatible with Küçükçelik, (2013) who mentioned that the impact of varying levels of calcium on mitigating BER, increased calcium from 0.25% to 0.75% decreased BER. These results

were in agreement with Ahmad, (2018); Rab et al., (2017) who noted that application calcium decreased ratio BER. These results were consistent with Tüzel et al., (2000); Cuartero and Fernández-Muñoz, (1998) who indicated that elevated salinity levels contribute to a higher incidence of BER. The effects of the treatments on the blossom end rot were presented in Table 4.8.

Table 4.8. Effect of salinity and Ca doses on rate of blossom end rot

Treatments		%			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	29.49±0.54 ^d	32.40±1.56 ^d	43.93±1.69 ^d	44.75±3.18 ^d
	50	18.38±2.44 ^g	20.81±1.45 ^e	24.73±1.96 ^f	26.69±1.58 ^e
	100	5.56±0.46 ^h	3.69±0.41 ^g	7.78±1.12 ^h	6.88±1.15 ^h
	200	0.62±0.20 ⁱ	0.25±0.09 ^h	0.40±0.01 ^j	0.27±0.12 ^j
4	0	43.43±0.76 ^b	46.83±1.84 ^b	64.89±0.21 ^b	68.36±3.48 ^b
	50	27.40±0.42 ^e	32.50±1.90 ^d	45.11±1.08 ^d	47.09±2.01 ^d
	100	17.66±0.33 ^g	17.24±0.51 ^f	16.26±1.19 ^g	15.55±0.45 ^g
	200	1.44±0.66 ⁱ	0.91±0.31 ^h	0.90±0.32 ^j	0.52±0.26 ^j
6	0	53.89±0.68 ^a	56.61±1.88 ^a	74.72±0.47 ^a	75.04±4.48 ^a
	50	38.68±1.49 ^c	41.98±1.55 ^c	53.75±0.26 ^c	59.87±3.99 ^c
	100	25.33±0.67 ^f	20.95±1.34 ^e	26.87±2.13 ^e	19.79±2.60 ^f
	200	4.31±0.58 ^h	3.89±0.20 ^g	5.20±0.51 ⁱ	4.02±0.38 ⁱ
Means					
Salinity	2	13.51 ^c	14.29 ^c	19.31 ^c	19.65 ^c
	4	22.48 ^b	24.37 ^b	31.79 ^b	32.88 ^b
	6	30.55 ^a	30.86 ^a	40.13 ^a	39.68 ^a
Ca	0	42.27 ^a	45.28 ^a	61.18 ^a	62.72 ^a
	50	28.15 ^b	31.76 ^b	41.19 ^b	44.55 ^b
	100	16.18 ^c	13.96 ^c	16.97 ^c	14.07 ^c
	200	2.13 ^d	1.68 ^d	2.17 ^d	1.60 ^d
Significant differences					
Salinity		**	**	**	**
Ca		**	**	**	**
Salinity*Ca		**	**	**	**

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** : Represent significance difference ($P \leq 0.01$).



Fig. 4.1. Effect of different salt concentrations on BER at 0 and 50 ppm Ca doses.



Fig. 4.2. Effect of different salt concentrations on BER at 100 and 200 ppm Ca doses.

4.7. Effect of salinity and Ca doses on Brix of tomato variety

The total soluble solids of tomato showed significant variations in response to different levels of calcium and salinity. In the year 2021, the LA4442 variety exhibited a greatest Brix value of 6.93 when subjected to the application of 0 ppm calcium and EC 6.0 dS/m. The recorded smallest Brix value of 5.50 appeared as a result of the interaction between a concentration of 200 ppm and an EC 2.0 dS/m.

The findings indicated that increases in salt levels can be attributed to an increase in total soluble solids. Our results were in agreement with the results of Agius et al., (2022) the results of our study indicated that the utilization of sodium chloride resulted in a significant elevation in the overall concentration of soluble solids.

In the year 2022, there was no significant difference observed between the effects of calcium and salt. Additionally, the increased salinity did not have an impact on the overall concentration of Brix.

In 2021, for Ufuk F₁ variety exhibited the highest total soluble solids measuring 5.18 resulting from the interaction of 200 ppm calcium and an EC of 6.0 dS/m. Conversely, the lowest total soluble solid 3.58 was noted when there was an interaction between 100 ppm calcium and EC of 2.0 dS/m. The results showed that Brix increased under high calcium doses and high salinity levels.

In 2022, the interaction between 0 ppm calcium and EC 6.0 dS/m resulted in the highest total soluble solids measurement of 6.13. Contrarily, the lowest level of total soluble solids (4.76) was noted in the interaction between 200 ppm calcium and EC 2.0 dS/m. Our results were consistent with the findings of Turhan, (2020) ;Tüzel et al., (2000); El-Mogy et al., (2018); Sajid et al., (2020) observed that an elevation in salinity levels resulted in a proportional augmentation of the overall concentration of soluble solids, so mitigating the decline in crop productivity. The effects of the applications Brix of tomato were presented in Table 4.9.

Table 4.9. Effect of salinity and Ca doses on Brix of tomato variety

Treatments		Brix %			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	6.03±0.21 ^{cd}	4.92±0.43	4.29±0.14 ^d	5.23±0.10 ^b
	50	6.70±0.00 ^{ab}	5.32±0.28	3.84±0.10 ^f	5.21±0.18 ^{bc}
	100	6.27±0.40 ^{bcd}	5.12±0.48	3.58±0.14 ^g	4.93±0.06 ^{cde}
	200	5.50±0.20 ^e	5.12±0.18	4.40±0.12 ^d	4.76±0.09 ^e
4	0	6.07±0.06 ^{cd}	5.24±0.42	4.44±0.10 ^d	5.24±0.12 ^b
	50	6.37±0.12 ^{bc}	4.84±0.18	4.04±0.08 ^e	5.06±0.07 ^{bcd}
	100	6.37±0.40 ^{bc}	5.20±0.70	4.24±0.14 ^d	4.87±0.12 ^{de}
	200	5.90±0.26 ^d	4.88±0.14	4.69±0.04 ^c	4.79±0.12 ^{de}
6	0	6.93±0.32 ^a	6.04±0.42	4.91±0.10 ^b	6.13±0.10 ^a
	50	6.53±0.06 ^{ab}	6.12±0.12	4.31±0.14 ^d	5.94±0.07 ^a
	100	6.57±0.15 ^{ab}	5.28±0.12	4.42±0.10 ^d	5.33±0.28 ^b
	200	6.37±0.15 ^{bc}	5.32±0.18	5.18±0.08 ^a	4.95±0.29 ^{cde}
Means					
Salinity	2	4.03 ^c	5.12 ^b	4.03 ^c	5.04 ^b
	4	4.36 ^b	5.04 ^b	4.36 ^b	4.99 ^b
	6	4.71 ^a	5.69 ^a	4.71 ^a	5.59 ^a
Ca	0	4.55 ^b	5.40	4.55 ^b	5.53 ^a
	50	4.07 ^c	5.43	4.07 ^c	5.40 ^a
	100	4.08 ^c	5.20	4.08 ^c	5.05 ^b
	200	4.76 ^a	5.11	4.76 ^a	4.84 ^c
Significant differences					
Salinity		**	**	**	**
Ca		**	n.s	**	**
Salinity*Ca		**	n.s	**	**

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** : Represent significance difference ($P \leq 0.01$). ns: Represent not significant difference.

4.8. Effect of salinity and Ca doses on electrical conductivity of fruits

The electrical conductivity of the fruit juice was significantly influenced by the interaction between calcium and salinity. In 2021, for LA4442 variety, the highest electrical conductivity value of 7.45 was observed in plants treated with 100 ppm and EC 6.0 dS/m. In contrast, the lowest electrical conductivity value 5.14, was associated with treatments of 100 ppm calcium with EC 2.0 dS/m.

In 2022, the greater electrical conductivity 6.34 was recorded from interaction between 0 ppm and EC 6.0 dS/m. However, the lowest value of electrical conductivity 4.11 was recorded from interaction between 200 ppm calcium and EC 2.0 dS/m.

In 2021 and 2022 years, for Ufuk F₁ variety, the maximum electrical conductivity values of electrical conductivity (6.60 and 7.07 respectively) were observed with 0 ppm calcium and EC 6.0 dS/m. Nevertheless, in 2021, the lowest value of electrical conductivity 3.65 was recorded from the interaction between 0 ppm calcium and EC 2.0 dS/m. Conversely, in 2022, a minimum electrical conductivity of 4.65 was observed from the interaction between 200 ppm calcium and EC 2.0 dS/m.

In 2021 and 2022, for LA4442 and Ufuk F₁ variety, Salinity had significantly effected on electrical conductivity of fruits juice. And, the electrical conductivity increase when exposed to high levels of NaCl. However, it diminished when calcium was applied.

Similar observation were also observed by Tüzel et al., (2000); Mizrahi, (1982); Satti and Al-Yahyai, (1995) who reported that the electrical conductivity of the fruit juice increased with the increase in saline levels. The influence of the applications on the electrical conductivity of fruits was showed in Table 4.10.

4.9. Effect of salinity and Ca doses pH of tomato variety

The pH of the fruit was not significantly affected by the presence of calcium or the relationship between calcium and salinity. There was no significant relationship observed between calcium and salinity for the LA4442 and Ufuk F₁ genotypes over the years 2021 and 2022. This result was supported by Satti and Al-Yahyai, 1995 who mentioned that there were no significant disparities in fruit pH observed across various salinity treatments. The influence of the applications on the pH of fruits was showed in Table 4.11.

Table 4.10. Effect of salinity and Ca doses on electrical conductivity (EC) of fruits

Treatments		EC (dS/m)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	5.69±0.23 ^{ef}	5.20±0.05 ^c	3.65±0.23 ^g	5.72±0.06 ^c
	50	5.15±0.09 ^f	5.58±0.05 ^c	4.07±0.20 ^f	5.55±0.07 ^{cd}
	100	5.14±0.39 ^f	5.30±0.12 ^c	4.91±0.29 ^{de}	4.92±0.20 ^{ef}
	200	5.60±0.06 ^{ef}	4.11±0.13 ^d	4.68±0.14 ^e	4.65±0.14 ^f
4	0	6.83±0.18 ^{bc}	5.54±0.09 ^c	4.29±0.13 ^f	6.49±0.41 ^b
	50	5.59±0.33 ^{ef}	5.36±0.10 ^c	5.16±0.33 ^{cd}	5.36±0.06 ^d
	100	6.59±0.18 ^{cd}	5.24±0.05 ^c	4.95±0.18 ^{de}	5.22±0.10 ^{de}
	200	6.12±0.06 ^{de}	4.42±0.17 ^d	4.85±0.12 ^{de}	5.00±0.23 ^e
6	0	7.18±0.15 ^{ab}	6.34±0.16 ^a	6.60±0.19 ^a	7.07±0.22 ^a
	50	6.61±0.71 ^{cd}	5.94±0.12 ^b	5.60±0.12 ^b	6.45±0.28 ^b
	100	7.45±0.11 ^a	5.57±0.13 ^c	5.72±0.08 ^b	5.53±0.11 ^{cd}
	200	6.68±0.28 ^{bc}	5.48±0.15 ^c	5.37±0.19 ^{bc}	5.22±0.11 ^{de}
Means					
Salinity	2	5.40 ^c	5.05 ^b	4.33 ^c	5.21 ^c
	4	6.28 ^b	5.14 ^b	4.81 ^b	5.52 ^b
	6	6.98 ^a	5.84 ^a	5.82 ^a	6.07 ^a
Ca	0	6.57 ^a	5.69 ^a	4.85 ^b	6.43 ^a
	50	5.79 ^c	5.63 ^a	4.95 ^b	5.79 ^b
	100	6.40 ^{ab}	5.37 ^b	5.19 ^a	5.22 ^c
	200	6.13 ^b	4.67 ^c	4.97 ^b	4.96 ^d
Significant differences					
Salinity		**	**	**	**
Ca		**	**	**	**
Salinity*Ca		*	**	**	**

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

4.10. Effect of salinity and Ca doses on fruit titratable acidity (TA) of tomato fruit

Salinity predominantly influenced the titratable acidity characteristic. The interaction between calcium and salinity was not statistically significant. In 2021 and 2022, for LA4442 variety, a noticeable increase in titratable acidity is observed with the rise in salt concentration, though this increase is not statistically significant. Additionally, there were no significant differences in titratable acidity between calcium and salt.

In Ufuk F1 variety, in 2021 there were no significant differences in titratable acidity between calcium and salt. In 2022 the best value of titratable acidity 0.312 was

observed from interaction 50 ppm calcium and EC 6.0 dS/m. Conversely, minimum titratable acidity 0.196 was recorded from interaction between 100 ppm calcium and EC 4.0 dS/m. These findings were line with Tüzel et al., (2000); Mizrahi, (1982); El-Mogy et al., (2018) who mentioned that increased salinity decline fruit weight but increased titratable acidity in fruit. These results was supported by Ahmad, (2018) found that increased calcium dosed reduced titratable acidity. The impact of the treatments on titratable acidity was detailed in Table 4.12.

Table 4.11. Effect of salinity and Ca doses on pH of tomato variety

Treatments		pH			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	4.57±0.06	4.59±0.04	4.53±0.06	4.56±0.04
	50	4.67±0.06	4.65±0.05	4.60±0.10	4.59±0.24
	100	4.43±0.06	4.75±0.06	4.60±0.00	4.90±0.06
	200	4.47±0.06	4.73±0.01	4.53±0.06	4.81±0.04
4	0	4.43±0.06	4.59±0.01	4.53±0.06	4.65±0.15
	50	4.60±0.03	4.66±0.02	4.47±0.12	4.84±0.03
	100	4.43±0.06	4.71±0.05	4.53±0.06	4.88±0.03
	200	4.40±0.03	4.72±0.02	4.43±0.06	4.85±0.10
6	0	4.50±0.04	4.53±0.04	4.27±0.06	4.67±0.06
	50	4.43±0.06	4.59±0.01	4.37±0.06	4.71±0.05
	100	4.33±0.06	4.68±0.02	4.43±0.06	4.85±0.02
	200	4.40±0.06	4.66±0.01	4.33±0.06	4.87±0.01
Means					
Salinity	2	4.53 ^a	4.68 ^a	4.57 ^a	4.71
	4	4.45 ^b	4.67 ^a	4.49 ^b	4.81
	6	4.42 ^b	4.61 ^b	4.35 ^c	4.78
Ca	0	4.50 ^b	4.57 ^c	4.44 ^b	4.63 ^b
	50	4.57 ^a	4.63 ^b	4.48 ^{ab}	4.71 ^b
	100	4.40 ^c	4.71 ^a	4.52 ^a	4.87 ^a
	200	4.42 ^c	4.70 ^a	4.43 ^b	4.85 ^a
Significant differences					
Salinity		*	**	**	n.s
Ca		*	**	*	*
Salinity*Ca		n.s	n.s	n.s	n.s

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.
 * and ** represent significance difference at $P \leq 0.01$ and 0.05 , respectively
 ns: Represent not significant difference.

Table 4.12. Effect of salinity and Ca doses on fruit titratable acidity (TA) of tomato fruit

Treatments		TA (mg/100 g)			
Salinity	Ca	LA4442		Ufuk F ₁	
		2021	2022	2021	2022
2	0	0.214±0.007	0.232±0.048	0.248±0.018	0.287±0.015 ^{ab}
	50	0.224±0.020	0.256±0.061	0.217±0.015	0.271±0.004 ^b
	100	0.213±0.036	0.216±0.065	0.212±0.001	0.204±0.005 ^{de}
	200	0.209±0.037	0.209±0.007	0.209±0.003	0.223±0.007 ^{cd}
4	0	0.228±0.003	0.207±0.018	0.240±0.009	0.215±0.025 ^{cde}
	50	0.214±0.027	0.217±0.009	0.224±0.009	0.204±0.023 ^{de}
	100	0.202±0.030	0.184±0.027	0.205±0.001	0.196±0.023 ^e
	200	0.211±0.013	0.205±0.014	0.212±0.001	0.206±0.033 ^{cde}
6	0	0.229±0.009	0.253±0.058	0.256±0.018	0.234±0.004 ^{cd}
	50	0.250±0.013	0.280±0.036	0.229±0.011	0.312±0.025 ^a
	100	0.216±0.022	0.242±0.013	0.212±0.008	0.234±0.015 ^{cd}
	200	0.238±0.018	0.233±0.017	0.207±0.008	0.240±0.002 ^c
Means					
Salinity	2	0.214 ^b	0.228 ^b	0.222	0.487 ^a
	4	0.214 ^b	0.203 ^c	0.220	0.407 ^b
	6	0.233 ^a	0.252 ^a	0.226	0.505 ^a
Ca	0	0.223 ^a	0.231 ^b	0.248 ^a	0.486 ^a
	50	0.229 ^a	0.251 ^a	0.223 ^b	0.519 ^a
	100	0.210 ^b	0.214 ^b	0.210 ^c	0.418 ^b
	200	0.219 ^{ab}	0.216 ^b	0.209 ^c	0.441 ^b
Significant differences					
Salinity		**	**	n.s	**
Ca		*	**	**	**
Salinity*Ca		n.s	n.s	n.s	**

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

* and ** represent significance difference at $P \leq 0.01$ and 0.05 , respectively

ns: Represent not significant difference .

4.11. Effect of salinity and Ca doses on leaf chlorophyll (SPAD)

The content of chlorophyll in the leaves indicated an important difference across different doses of calcium and levels of sodium chloride. In 2021, the LA4442 variety displayed an increase in chlorophyll response to higher calcium doses, with the optimal value of 49.24 observed when 200 ppm of calcium was combined with EC 2.0 dS/m. However, an increased in electric conductivity led to a decline in chlorophyll leaf, resulting in minimum chlorophyll of 39.34 from the interaction between 0 ppm calcium

and EC 6.0 dS/m. These results indicated that the chlorophyll content showed a significant decrease when exposed to a salinity level of 6 dS/m (Hasanuzzaman et al., 2014).

In 2022, the interaction between a calcium concentration of 200 ppm and EC 4.0 dS/m resulted in the highest recorded chlorophyll value of 53.64. Nevertheless, a minimum chlorophyll value of 41.02 was discovered as a result of the interaction between a calcium concentration of 0 ppm and EC 6.0 dS/m. Our results were in agreement with the result Rani et al., (2017); Netondo et al., (2004) when they found that the presence of salinity resulted in a decrease in the overall chlorophyll concentration within the leaves.

In the year 2021, an investigation of Ufuk F₁ revealed that the highest recorded chlorophyll content was 59.75. This observation was made as a result of the interaction between a calcium concentration of 200 ppm and EC 2.0 dS/m. In contrast, in 2022, for Ufuk F₁, the highest value of chlorophyll 54.75 was recorded from the interaction between 200 ppm calcium and EC 4.0 dS/m. In both 2021 and 2022, the minimal chlorophyll levels were recorded at 49.63 and 43.26, respectively, resulting from the interaction of 0 ppm calcium and an EC of 6.0 dS/m. In generally, the findings indicated a substantial effect of calcium on the chlorophyll within the leaves. Additionally, elevated levels of calcium led to a reduction in salinity's impact on leaf chlorophyll. Furthermore, the presence of calcium in the nutritional solution enhanced the plant cells' chlorophyll pigments, resulting in improved light absorption by the plant. Our results were in agreement with the result Forghani et al., (2021) who mentioned that the use of calcium nitrate ($\text{Ca}(\text{NO}_3)_2$) in a highly saline media led to an increase of 75% in the chlorophyll concentration. These results totally agreed with Howladar and Rady, (2012) who found that the application of exogenous calcium has been shown to enhance the overall chlorophyll concentration in plants, a factor that has been found to have a significant correlation with tomato yield. The effects of the applications on leaf chlorophyll content were presented in Table 4.13.

Table 4.13. Effect of salinity and Ca doses on leaf chlorophyll content

Treatments		SPAD			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	42.48±0.33 ^{de}	48.18±0.37 ^d	51.70±1.00 ^e	49.86±0.65 ^c
	50	43.74±0.99 ^{cd}	50.16±0.85 ^c	53.01±1.68 ^{de}	50.15±0.56 ^c
	100	42.24±0.70 ^e	50.28±0.95 ^c	54.23±1.12 ^d	50.58±1.75 ^{bc}
	200	49.24±0.76 ^a	53.19±0.24 ^{ab}	59.75±0.49 ^a	54.42±0.74 ^a
4	0	42.87±0.29 ^{de}	46.82±0.35 ^e	52.18±0.80 ^e	44.31±1.12 ^d
	50	44.46±1.10 ^c	48.13±0.98 ^d	53.43±0.26 ^{de}	50.81±1.49 ^{bc}
	100	43.79±0.03 ^{cd}	49.09±1.33 ^{cd}	55.99±0.14 ^c	50.54±1.31 ^{bc}
	200	46.67±0.13 ^b	53.64±0.38 ^a	58.29±1.29 ^{ab}	54.75±1.09 ^a
6	0	39.34±0.66 ^f	41.02±0.41 ^f	49.63±0.35 ^f	43.26±0.98 ^d
	50	42.26±0.42 ^e	46.66±0.53 ^e	52.93±0.41 ^{de}	49.20±0.81 ^c
	100	43.72±1.40 ^{cd}	50.04±0.40 ^c	53.32±0.48 ^{de}	51.20±1.36 ^{bc}
	200	46.02±0.60 ^b	52.11±0.63 ^b	57.66±0.44 ^{bc}	52.37±0.60 ^b
Means					
Salinity	2	44.43 ^a	50.45 ^a	54.67 ^a	51.25 ^a
	4	44.45 ^a	49.42 ^b	54.97 ^a	50.10 ^b
	6	42.84 ^b	47.46 ^c	53.39 ^b	49.01 ^c
Ca	0	41.57 ^c	45.34 ^d	51.17 ^d	45.81 ^c
	50	43.49 ^{bc}	48.32 ^c	53.12 ^c	50.05 ^b
	100	43.25 ^{bc}	49.81 ^b	54.52 ^b	50.77 ^b
	200	47.31 ^a	52.98 ^a	58.57 ^a	53.84 ^a
Significant differences					
Salinity		**	**	**	**
Ca		**	**	**	**
Salinity*Ca		**	**	*	**

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

* and ** represent significance difference at $P \leq 0.01$ and 0.05 , respectively

4.12. Effect of salinity and Ca doses on leaf micronutrients content

4.12.1. Iron content in leaf

A significant variance in F was also detected in the investigation between different calcium concentrations and levels of salinity. In 2021, for LA4442 variety, the optimal value of Fe 129.10 was obtained when there was an interaction between 0 ppm calcium and EC 2.0 dS/m. Nevertheless, the minimum Fe 79.40 was observed as a result of the interaction between 200 ppm calcium and EC 6.0 dS/m.

In 2022, the highest level of Fe, recorded at 126.10 was noted when there was no calcium applied and the EC was at 4.0 dS/m. On the other hand, the lowest Fe level, at 80.93, was documented with the application of 200 ppm calcium and EC 2.0 dS/m.

In the case of the Ufuk F₁ variety, the influence of the interaction between calcium and salt on the leaf iron concentration was shown to be statistically nonsignificant in 2021. For Ufuk F₁ variety in 2022, the best value of Fe 82.55 was observed from interaction between 0 ppm calcium and EC 2.0 dS/m. However, lowest Fe 46.47 was recorded from interaction between 200 ppm calcium and EC 6.0 dS/m. The results indicated a negative correlation between calcium and salinity in relation to Fe content in leaves, with increased EC levels leading to reduced Fe.

There was an antagonistic relationship between calcium and Fe, resulting in a significant decrease in leaf Fe content due to calcium and salt. These findings were in line with Durukan and Demirbas, (2018) who mentioned that salinity levels increased from 0 dS/m to 9 dS/m, there was a significant reduction in the Fe content within the leaves. The influence of the treatments on the iron content in the leaves was presented in Table 4.14.

4.12.2. Copper content in leaf

The study revealed significant differences in Cu across various calcium levels and salinity conditions. In 2021, for the LA4442 variety, the application of calcium enhanced the Cu content in the leaves under salt stress. However, there were no statistically significant differences between calcium and salinity.

In 2022, the highest Cu concentration in leaves, measuring at 11.90 was noted when 100 ppm of calcium applied with EC 2.0 dS/m. On the contrary, the lowest Cu concentration in leaves at 7.63 was documented with the combination of 0 ppm calcium and EC 2.0 dS/m.

In 2021, for Ufuk F₁, the highest value of Cu content in leaves 15,53 was found in interaction between 200 ppm calcium and EC 2.0 dS/m. Conversely, lowest value of Cu content in leaves 8.73 was obtained from interaction between 50 ppm calcium and EC 6.0 dS/m. the result showed that, the salinity level escalated from 2.0 dS/m to 6.0 dS/m in the absence of calcium application, there was a marked reduction in the Cu content

within the leaves. The interaction between calcium and salinity significantly increased Cu content in leaves. These results were agreement with Birgin et al., (2021) who mentioned that applied calcium increased Cu in leaves content.

Table 4.14. Effect of salinity and Ca doses on leaf Fe content

Treatments		Fe (ppm)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	129.10±3.50 ^a	118.33±5.85 ^a	82.03±3.75	82.55±2.78 ^a
	50	106.13±0.55 ^{cde}	91.50±4.31 ^{bcd}	77.40±2.50	76.47±1.18 ^b
	100	105.40±3.00 ^{de}	87.83±4.75 ^{bcd}	74.48±2.75	70.20±2.38 ^c
	200	83.93±1.85 ^{gh}	80.93±3.98 ^d	68.47±2.55	63.92±1.80 ^d
4	0	116.43±3.95 ^b	126.10±5.46 ^a	85.87±1.85	82.00±1.00 ^a
	50	110.43±2.05 ^{cd}	84.70±3.51 ^{cd}	81.37±3.00	65.90±4.15 ^d
	100	94.40±4.00 ^f	87.50±3.40 ^{bcd}	75.03±1.63	57.65±2.56 ^e
	200	80.10±3.30 ^h	94.03±6.55 ^{bc}	66.33±1.45	54.71±2.70 ^{ef}
6	0	111.93±0.55 ^{bc}	98.73±5.45 ^b	81.80±2.10	53.53±2.56 ^f
	50	103.70±5.20 ^e	94.80±4.82 ^{bc}	80.33±5.86	49.22±1.89 ^g
	100	87.80±4.60 ^g	84.50±3.80 ^{cd}	72.03±1.85	48.43±1.48 ^g
	200	79.40±3.10 ^h	82.97±3.52 ^{cd}	68.90±3.10	46.47±1.18 ^g
Means					
Salinity	2	106.14 ^a	94.65 ^b	75.60	73.28 ^a
	4	100.34 ^b	98.08 ^a	77.15	65.06 ^b
	6	95.71 ^c	90.25 ^{ab}	75.77	49.41 ^c
Ca	0	119.16 ^a	105.44 ^a	83.23 ^a	72.69 ^a
	50	106.76 ^b	99.28 ^a	79.70 ^b	63.86 ^b
	100	95.87 ^c	86.61 ^b	73.85 ^c	58.76 ^c
	200	81.14 ^d	85.98 ^b	67.90 ^d	55.03 ^d
Significant differences					
Salinity		**	*	n.s	**
Ca		**	**	**	**
Salinity*Ca		**	**	n.s	**

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.
 ** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively
 ns: Represent not significant difference.

In 2022, there was no statistically significant correlation between calcium and salinity, and the interaction between calcium and salt did not significantly impact the copper content in the leaves. Table 4.15 displayed the effect of the treatments on the Cu content within the leaves.

Table 4.15. Effect of salinity and Ca doses on leaf Cu content

Treatments		Cu (ppm)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	9.50±1.00	7.63±0.15 ^d	14.73±1.15 ^{ab}	12.63±0.35
	50	9.13±0.35	9.13±0.25 ^{cd}	12.30±1.04 ^{bcd}	12.63±0.75
	100	9.20±0.90	11.90±0.60 ^a	14.00±1.60 ^{ab}	12.93±0.45
	200	10.03±0.15	8.73±0.15 ^{cd}	15.53±1.18 ^a	8.43±0.85
4	0	9.10±1.00	8.40±0.10 ^{cd}	11.13±0.68 ^{cde}	12.03±3.55
	50	9.33±0.45	11.50±0.90 ^a	10.20±0.90 ^{de}	10.03±0.55
	100	9.73±0.55	8.63±0.75 ^{cd}	10.30±0.98 ^{de}	10.90±1.50
	200	10.90±1.40	9.43±0.06 ^{bc}	11.43±1.15 ^{cd}	8.30±0.80
6	0	9.03±1.15	9.83±0.06 ^{bc}	10.50±0.89 ^{de}	12.83±0.35
	50	9.40±0.20	11.43±1.05 ^a	8.73±0.98 ^e	11.20±2.30
	100	10.00±0.40	10.52±0.88 ^{ab}	14.10±1.05 ^{ab}	9.60±2.90
	200	10.50±0.90	8.70±0.80 ^{cd}	13.25±1.35 ^{abc}	7.83±0.75
Means					
Salinity	2	10.40	9.35 ^b	14.14 ^a	11.66
	4	9.77	9.49 ^b	10.77 ^b	10.32
	6	9.73	10.12 ^a	11.65 ^b	10.37
Ca	0	9.21 ^b	8.62 ^b	12.12 ^a	12.50 ^a
	50	9.29 ^b	10.70 ^a	10.41 ^b	11.29 ^a
	100	9.64 ^b	10.35 ^a	12.80 ^a	11.14 ^a
	200	10.48 ^a	8.96 ^b	13.41 ^a	8.19 ^b
Significant differences					
Salinity		n.s	*	**	n.s
Ca		**	**	**	**
Salinity*Ca		n.s	**	*	n.s

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

ns: Represent not significant difference.

4.12.3. Zinc content in leaf

The application of calcium at different levels of salinity negatively affects the Zn content of leaves. Increased calcium doses to 200 ppm due to declining Zn in leaves. In 2021 for LA4442, the greatest level of Zn content in leaves, measuring 77.93, occurred at 0 ppm calcium and EC of 2.0 dS/m. Conversely, the lowest Zn content in leaves, which was 53.00, resulted from the combined effect of 100 ppm calcium and an EC of 6.0 dS/m. These results agreed with Durukan & Demirbas, (2018) who mentioned that

Elevated salinity levels led to a noticeable decreased in the Zn content in the leaves. A negative correlation was observed between Ca and Zn.

Table 4.16. Effect of salinity and Ca doses on leaf Zn content

Treatments		Zn (ppm)			
		LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	77.93±3.39 ^a	69.10±3.40 ^b	66.73±5.45	65.00±1.50
	50	69.90±3.70 ^{bc}	58.53±2.95 ^c	71.50±5.69	61.07±2.06
	100	62.53±4.15 ^{cde}	46.10±1.50 ^{ef}	71.73±6.55	60.27±2.24
	200	61.10±1.70 ^{de}	48.93±4.45 ^{de}	65.03±4.25	57.90±1.51
4	0	59.60±1.10 ^{def}	74.43±2.75 ^a	87.13±6.65	59.43±1.40
	50	60.83±2.65 ^{de}	48.30±0.40 ^e	67.63±6.35	59.40±2.10
	100	66.30±3.10 ^{bcd}	52.83±0.35 ^d	67.70±6.23	60.10±0.85
	200	56.93±5.10 ^{ef}	48.53±0.06 ^{de}	74.20±7.02	60.93±2.55
6	0	64.03±1.55 ^{b-e}	62.13±3.25 ^c	78.20±6.12	61.73±3.95
	50	71.53±3.75 ^{ab}	49.63±1.85 ^{de}	81.20±6.30	61.83±0.45
	100	53.00±2.20 ^f	43.83±1.75 ^{fg}	74.40±6.65	61.60±0.66
	200	62.43±4.45 ^{cde}	40.10±0.40 ^g	77.30±6.89	57.93±3.25
Means					
Salinity	2	67.87 ^a	55.67 ^a	68.75 ^b	61.06
	4	60.92 ^b	56.03 ^a	74.17 ^{ab}	59.97
	6	62.75 ^b	48.93 ^b	77.78 ^a	60.78
Ca	0	67.19 ^a	68.56 ^a	77.36	62.06 ^a
	50	67.42 ^a	52.16 ^b	73.44	60.77 ^{ab}
	100	60.61 ^b	47.59 ^c	71.28	60.66 ^{ab}
	200	60.16 ^b	45.85 ^c	72.18	58.92 ^b
Significant differences					
Salinity		**	**	*	n.s
Ca		**	**	n.s	*
Salinity*Ca		**	**	n.s	n.s

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

n.s: Represent not significant difference.

In 2022 the highest value of Zn content in leaves 74.43 was recorded from interaction between 0 ppm calcium and EC 4.0 dS/m. However, minimum Zn content in leaves 40.10 was observed from interaction between 200 ppm calcium and EC 6.0 dS/m. this results showed that interaction between calcium and salinity declined the Zn content in leaves.

During the years 2021 and 2022 for Ufuk F₁, there was no significant interaction detected between calcium and salinity levels. The effect of the treatments on the Zn content in the leaves was presented in Table 4.16

4.12.4. Manganese content in leaf

The effects of calcium, salinity, and the interaction between calcium and salinity on Mn content in leaves were found to be statistically significant. In 2021, for the LA4442 variety, the interaction between 50 ppm calcium and EC 2.0 dS/m resulted in the highest Mn content in leaves, measuring 75.97. On the other hand, the lowest Mn content in leaves, at 63.03, was noted when there was an interaction between 200 ppm calcium and an EC of 4.0 dS/m. the result showed that at lower salinity levels, an increase in calcium tends to decreased the Mn content in leaves. However, at a higher salinity level of EC 6.0 dS/m, the Mn content in leaves does not vary significantly with different calcium levels.

In 2022, the maximum Mn content in leaves 91.51 was recorded from interaction between 50 ppm calcium and EC 2.0 dS/m. On the contrary, the lowest value of Mn content in leaves 56.30 was observed from interaction 200 ppm calcium and EC 4.0 dS/m. In 2021 for the Ufuk F₁ variety, the interaction of 0 ppm calcium with an EC of 6.0 dS/m resulted in a peak Mn content in leaves, registering at 94.70. In contrast, the interaction between 100 ppm calcium and an EC of 2.0 dS/m resulted in the minimum Mn content in leaves, noted at 63.10.

In 2022, the Mn content in leaves tends to be higher at lower salinity and calcium levels, with the highest recorded value being 84.94 at 0 ppm Calcium and 2.0 dS/m salinity. On the other hand, the lowest recorded value was 63.33 at 4.0 dS/m salinity and 200 ppm Calcium. The results showed that there was a noticeable trend where increasing calcium levels generally resulted in a decrease in Mn content across all salinity levels. However, increased salinity leavels from 2.0 to 6.0 dS/m, there was a general trend of decreasing Mn content in the leaf. These results agreed with Gunes et al., (1998) Discovered that the application of Ca led to a rise in the levels of Ca and N, whereas it resulted in a reduction of the quantities of P, Mg, Fe, Zn, and Mn. The manganese concentration in the leaves was examined in Table 4.17 to evaluate the impacts of different treatments.

Table 4.17. Effect of salinity and Ca doses on leaf Mn content

Treatments		Mn (ppm)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	69.43±1.65 ^{bc}	81.18±6.51 ^b	86.03±7.35 ^{ab}	84.94±2.43 ^a
	50	75.97±2.12 ^a	69.71±4.38 ^c	83.60±7.00 ^{bcd}	81.02±0.97 ^{bc}
	100	72.43±2.15 ^{ab}	58.51±3.15 ^{de}	63.10±6.23 ^f	73.14±1.80 ^d
	200	63.90±0.40 ^{de}	66.64±3.36 ^{cd}	75.70±7.90 ^{cd}	72.18±1.77 ^d
4	0	75.00±2.50 ^a	91.51±5.22 ^a	82.43±6.32 ^{bcd}	83.73±1.48 ^{ab}
	50	68.63±1.95 ^{bcd}	81.54±2.62 ^b	76.53±7.68 ^{bcd}	80.59±1.56 ^c
	100	63.13±1.25 ^e	66.14±3.28 ^{cd}	76.10±4.40 ^{cd}	68.24±2.35 ^e
	200	63.03±1.35 ^e	56.30±2.99 ^e	74.20±4.36 ^{de}	63.33±1.48 ^f
6	0	72.50±2.04 ^{ab}	79.24±2.08 ^b	94.70±6.18 ^a	72.16±1.48 ^d
	50	66.50±1.90 ^{cde}	80.87±3.63 ^b	84.43±6.05 ^{bc}	68.82±1.56 ^e
	100	67.63±0.95 ^{b-e}	59.38±4.48 ^{de}	65.80±4.65 ^{ef}	65.88±1.56 ^{ef}
	200	66.70±2.12 ^{cde}	61.01±4.32 ^{cde}	66.30±4.32 ^{ef}	63.73±1.22 ^f
Means					
Salinity	2	70.43 ^a	69.01	77.11	77.82 ^a
	4	62.45 ^b	73.88	77.32	73.97 ^a
	6	62.83 ^b	70.13	77.81	67.65 ^b
Ca	0	67.31 ^a	83.98 ^a	87.72 ^a	80.28 ^a
	50	65.37 ^a	77.37 ^b	81.52 ^b	76.81 ^{ab}
	100	62.73 ^b	61.34 ^c	68.33 ^c	69.09 ^b
	200	58.88 ^c	61.32 ^c	72.07 ^c	66.41 ^b
Significant differences					
Salinity		*	n.s	n.s	*
Ca		**	**	**	*
Salinity*Ca		**	**	**	*

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

ns: Represent not significant difference.

4.13. Effect of salinity and Ca doses on leaf macronutrients content

4.13.1. Phosphorus content in leaf

Salinity and calcium levels significantly impact phosphorus content in plant leaves. In 2021 for LA4442 variety, the maximum phosphorus content in leaves 1.12 was observed EC 2.0 dS/m with 100 ppm calcium, while the lowest value of P content in leaves 0.73 occurred at the EC 6.0 dS/m with 200 ppm calcium. The results showed that

at lower salinity EC 2.0 dS/m, increased calcium generally enhances P content in the leaf, with the highest value at 100 Ca. However, at EC 4.0 and 6.0 dS/m, the trend reverses, with increased calcium leading to a decrease in P content, particularly at the highest calcium concentration 200 ppm.

In 2022, the overall greatest P content 1.07 was observed from the interaction between EC 2.0 dS/m with a moderate level of calcium 100 ppm, while the overall lowest P content 0.67 was found at the same EC level but with no calcium applied. These findings are consistent with Gunes et al., (1998) observed a reduction in the P levels of tomato leaves as the amount of calcium in the fertilizing solution was elevated.

In 2021 for the Ufuk F₁ variety, the best result of P content 1.14 was recorded from interaction between 50 ppm calcium and EC 4.0 dS/m. Conversely, the minimum P content 0.70 was observed from interaction between 100 ppm calcium with EC 6.0 dS/m. The results showed that P content in leaves increased under salinity levels of EC 2.0 and 4.0 dS/m with increased calcium doses. However, at high salinity (EC 6.0 dS/m), high calcium doses decreased the P content in the leaves. This indicates negative effects of salinity and calcium on the P content in the leaves.

In 2022 the highest value of phosphorus content 1.02 was observed from interaction between 100 ppm calcium and EC 2.0 dS/m. Conversely, minimum P content was observed from interaction between 100 ppm calcium and EC 6.0 dS/m. This results agreement with Mashhady et al., (1982) observed that there is a significant rise in phosphorus concentration when salinity levels reach up to 6 mS/cm, after which there is a sharp decline as salinity continues to increase. The greatest salinity level applied was 8.4 mS/cm, and it demonstrated the minimum P content in the leaf (Satti et al., 1995). The effects of the treatments on the phosphorus content in leaves were illustrated in Table 4.18.

Table 4.18. Effect of salinity and Ca doses on leaf P content

Treatments		P (%)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	0.93±0.05 ^{bcd}	0.67±0.04 ^f	1.07±0.05 ^{ab}	0.95±0.04 ^{ab}
	50	1.00±0.02 ^{abc}	0.92±0.02 ^{a-d}	1.04±0.13 ^{ab}	1.01±0.09 ^a
	100	1.12±0.10 ^a	1.07±0.17 ^a	1.13±0.21 ^a	1.02±0.10 ^a
	200	1.00±0.01 ^{abc}	0.79±0.12 ^{def}	1.12±0.09 ^{ab}	0.88±0.10 ^{abc}
4	0	1.05±0.06 ^{ab}	0.91±0.00 ^{a-e}	0.96±0.06 ^{ab}	0.75±0.03 ^{cd}
	50	0.94±0.05 ^{bcd}	0.83±0.06 ^{c-f}	1.14±0.23 ^a	0.88±0.10 ^{abc}
	100	0.96±0.03 ^{bcd}	1.05±0.29 ^{ab}	0.95±0.03 ^{ab}	0.88±0.11 ^{abc}
	200	0.91±0.02 ^{bcd}	0.85±0.07 ^{b-f}	1.09±0.12 ^{ab}	0.91±0.13 ^{ab}
6	0	0.83±0.05 ^{cd}	0.76±0.02 ^{def}	0.91±0.02 ^{ab} c	0.82±0.01 ^{bcd}
	50	0.90±0.02 ^{bcd}	1.01±0.11 ^{abc}	1.02±0.14 ^{ab}	0.80±0.03 ^{bcd}
	100	0.88±0.08 ^{cd}	0.67±0.11 ^f	0.70±0.06 ^c	0.72±0.06 ^d
	200	0.73±0.04 ^d	0.69±0.05 ^{ef}	0.88±0.18 ^{bc}	0.85±0.07 ^{bcd}
Means					
Salinity	2	1.01 ^a	0.86 ^{ab}	1.09 ^a	0.97 ^a
	4	0.97 ^a	0.91 ^a	1.04 ^a	0.86 ^b
	6	0.84 ^b	0.78 ^b	0.88 ^b	0.80 ^b
Ca	0	0.94 ^b	0.78 ^b	0.98	0.84
	50	0.95 ^{ab}	0.92 ^a	1.07	0.90
	100	0.99 ^a	0.93 ^a	0.93	0.88
	200	0.88 ^b	0.78 ^b	1.03	0.88
Significant differences					
Salinity		**	*	**	**
Ca		**	**	n.s	n.s
Salinity*Ca		**	**	*	*

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

* and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

ns: Represent not significant difference.

4.13.2. Potassium content in leaf

The relationship between calcium levels and salinity on K content in leaves for the year 2021 is outlined. For LA4442 variety, the highest value of K content in leaves 3.32 was observed from interaction between 50 ppm calcium and EC 2.0 dS/m. Nevertheless, the minimum K content in leaves 1.91 was obtained when 0 ppm calcium was applied with EC 6.0 dS/m. Under EC 2.0 dS/m, increasing calcium from 0 ppm to 50 ppm resulted in a significant increase in K content (from 2.84 to 3.32), showing a positive effect of

calcium on K content. However, at 200 ppm of calcium, K content increased slightly again (2.72), but it did not reach the levels observed at 50 ppm of calcium. Under EC 6.0 dS/m, the K content was the lowest across all salinity levels, indicating that high salinity negatively affected K accumulation in leaves. Nevertheless, increasing calcium levels, especially to 100 and 200 ppm, helped mitigate the negative effects of salinity, as seen by the higher K content (2.81) compared to 0 ppm and 50 ppm of calcium. These results agree with Su et al., (2002). Who mentioned that the reduction in K levels could also be ascribed to diminished absorption, which may result from its competition with Na.

In 2022, the maximum K content in leaves 2.58 was observed from interaction between 200 ppm calcium and EC 6.0 dS/m. However, lowest value of K content in leaves 1.39 was obtained from interaction between 50 ppm calcium and 2.0 dS/m. The relationship between calcium and salt showed that calcium generally had a positive effect on K content in leaves, especially under EC 4.0 dS/m and EC 6.0 dS/m conditions. Calcium helped to mitigate the adverse effects of salt on K accumulation, with the maximum benefit observed at higher calcium doses. However, under EC 4.0 dS/m, there was a complex interaction where an initial increase in calcium led to a decrease in K content, followed by an increase at higher calcium doses. These results were supported by Parvin, (2013). Who mentioned that salinity declined K content in leaves and application calcium increased K content in leaves.

In 2021 for Ufuk F₁ variety, the greatest value of K content in leaves 3.03 was obtained from the interaction between 50 ppm calcium and EC 2.0 dS/m. Nonetheless, minimum K content in leaves obtained 1.70 was observed from the interaction between 100 ppm calcium and EC 6.0 dS/m. In 2022, the best value of K content in leaves 2.14 was recorded from interaction 100 ppm calcium with EC 2.0 dS/m. While, the minimum K content in leaves 0.68 was found between interaction of 100 ppm calcium with EC 6.0 dS/m. In 2021 and 2022 years, for Ufuk F₁, the results showed that under EC 4.0 dS/m conditions, increased calcium doses decrease the adverse effects of salt on K accumulation. However, under EC 6.0 dS/m conditions, increased calcium doses decrease the K accumulation in leaves. The findings were in accord with Zhu, (2002) mentioned that the application of calcium sprayed to the leaves also resulted in a

reduction of K content within the leaves. The impacts of the treatments on the K content in leaves were presented in Table 4.19.

Table 4.19. Effect of salinity and Ca doses on leaf K content

Treatments		K (%)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	2.84±0.62 ^{bc}	2.24±0.07 ^{ab}	2.76±0.13 ^{ab}	1.41±0.26 ^{cde}
	50	3.32±0.23 ^a	1.39±0.24 ^d	3.03±0.87 ^a	1.19±0.20 ^{def}
	100	2.39±0.33 ^{cd}	2.01±0.11 ^{a-d}	2.19±0.46 ^{bcd}	2.14±0.25 ^a
	200	2.72±0.14 ^{bcd}	1.82±0.12 ^{bcd}	2.61±0.02 ^{abc}	1.37±0.06 ^{cde}
4	0	2.66±0.02 ^{bcd}	1.68±0.11 ^{bcd}	2.24±0.38 ^{bcd}	1.55±0.03 ^{bcd}
	50	2.77±0.07 ^{bc}	1.41±0.18 ^d	2.70±0.14 ^{ab}	1.78±0.46 ^b
	100	2.90±0.05 ^{ab}	2.08±0.14 ^{abc}	2.04±0.07 ^{cd}	1.63±0.24 ^{bc}
	200	2.61±0.40 ^{bcd}	1.66±0.25 ^{bcd}	2.78±0.03 ^{ab}	1.71±0.17 ^{bc}
6	0	1.91±0.10 ^d	1.48±0.11 ^{cd}	2.22±0.07 ^{bcd}	1.19±0.03 ^{def}
	50	2.27±0.06 ^{cd}	1.63±0.07 ^{bcd}	2.24±0.02 ^{bcd}	1.11±0.04 ^{ef}
	100	2.81±0.04 ^{bc}	2.47±0.24 ^a	1.70±0.06 ^d	0.68±0.04 ^g
	200	2.81±0.07 ^{bc}	2.58±0.06 ^a	1.83±0.13 ^d	0.83±0.09 ^{fg}
Means					
Salinity	2	2.82 ^a	1.87 ^b	2.65 ^a	1.53 ^a
	4	2.74 ^a	1.71 ^c	2.44 ^a	1.67 ^a
	6	2.45 ^b	2.04 ^a	2.00 ^b	0.95 ^b
Ca	0	2.47 ^b	1.80 ^c	2.41 ^a	1.38
	50	2.79 ^a	1.48 ^d	2.66 ^a	1.36
	100	2.70 ^{ab}	2.19 ^a	1.98 ^b	1.48
	200	2.71 ^{ab}	2.02 ^b	2.41 ^a	1.31
Significant differences					
Salinity		**	**	**	**
Ca		*	**	**	n.s
Salinity*Ca		**	**	*	**

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

ns: Represent not significant difference.

4.13.3. Calcium content in leaf

The calcium, salinity and interaction between calcium and salinity significantly increased Ca content in leaves. In 2021, for LA4442 variety, the greatest values of Ca content leaves 2.38 was observed from interaction between 200 ppm calcium and EC

6.0 dS/m. In contrast, the lowest value of Ca content leaves 1.17 was obtained from interaction between 0 ppm calcium and EC 2.0 dS/m. In 2022, the interaction of 200 ppm of calcium with EC level of 2.0 dS/m resulted in the maximum recorded calcium content in leaves, being 2.39. On the flip side, the minimum calcium content in leaves, which was 1.17, was observed when there was no calcium present (0 ppm) and the EC level was at 2.0 dS/m.

During the years 2021 and 2022, for Ufuk F₁ variety the maximum calcium concentrations in leaves were observed to be (2.84 and 2.28 respectively), this occurred under conditions of 200 ppm calcium and EC 2.0 dS/m. On the contrary, the year 2021 saw the smallest amount of calcium in the leaves, measuring 1.62, which resulted from the interaction of 0 ppm calcium and EC 6.0 dS/m. In contrast, in the year 2022, the lowest leaf calcium content of 1.18, was associated with 0 ppm calcium and EC 2.0 dS/m.

In both genotypes, in 2021 and 2022 years, the relationship between calcium levels and salinity indicated that calcium played a crucial role in maintaining or increasing calcium content in leaves, regardless of the salinity level. This implied that calcium supplementation in soilless culture could be a viable strategy to counteract the negative effects of salinity on plants, helping to ensure adequate calcium uptake and maintenance of cellular functions. These results match Terraza et al., (2008) who found that the elevation of calcium levels resulted exclusively in a heightened content of calcium within the leaves. These results were compatible with Lolaei et al., (2012); and Parvin, (2013) when mentioned that Calcium mitigates the harmful impacts of toxic sodium, and the application of calcium can enhance the calcium concentration in the leaves. The effects of the treatments on Calcium content in leaves were presented in Table 4.20.

4.13.4. Magnesium content in leaf

Salinity and calcium levels had not significantly impact Mg content in plant leaves in 2021 for LA4442. In 2022 the interaction between calcium and salinity had significant effect on Mg content in leaves. The best value of Mg content in leaves 0.91 was observed from interaction between 0 ppm calcium and EC 6.0 dS/m. Conversely, lowest value of Mg content in leaves 0.68 was obtained from interaction between 200 ppm

calcium and EC 6.0 dS/m. these findings were line with Marschner, (2012) who mentioned that the elevated levels of Calcium mostly influenced the absorption and translocation of Magnesium.

In 2021For Ufuk F₁, the optimal Mg content in leaves, measuring 1.32, was noted when 50 ppm of calcium was combined with an EC of 6.0 dS/m. In contrast, the minimal Mg content in leaves, at 1.05, resulted from the combination of 50 ppm calcium with an EC of 2.0 dS/m.

Table 4.20. Effect of salinity and Ca doses on leaf calcium content

Treatments		Ca (%)			
Salinity	Ca	LA4442		Ufuk F ₁	
		2021	2022	2021	2022
2	0	1.17±0.04 ⁱ	1.17±0.01 ^e	1.73±0.09 ^{fg}	1.18±0.04 ^e
	50	1.42±0.03 ^{ef}	1.36±0.03 ^d	1.94±0.02 ^e	1.44±0.28 ^d
	100	2.00±0.01 ^d	2.16±0.05 ^b	2.23±0.11 ^{cd}	1.92±0.07 ^b
	200	2.26±0.05 ^b	2.39±0.06 ^a	2.84±0.05 ^a	2.28±0.06 ^a
4	0	1.26±0.01 ^{gh}	1.25±0.04 ^e	1.66±0.10 ^g	1.19±0.00 ^e
	50	1.43±0.04 ^e	1.42±0.02 ^d	1.83±0.06 ^{ef}	1.75±0.12 ^{bc}
	100	2.05±0.06 ^d	2.00±0.14 ^c	2.30±0.08 ^c	1.79±0.10 ^{bc}
	200	2.31±0.07 ^{ab}	2.37±0.05 ^a	2.62±0.07 ^b	2.12±0.02 ^a
6	0	1.18±0.05 ^{hi}	1.24±0.05 ^e	1.62±0.12 ^g	1.28±0.09 ^{de}
	50	1.34±0.01 ^{fg}	1.37±0.02 ^d	1.71±0.04 ^{fg}	1.39±0.06 ^d
	100	2.18±0.05 ^c	2.19±0.02 ^b	2.17±0.04 ^d	1.69±0.06 ^c
	200	2.38±0.07 ^a	2.35±0.08 ^a	2.83±0.06 ^a	2.13±0.03 ^a
Means					
Salinity	2	1.71 ^b	1.77	2.19 ^a	1.70 ^a
	4	1.76 ^a	1.76	2.11 ^b	1.71 ^a
	6	1.77 ^a	1.79	2.08 ^b	1.62 ^b
Ca	0	1.20 ^d	1.22 ^d	1.67 ^d	1.21 ^d
	50	1.39 ^c	1.39 ^c	1.83 ^c	1.53 ^c
	100	2.07 ^b	2.12 ^b	2.23 ^b	1.80 ^b
	200	2.32 ^a	2.37 ^a	2.77 ^a	2.18 ^a
Significant differences					
Salinity		*	n.s	**	*
Ca		*	**	**	**
Salinity*Ca		*	**	**	**

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.
 ** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively
 ns: Represent not significant difference.

In 2022, the interaction between calcium levels and salinity has no significant effect on the Mg content in plant leaves. This result agreed with Satti and Al-Yahyai, (1995) who found that under conditions of salt stress, the Mg content in tomato leaves did not show any notable variation.

In generally, the results showed that, at lower salinity levels, a moderate increase in calcium could enhance Mg content slightly, but higher levels of calcium corresponded to reduced Mg levels. At higher salinity, additional calcium did not benefit Mg accumulation and might have even further reduced Mg content in the leaves. These results are compatible with Rabie and Kumazawa, (1988) Elevated levels of NaCl resulted in a slight rise in Mg content within the leaves. The impacts of the treatments on the magnesium levels in the leaves were detailed in Table 4.21.

4.13.5. Sodium content in leaf

The accumulation of Na in leaves was significantly influenced by the levels of salinity, the concentration of calcium, and the interaction between salinity and calcium. In 2021 and 2022, for LA4442 variety the maximum Na content in leaves (0.79 and 0.82 respectively) were recorded from interaction between 0 ppm calcium and EC 6.0 dS/m. Conversely, in 2021, the minimum Na content in leaves 0.15 was observed from interaction between 200 ppm calcium and EC 2.0 dS/m. However, in 2022, the lowest Na content in leaves 0.31 was found in (50 ppm and 200 ppm) calcium with EC 2.0 dS/m.

In 2021 year, for Ufuk F₁, the greatest value of Na content in leaves 0.82 was obtained from interaction between 0 ppm calcium and EC 6.0 dS/m while, in 2022 the highest value of Na content in leaves 0.89 was recorded from interaction between 50 ppm calcium and EC 6.0 dS/m. In 2021 and 2022, the lowest values of Na content in leaves (0.29 and 0.24 respectively) were observed from interaction between 200 ppm calcium and EC 2.0 dS/m.

In 2021 and 2022 years, for LA4442 and Ufuk F₁ geynotypes, Under EC 2.0 dS/m conditions, increasing calcium levels correlated with a reduction in Na content in leaves. As salinity increased, the effect of calcium on lowering Na content seemed less effective, particularly at the EC 6.0 dS/m level, where Na content remained relatively

high even with increased calcium supplementation. Interestingly, at the EC 4.0 dS/m level, an increase in calcium doses resulted in an increase in leaf Na content. These findings were line with Korkmaz et al., (2017) who found that the increased calcium doses due to decreased Na content in leaves under salt stress. Also, these results were supported by Rab et al., (2017) when mentioned that increased NaCl levels from 0 to 150 mM had resulted in an increase in Na content in leaves. On the other hand, increasing calcium doses from 0 to 1.25% had led to a decrease in the accumulation of Na in the leaves. The effects of the treatments on the Na levels in the leaves were detailed in Table 4.22.

Table 4.21. Effect of salinity and Ca doses on leaf Mg content

Treatments		Mg (%)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	1.17±0.02	0.71±0.04 ^d	1.16±0.03 ^{bc}	1.00±0.02
	50	1.12±0.09	0.87±0.04 ^{ab}	1.05±0.07 ^d	1.17±0.06
	100	1.15±0.04	0.74±0.10 ^d	1.17±0.00 ^{bc}	1.07±0.05
	200	1.14±0.42	0.69±0.02 ^d	1.15±0.01 ^{bc}	0.93±0.06
4	0	1.27±0.10	0.78±0.11 ^{bcd}	1.22±0.02 ^b	1.02±0.10
	50	1.22±0.09	0.85±0.08 ^{abc}	1.17±0.02 ^{bc}	1.06±0.15
	100	1.12±0.02	0.70±0.03 ^d	1.05±0.09 ^d	0.85±0.07
	200	1.19±0.07	0.69±0.03 ^d	1.12±0.04 ^c	0.96±0.02
6	0	1.21±0.19	0.91±0.02 ^a	1.15±0.00 ^{bc}	0.92±0.05
	50	1.10±0.04	0.69±0.02 ^d	1.32±0.06 ^a	0.93±0.05
	100	1.13±0.01	0.76±0.06 ^{cd}	1.14±0.02 ^c	0.88±0.01
	200	1.14±0.07	0.68±0.01 ^d	1.15±0.02 ^{bc}	0.83±0.02
Means					
Salinity	2	1.15	0.75	1.13	1.04 ^a
	4	1.20	0.76	1.14	0.97 ^b
	6	1.15	0.76	1.19	0.89 ^c
Ca	0	1.22	0.80 ^a	1.18 ^a	0.98 ^{ab}
	50	1.15	0.80 ^a	1.18 ^a	1.06 ^a
	100	1.13	0.74 ^b	1.12 ^b	0.93 ^b
	200	1.16	0.69 ^b	1.14 ^b	0.91 ^b
Significant differences					
Salinity		n.s	n.s	n.s	**
Ca		n.s	**	*	**
Salinity*Ca		n.s	**	**	n.s

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

ns: Represent not significant difference.

Table 4.22. Effect of salinity and Ca doses on leaf Na content

Treatments		Na %			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	0.39±0.004 ^c	0.32±0.10 ^e	0.31±0.03 ^f	0.29±0.03 ^{fg}
	50	0.21±0.019 ^{de}	0.31±0.05 ^e	0.39±0.04 ^f	0.38±0.06 ^e
	100	0.26±0.060 ^d	0.35±0.05 ^e	0.56±0.12 ^{de}	0.35±0.01 ^{ef}
	200	0.15±0.050 ^e	0.31±0.05 ^e	0.29±0.06 ^f	0.24±0.02 ^g
4	0	0.38±0.013 ^c	0.40±0.02 ^e	0.52±0.06 ^{de}	0.40±0.03 ^e
	50	0.37±0.038 ^c	0.65±0.11 ^{cd}	0.61±0.05 ^{cd}	0.40±0.06 ^e
	100	0.39±0.078 ^c	0.68±0.11 ^{bcd}	0.67±0.10 ^c	0.72±0.04 ^c
	200	0.60±0.009 ^b	0.57±0.11 ^d	0.50±0.02 ^e	0.59±0.03 ^d
6	0	0.79±0.058 ^a	0.82±0.06 ^a	0.82±0.03 ^a	0.80±0.04 ^b
	50	0.77±0.013 ^a	0.80±0.08 ^{ab}	0.71±0.00 ^{bc}	0.89±0.10 ^a
	100	0.66±0.001 ^b	0.73±0.01 ^{abc}	0.81±0.02 ^{ab}	0.75±0.02 ^{bc}
	200	0.61±0.002 ^b	0.68±0.05 ^{bcd}	0.66±0.04 ^c	0.70±0.03 ^c
Means					
Salinity	2	0.25 ^c	0.32 ^c	0.39 ^c	0.32 ^c
	4	0.43 ^b	0.57 ^b	0.58 ^b	0.53 ^b
	6	0.71 ^a	0.76 ^a	0.75 ^a	0.78 ^a
Ca	0	0.52 ^a	0.51	0.55 ^b	0.50 ^c
	50	0.45 ^b	0.59	0.57 ^b	0.56 ^b
	100	0.44 ^b	0.59	0.68 ^a	0.61 ^a
	200	0.46 ^b	0.52	0.49 ^c	0.51 ^c
Significant differences					
Salinity		**	**	**	**
Ca		**	n.s	**	*
Salinity*Ca		**	**	*	**

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

ns: Represent not significant difference.

4.14. Effect of salinity and Ca doses on fruit micronutrients content

4.14.1. Iron content in fruit

The effect of calcium, salt and interaction between them had significant effect of Fe content in fruit, in 2021, for LA4442 variety, the highest value of Fe content in fruit 59.80 was recorded from interaction between 0 ppm calcium and EC 6.0 dS/m. In contrast, the smallest Fe content in fruit 40.90 was observed from interaction between

200 ppm calcium and EC 4.0 dS/m. The following year, in 2022, the maximum Fe content in fruit peaked at 45.70, associated with 0 ppm calcium and an EC of 2.0 dS/m, whereas the minimum Fe content dropped to 30.80, found in fruits at 100 ppm calcium with an EC of 2.0 dS/m.

In the 2021 and 2022 years of the LA4442 variety, high salinity (6.0 dS/m) without added calcium seemed to promote the highest Fe content, while added calcium at this salinity level decreased Fe content. At lower salinity levels, moderate calcium supplementation (50-100 ppm) enhanced Fe content, but too much calcium (200 ppm) had a detrimental effect.

In 2021 for Ufuk F₁, the best results of Fe content in fruit 45.67 was observed when 200 ppm calcium added with EC 4.0 dS/m. While, the minimum Fe content in fruit 36.05 was obtained from interaction between 0 ppm calcium and EC 6.0 dS/m. In 2022, the highest value of Fe content in fruit 49.58 was recorded from interaction between 0 ppm calcium and EC 2.0 dS/m. However, the lowest value of Fe content in fruit 35.85 was observed from interaction between 50 ppm calcium and EC 2.0 dS/m.

In the years 2021 and 2022 for the Ufuk F₁ variety, at different salinity levels, Fe content in the fruit initially decreased as salinity increased but improved with the addition of calcium. The improvement was more pronounced at higher salinity levels. At the highest salinity level, Fe content was substantially enhanced with the addition of calcium, suggesting a mitigating effect of calcium on the stress caused by high salinity. These findings were line with Saleh et al., (2019) when mentioned that adding extra calcium into a saline nutrient solution or the foliar spraying with calcium had a beneficial impact on the levels of fruit vital nutrients like Ca, Mg, Fe, Mn, and Zn, in addition to the protein content in tomato fruits when grown under saline conditions. The effects of the treatments on the Fe content in fruit were illustrated in Table 4.23.

Table 4.23 Effect of salinity and Ca doses on fruit Fe content

Treatments		Fruit Fe (ppm)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	42.60±4.20 ^c	45.70±1.61 ^a	40.33±0.15 ^{cd}	49.58±1.35 ^a
	50	48.90±3.40 ^{bc}	36.20±1.40 ^{cd}	41.10±0.60 ^{bcd}	35.85±0.83 ^e
	100	50.90±3.40 ^b	30.80±1.23 ^f	41.97±0.95 ^{bc}	42.45±0.08 ^c
	200	41.50±2.00 ^c	33.60±1.20 ^{ef}	42.87±0.81 ^{bc}	36.91±3.45 ^e
4	0	43.53±2.15 ^{bc}	39.36±1.17 ^b	39.03±1.17 ^d	42.38±1.50 ^c
	50	44.43±0.85 ^{bc}	32.90±1.24 ^e	42.45±0.69 ^{bc}	40.28±0.23 ^{cd}
	100	45.53±3.15 ^{bc}	34.20±1.12 ^{de}	41.97±0.83 ^{bc}	37.83±2.21 ^{de}
	200	40.90±1.50 ^c	34.80±1.41 ^{cde}	45.67±2.10 ^a	45.08±1.73 ^b
6	0	59.80±7.50 ^a	33.20±1.52 ^{ef}	36.05±0.78 ^e	44.55±2.25 ^b
	50	42.50±2.80 ^c	36.63±1.25 ^c	38.80±2.76 ^d	40.88±0.83 ^c
	100	42.33±2.95 ^c	45.23±1.45 ^a	43.47±1.75 ^{ab}	45.33±1.43 ^b
	200	41.70±1.55 ^c	37.04±1.44 ^c	43.63±2.75 ^{ab}	44.58±1.46 ^b
Means					
Salinity	2	45.98	36.58 ^b	41.57 ^{ab}	41.20 ^b
	4	43.60	35.32 ^c	42.28 ^a	41.39 ^b
	6	46.58	38.03 ^a	40.49 ^b	43.83 ^a
Ca	0	48.64 ^a	39.42 ^a	38.47 ^d	45.50 ^a
	50	45.28 ^a	35.24 ^c	40.78 ^c	39.00 ^c
	100	46.26 ^a	36.74 ^b	42.47 ^b	41.87 ^b
	200	41.37 ^b	35.15 ^c	44.06 ^a	42.19 ^b
Significant differences					
Salinity	n.s	**	*	**	
Ca	**	**	**	**	**
Salinity*Ca	**	**	*	**	**

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

ns: Represent not significant difference.

4.14.2. Copper content in fruit

The interaction between calcium and salinity not significantly affected on Cu content in fruit, in 2021 for LA4442. In 2022, the interaction between calcium levels and salinity significantly affected the Cu content in fruit, the highest value of Cu content in fruit 5.23 was observed from interaction between 50 ppm with EC 6.0 dS/m. However, the minimum value of Cu content in fruit 2.83 was observed from interaction between 200 ppm calcium with EC 6.0 dS/m.

In 2021 for Ufuk F1 variety, the greatest of Cu content in fruit 5.50 was obtained from interaction between 100 ppm with EC 2.0 dS/m. However, the minimum Cu content in fruit was 3.83 recorded from interaction between 0 ppm calcium and EC 4.0 dS/m. In 2022, there was not significant effect of calcium and salinity on Cu content in fruit. The impacts of the treatments on the Cu content in the fruit were depicted in Table 4.24.

Table 4.24. Effect of salinity and Ca doses on fruit Cu content

Treatments		Fruit Cu (ppm)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	4.20±0.89	3.50±0.30 ^d	3.93±0.56 ^{cd}	4.63±0.06
	50	3.73±0.06	5.00±0.30 ^{ab}	4.90±0.40 ^{ab}	4.50±0.10
	100	4.20±0.58	4.83±0.55 ^{abc}	5.50±0.70 ^a	4.23±0.15
	200	4.33±0.85	4.73±0.55 ^{abc}	4.83±0.35 ^{abc}	4.17±0.35
4	0	4.93±0.95	4.20±0.10 ^c	3.83±0.38 ^d	4.20±0.10
	50	4.60±0.60	4.90±0.40 ^{ab}	4.83±0.69 ^{abc}	4.33±0.06
	100	4.10±0.60	4.83±0.35 ^{ab}	4.50±0.40 ^{bcd}	4.40±0.10
	200	4.93±1.10	3.40±0.00 ^{de}	4.30±0.20 ^{bcd}	3.97±0.21
6	0	3.63±0.45	5.00±0.50 ^{ab}	5.13±0.65 ^{ab}	4.47±0.15
	50	3.83±0.56	5.23±0.35 ^a	4.80±0.50 ^{abc}	4.27±0.21
	100	4.00±0.10	4.40±0.10 ^{bc}	4.40±0.20 ^{bcd}	3.83±0.65
	200	5.10±1.10	2.83±0.25 ^e	5.13±0.25 ^{ab}	3.40±0.26
Means					
Salinity	2	4.12	4.52	4.79 ^a	4.38 ^a
	4	4.64	4.33	4.37 ^b	4.23 ^a
	6	4.14	4.37	4.87 ^a	3.99 ^b
Ca	0	4.26	4.23 ^c	4.30	4.43 ^a
	50	4.06	5.04 ^a	4.84	4.37 ^{ab}
	100	4.10	4.69 ^b	4.80	4.16 ^b
	200	4.79	3.66 ^d	4.76	3.84 ^c
Significant differences					
Salinity		n.s	n.s	*	*
Ca		n.s	**	n.s	*
Salinity*Ca		n.s	**	*	n.s

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

ns: Represent not significant difference.

4.14.3. Zinc content in fruit

The significant effect of calcium and salt (NaCl) on the Zn content in the fruit of tomato plants. In 2021, for the LA4442 variety, the maximum Zn concentration in the fruit, measuring 30.40, was noted when 100 ppm of calcium was combined with EC 4.0 dS/m. On the other hand, the minimum Zn concentration in the fruit, at 25.03, occurred with 0 ppm calcium and EC of 6.0 dS/m. The results showed that moderate levels of calcium (50 ppm at 2.0 dS/m and 100 ppm at 4.0 dS/m) enhanced Zn content in tomato fruit, suggesting an optimal range of calcium supplementation that benefited Zn uptake or accumulation. However, under high salinity stress (EC 6.0 dS/m), while the minimum Zn content was seen with no calcium supplementation, an increased calcium level mitigated this effect, potentially indicating a protective role of calcium against salinity stress.

In 2022, there was no significant effect of calcium and salinity on Zn content in the fruit. In 2021 for Ufuk F₁, the highest value of Zn content in the fruit 33.53 was observed from interaction between 0 ppm calcium and 2.0 EC dS/m. While, the lowest value of Zn content in the fruit 26.40 was recorded from interaction between 100 ppm calcium and EC 6.0 dS/m. the results showed this, in EC 2.0 dS/m, no calcium or a higher dose of calcium seemed to support higher Zn content in the fruit. At EC 4.0 dS/m, an intermediate dose of calcium seemed to sustain Zn content. However, at high salinity, increased calcium levels might have helped to improve the Zn content, suggesting a potential protective or mitigative role of calcium against the negative effects of salinity on Zn accumulation in tomato fruits.

In 2022, no statistically significant Zn content in the fruit. These results were consistent with Saleh et al. (2019), who noted that the introduction of additional calcium to saline nutrient solutions or the application of foliar calcium sprays positively influenced the concentrations of essential nutrients in fruit such as Ca, Mg, Fe, Mn, and Zn, in addition to the protein content in tomato fruits when grown under saline conditions. The impacts of the treatments on the Zn content in the fruit are depicted in Table 4.25.

Table 4.25. Effect of salinity and Ca doses on fruit Zu content

Treatments		Fruit Zn (ppm)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	27.43±0.51 ^{abc}	28.40±2.80	33.53±0.95 ^a	25.93±1.45
	50	30.13±1.96 ^a	27.13±0.45	28.43±0.95 ^c	28.43±2.85
	100	26.80±0.80 ^{bc}	27.20±1.50	28.33±1.08 ^c	26.13±0.55
	200	27.03±1.27 ^{bc}	27.83±3.35	31.93±1.15 ^{ab}	25.33±1.95
4	0	29.47±1.75 ^{ab}	26.53±0.85	32.40±1.65 ^{ab}	25.60±1.10
	50	26.50±0.90 ^{bc}	25.43±0.85	27.23±1.60 ^c	26.13±0.55
	100	30.40±1.00 ^a	24.60±1.10	31.83±1.15 ^{ab}	24.60±1.20
	200	26.17±1.15 ^{bc}	25.20±1.50	26.60±1.00 ^c	23.40±1.10
6	0	25.03±0.55 ^c	24.00±0.60	26.60±1.20 ^c	24.80±2.50
	50	25.50±0.10 ^{bc}	24.10±2.40	28.43±1.85 ^c	23.50±2.10
	100	25.43±0.95 ^{bc}	23.43±1.05	26.40±1.32 ^c	23.83±1.75
	200	28.83±2.08 ^{ab}	23.90±0.40	29.27±1.87 ^{bc}	24.83±0.55
Means					
Salinity	2	27.85 ^a	27.64 ^a	30.56 ^a	26.46 ^a
	4	28.13 ^a	25.44 ^b	29.52 ^a	24.93 ^b
	6	26.20 ^b	23.85 ^c	27.68 ^b	24.24 ^b
Ca	0	27.31	26.31	30.84 ^a	25.44
	50	27.38	25.56	28.03 ^b	26.02
	100	27.54	25.08	28.86 ^b	24.86
	200	27.34	25.64	29.27 ^{ab}	24.53
Significant differences					
Salinity		**	**	**	**
Ca		n.s	n.s	*	n.s
Salinity*Ca		**	n.s	**	n.s

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** and * represent significance difference at $P \leq 0.01$ and 0.05 , respectively

ns: Represent not significant difference.

4.14.4. Manganese content in fruit

The interaction between calcium and salinity had a significant effect on the Mn content in the fruit. In 2021, for LA4442 variety, the highest value of Mn content in fruit 6.83 was obtained from interaction between 0 ppm calcium and EC 4.0 dS/m. Conversely, the minimum Mn content in fruit 5.30 was observed from interaction between 200 ppm calcium and EC 4.0 dS/m.

In 2022 the maximum Mn content in fruit 8.57 was recorded from 100 ppm calcium and EC 6.0 dS/m. On the contrary, the lowest value for Mn content in fruit 5.42 was observed from 200 ppm calcium and EC 6.0 dS/m.

In 2022 for Ufuk F1 variety, the maximum value of Mn content in fruit 8.93 was observed from 100 ppm calcium and EC 4.0 dS/m. However, the lowest value of Mn content in fruit 6.03 was obtained from interaction between 200 ppm calcium and EC 6.0 dS/m. The impacts of the treatments on the Mn content in the fruit are depicted in Table 4.26.

Table 4.26. Effect of salinity and Ca doses on fruit Mn content

Treatments		Mn (ppm)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	6.60±0.20 ^{ab}	7.70±0.36 ^b	8.80±0.10	8.70±0.20 ^{ab}
	50	6.40±0.20 ^{abc}	6.02±0.06 ^{cd}	9.23±0.95	8.40±0.10 ^{ab}
	100	5.83±0.35 ^{a-d}	5.93±0.10 ^{cd}	7.23±0.55	8.20±0.10 ^{ab}
	200	6.23±0.06 ^{a-d}	5.99±0.32 ^{cd}	7.90±0.50	6.53±0.25 ^f
4	0	6.83±0.35 ^a	5.73±0.31 ^{cd}	7.23±0.65	8.63±0.06 ^{ab}
	50	5.67±0.55 ^{cd}	5.99±0.58 ^{cd}	8.33±2.15	7.40±0.70 ^{de}
	100	5.73±0.06 ^{a-d}	5.97±1.28 ^{cd}	8.10±0.20	8.93±0.55 ^a
	200	5.30±0.40 ^d	6.57±0.68 ^c	7.90±0.60	6.70±0.20 ^{ef}
6	0	6.03±0.35 ^{a-d}	5.86±0.59 ^{cd}	8.43±0.25	8.13±0.25 ^{abc}
	50	5.63±0.06 ^{bcd}	5.87±0.11 ^{cd}	7.30±0.10	8.10±0.60 ^{cd}
	100	5.50±0.20 ^{bcd}	8.57±0.09 ^a	8.13±0.25	7.30±0.90 ^e
	200	6.20±0.35 ^{a-d}	5.42±0.06 ^d	7.63±1.95	6.03±0.15 ^f
Means					
Salinity	2	6.27 ^a	6.41	8.29	7.96 ^a
	4	5.88 ^b	6.07	7.89	7.92 ^a
	6	5.84 ^b	6.43	7.88	7.39 ^b
Ca	0	6.49 ^a	6.43 ^{ab}	8.16	8.49 ^a
	50	5.90 ^b	5.96 ^b	8.29	7.97 ^b
	100	5.69 ^b	6.83 ^a	7.82	8.14 ^{ab}
	200	5.91 ^b	5.99 ^b	7.81	6.42 ^c
Significant differences					
Salinity		**	n.s	n.s	**
Ca		**	**	n.s	**
Salinity*Ca		**	**	n.s	**

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.
 **: Represent significance difference ($P \leq 0.01$). ns: Represent not significant difference.

4.15. Effect of salinity and Ca doses on fruit macronutrients content

4.15.1. Phosphorus content in fruit

The effect of calcium and salinity significantly impacted fruit P content at different levels. In 2021 for LA4442 variety, the maximum P content in fruit 0.52 was obtained from interaction between 200 ppm calcium and EC 4.0 dS/m. On the flip side, the minimum P content in fruit 0.39 was recorded from interaction between 0 ppm and EC 4.0 dS/m.

In 2022, the highest phosphorus content in fruit, measured at 0.44 resulted from the combination of 200 ppm calcium and EC 6.0 dS/m. Conversely, the lowest phosphorus content found in fruit at 0.27 was observed when there was no calcium present with EC level of 4.0 dS/m.

The results showed that, in 2021 and 2022 for LA4442 variety, the relationship between calcium and salinity on P content in fruit suggests that higher calcium levels generally correspond to higher P content, indicating an interaction effect where both factors together lead to an optimal P uptake or retention in the fruit.

In 2021 for Ufuk F₁, The maximum level of P in the fruit, registering at 0.42 was achieved with a mix of 100 ppm of calcium and EC 6.0 dS/m. On the other hand, the minimum P level detected in the fruit, which was 0.29, occurred in 50 ppm calcium and 2.0 dS/m.

In 2022, the greatest value of P content in fruit 0.43 was observed from interaction between 100 ppm calcium and EC 6.0 dS/m. While, the minimum P content in fruit 0.34 was recorded from interaction between 100 ppm and EC 2.0 dS/m.

In 2021 and 2022 for Ufuk F₁ variety, the results showed that, in EC 2.0 dS/m, increased calcium was not due to increased P content. At EC 4.0 dS/m, the variations in P content were small and did not show a clear correlation with calcium levels. However, at a higher salinity EC of 6.0 dS/m, there was an increase in P content with higher calcium levels, peaking at 100 ppm. Overall, this suggests that while calcium and salinity had affect P content in leaves, the relationship is complex and may be influenced by other environmental or physiological factors. These results were compatible with Saleh et al., (2019) who mentioned that 5 mmol L⁻¹ of calcium applied,

and the interaction between calcium and salinity had a significantly increased P content in fruits. The effects of the treatments on the P content in the fruit were illustrated in Table 4.27.

Table 4.27. Effect of salinity and Ca doses on fruit P content

Treatments		P (%)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	0.41±0.02 ^{cd}	0.30±0.02 ^{de}	0.39±0.02 ^{cd}	0.37±0.01 ^{cd}
	50	0.48±0.06 ^{ab}	0.37±0.06 ^{bc}	0.29±0.05 ^d	0.34±0.02 ^d
	100	0.40±0.03 ^{cd}	0.30±0.04 ^{de}	0.39±0.04 ^a	0.38±0.05 ^{bcd}
	200	0.44±0.01 ^{bc}	0.39±0.03 ^{ab}	0.39±0.04 ^a	0.44±0.02 ^a
4	0	0.39±0.03 ^d	0.27±0.01 ^e	0.37±0.01 ^{ab}	0.43±0.01 ^{ab}
	50	0.43±0.04 ^c	0.38±0.04 ^{bc}	0.38±0.05 ^{cd}	0.37±0.01 ^{cd}
	100	0.40±0.03 ^{cd}	0.41±0.02 ^{ab}	0.35±0.02 ^{cd}	0.36±0.02 ^{cd}
	200	0.52±0.06 ^a	0.37±0.06 ^{bc}	0.37±0.020 ^{abc}	0.41±0.04 ^{abc}
6	0	0.40±0.07 ^{cd}	0.33±0.02 ^{cd}	0.39±0.06 ^a	0.44±0.01 ^a
	50	0.45±0.01 ^{bc}	0.33±0.01 ^{cd}	0.30±0.04 ^{bcd}	0.44±0.03 ^a
	100	0.41±0.03 ^{cd}	0.40±0.02 ^{ab}	0.42±0.01 ^a	0.43±0.02 ^a
	200	0.46±0.04 ^b	0.44±0.01 ^a	0.41±0.02 ^{ab}	0.43±0.00 ^{ab}
Means					
Salinity	2	0.43	0.34 ^b	0.38 ^b	0.38 ^b
	4	0.44	0.36 ^{ab}	0.39 ^b	0.40 ^b
	6	0.43	0.38 ^a	0.44 ^a	0.44 ^a
Ca	0	0.40 ^b	0.30 ^b	0.41 ^{ab}	0.41 ^{ab}
	50	0.45 ^a	0.36 ^{ab}	0.39 ^c	0.39 ^c
	100	0.40 ^b	0.37 ^{ab}	0.39 ^{bc}	0.39 ^{bc}
	200	0.47 ^a	0.40 ^a	0.428 ^a	0.43 ^a
Significant differences					
Salinity		n.s	*	**	**
Ca		**	**	**	**
Salinity*Ca		**	**	**	*

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.
 **: Represent significance difference ($P \leq 0.01$). *: Represent significance difference ($P \leq 0.05$).
 n.s: Represent not significant difference.

4.15.2. Potassium content in fruit

Effect of calcium, salinity and interaction between calcium and salinity no significant effected on K content in fruit, in 2021 and 2022 years for LA4442 variety. In 2021 and

2022 for Ufuk F₁ variety, the greatest values were K content in fruit (2.97 and 2.72 respectively) were obtained from interaction between 0 ppm calcium and EC 2.0 dS/m. In contrast, in 2021 the minimum K content in fruit 1.80 was observed from interaction between 0 ppm calcium and EC 6.0 dS/m. While, in 2022, the lowest value of K content in fruit 2.03 was noted from interaction between 50 ppm calcium and EC 2.0 dS/m. The results showed that the effect of calcium on K content at EC 2.0 dS/m was minimal in 2021, while in 2022, higher calcium significantly decreased K content. However, at an EC of 4.0 dS/m, higher calcium levels tended to decrease K content more in 2021 than in 2022. At high salinity (6.0 dS/m), calcium supplementation seemed beneficial in 2021, in contrast to 2022, where there was no clear pattern. These findings were in line with Giuffrida et al., (2009) found that as the concentration of sodium chloride in nutrient solutions rose, the potassium levels in fruit significantly declined. Similarly, Satti and Al-Yahyai, (1995) observed that fruits contained the least amount of potassium when sodium chloride was present in the nutrient mixture. The impacts of the treatments on the K content in the fruit are depicted in Table 4.28.

4.15.3. Calcium content in fruit

The interaction between calcium and salinity had significant effect of Ca content in fruit, in 2021 and 2022 years for LA4442 variety, the best results of Ca content in fruit 0.19 and 0.14 respectively, were observed when 200 ppm of calcium was added with an EC of 2.0 dS/m. On the contrary, in 2021, the smallest value of Ca content in fruit 0.06 was recorded for calcium at concentrations of 0 ppm and 50 ppm, respectively, with EC 2.0 dS/m. Conversely, in 2022 the lowest value of Ca content in fruit 0.06 was obtained from interaction between 50 ppm calcium and EC 6.0 dS/m.

In 2021 and 2022 for Ufuk F₁, the greatest values of Ca content in fruit (0.12 and 0.11 respectively) were observed from interaction between 200 ppm calcium and EC 2.0 dS/m. However, in 2021, the minimum value of Ca 0.05 was found between the interaction of 0 ppm calcium and EC levels of (2.0, 4.0, and 6.0 dS/m respectively). In contrast, in 2022, the lowest value of Ca content in fruit 0.05 was observed from the interaction between 0 ppm calcium and EC levels of (4.0 and 6.0 dS/m respectively).

Table 4.28. Effect of salinity and Ca doses on fruit K content

Treatments		K (%)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	2.84±0.28	1.86±0.22	2.97±0.33 ^a	2.72±0.02 ^a
	50	2.88±0.02	2.61±0.04	2.88±0.37 ^{ab}	2.03±0.61 ^d
	100	2.89±0.14	2.08±0.56	2.87±0.23 ^{ab}	2.68±0.03 ^{ab}
	200	2.89±0.07	2.28±0.46	2.95±0.26 ^a	2.66±0.08 ^{ab}
4	0	2.95±0.28	2.28±0.24	2.81±0.15 ^{ab}	2.50±0.16 ^{abc}
	50	2.64±0.22	2.28±0.29	2.86±0.32 ^{ab}	2.48±0.12 ^{abc}
	100	3.09±0.05	2.18±0.45	2.50±0.51 ^{abc}	2.30±0.09 ^{bcd}
	200	2.84±0.14	2.33±0.38	2.14±0.45 ^{cd}	2.50±0.13 ^{abc}
6	0	2.73±0.12	2.23±0.13	1.80±0.12 ^d	2.68±0.03 ^{ab}
	50	2.62±0.10	2.03±0.13	2.00±0.19 ^{cd}	2.16±0.26 ^{cd}
	100	2.84±0.10	2.07±0.05	2.33±0.39 ^{bcd}	2.51±0.15 ^{abc}
	200	2.76±0.20	2.50±0.12	2.54±0.33 ^{abc}	2.37±0.14 ^{bcd}
Means					
Salinity	2	2.88	2.21	2.92 ^a	2.52
	4	2.88	2.27	2.58 ^b	2.45
	6	2.74	2.28	2.17 ^c	2.43
Ca	0	2.84	2.12	2.53	2.64 ^a
	50	2.72	2.31	2.58	2.23 ^b
	100	2.94	2.11	2.57	2.50 ^a
	200	2.83	2.37	2.54	2.51 ^a
Significant differences					
Salinity		n.s	n.s	**	n.s
Ca		n.s	n.s	n.s	*
Salinity*Ca		n.s	n.s	*	*

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** : Represent significance difference ($P \leq 0.01$). * : Represent significance difference ($P \leq 0.05$).

ns: Represent not significant difference.

Over the two-year and for both genotypes comparison, the relationship between calcium addition and salinity levels showed a consistent pattern in affecting the calcium content in fruit. In 2021 and 2022, increasing levels of calcium supplementation, particularly at 200 ppm, generally led to higher calcium content in the fruit across different salinity levels (2.0, 4.0 and 6.0 dS/m). These results were supported by Rab et al., (2017) when mentioned that Salinity reduced the calcium ion concentration in the fruit. However, spraying the leaves with calcium notably enhanced the fruit's calcium levels. Calcium

plays a crucial role as a plant nutrient, essential for the structure and function of cell walls. Elevated levels of calcium may decrease the plasma membranes permeability to Na^+ (Marschner, 2011). The decrease in membrane permeability to Na^+ due to the presence of calcium limits the passive accumulation of Na^+ ions by passive influx (Tuna et al., 2007).

Table 4.29. Effect of salinity and Ca doses on fruit Ca content

Treatments		Ca (%)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	0.06±0.01 ^e	0.08±0.01 ^{de}	0.05±0.01 ^d	0.06±0.07 ^e
	50	0.06±0.01 ^e	0.07±0.02 ^{ef}	0.07±0.02 ^c	0.09±0.03 ^{bcd}
	100	0.17±0.02 ^{ab}	0.11±0.02 ^c	0.09±0.01 ^b	0.09±0.03 ^b
	200	0.19±0.02 ^a	0.14±0.01 ^a	0.12±0.01 ^a	0.11±0.04 ^a
4	0	0.07±0.01 ^{de}	0.08±0.02 ^{de}	0.05±0.01 ^d	0.05±0.03 ^f
	50	0.10±0.03 ^{cde}	0.08±0.01 ^{de}	0.08±0.01 ^{bc}	0.08±0.07 ^{cd}
	100	0.13±0.00 ^{bc}	0.11±0.02 ^c	0.09±0.02 ^b	0.09±0.05 ^{bc}
	200	0.13±0.03 ^{bc}	0.13±0.01 ^{ab}	0.11±0.02 ^a	0.09±0.06 ^b
6	0	0.08±0.03 ^{de}	0.07±0.02 ^{ef}	0.05±0.03 ^d	0.05±0.04 ^f
	50	0.10±0.02 ^{cde}	0.06±0.02 ^f	0.07±0.06 ^c	0.07±0.06 ^e
	100	0.12±0.06 ^{cd}	0.10±0.02 ^{cd}	0.09±0.02 ^b	0.08±0.03 ^d
	200	0.13±0.01 ^{bc}	0.11±0.01 ^{bc}	0.11±0.03 ^a	0.10±0.01 ^b
Means					
Salinity	2	0.12	0.10 ^a	0.09	0.09 ^a
	4	0.11	0.10 ^a	0.08	0.08 ^b
	6	0.11	0.08 ^b	0.08	0.07 ^c
Ca	0	0.07 ^b	0.07 ^c	0.05 ^d	0.06 ^d
	50	0.09 ^b	0.07 ^c	0.08 ^c	0.08 ^c
	100	0.13 ^a	0.11 ^b	0.09 ^b	0.09 ^b
	200	0.15 ^a	0.13 ^a	0.11 ^a	0.10 ^a
Significant differences					
Salinity		n.s	**	n.s	**
Ca		**	**	**	**
Salinity*Ca		**	*	*	*

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

***: Represent significance difference ($P \leq 0.01$). *: Represent significance difference ($P \leq 0.05$).

n.s: Represent not significant difference.

These findings were in line with Borkowski, (1983) who found that the calcium content in fruit during rapid growth is lower than the rate of the fruit's growth. As a result, during this period, the calcium content in the tomato fruit diminishes.

Ho and White, (2005) reported that leaves have much higher rates of transpiration in comparison to fruits, which causes leaves to contain significantly more calcium than fruits. The impact of the treatments on the Mg content was showed in Table 4.29.

4.15.4. Magnesium content in fruit

The effects of different levels of calcium and salinity on the Mg content in leaves were investigated. The maximum Mg content recorded in the fruit was 0.321 at EC of 6.0 dS/m with no calcium added. While, the minimum Mg content was 0.228 at EC of 2.0 dS/m with EC 50 ppm calcium. The results observed that in lower salinity (2.0 dS/m), increased levels of calcium correlated with increased Mg content up to a point. However, in higher salinity levels (4.0 and 6.0 dS/m), the Mg content in the fruit was less variable and remained high across all levels of calcium supplementation, suggesting that salinity may have had a more dominant effect than calcium on Mg content in these conditions.

In 2022, there was not significant effect of calcium, salinity and interaction between calcium and salinity on Mg content in fruit. These results were supported by Agius et al., (2022) who found that the concentration of sodium chloride did not influence the magnesium levels in the fruits.

In 2021 for Ufuk F₁, in EC 2.0 dS/m, there was a significant variation in Mg content with different levels of calcium, showing higher Mg content at 50 ppm and 200 ppm Ca, which were 0.322 and 0.302, respectively. In EC 4.0 dS/m, calcium levels had a negligible effect on Mg content. At EC 6.0 dS/m, there was a trend of increasing Mg content with increasing calcium levels, although the starting Mg content at 0 ppm Ca was the lowest observed, at 0.216.

In 2022, the influence of calcium, salinity, and combined interaction did not significantly affect the magnesium levels in the fruit. The effects of the applications on Mg content in fruit was presented in Table 4.30.

Table 4.30. Effect of salinity and Ca doses on fruit Mg content

Treatments		Mg (%)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	0.295±0.014 ^{ab}	0.314±0.016	0.236±0.012 ^d	0.312±0.013
	50	0.228±0.011 ^c	0.316±0.016	0.322±0.020 ^a	0.313±0.015
	100	0.277±0.013 ^b	0.313±0.020	0.268±0.018 ^c	0.313±0.011
	200	0.311±0.015 ^a	0.311±0.017	0.302±0.022 ^a	0.312±0.021
4	0	0.308±0.002 ^a	0.308±0.019	0.261±0.091 ^c	0.313±0.021
	50	0.314±0.019 ^a	0.314±0.012	0.257±0.016 ^{cd}	0.315±0.018
	100	0.312±0.017 ^a	0.312±0.021	0.260±0.013 ^c	0.315±0.020
	200	0.313±0.013 ^a	0.313±0.016	0.261±0.014 ^c	0.314±0.021
6	0	0.321±0.012 ^a	0.320±0.018	0.216±0.011 ^e	0.313±0.021
	50	0.314±0.012 ^a	0.314±0.021	0.233±0.014 ^{de}	0.313±0.022
	100	0.318±0.021 ^a	0.318±0.019	0.244±0.017 ^d	0.312±0.023
	200	0.315±0.019 ^a	0.315±0.020	0.270±0.019 ^c	0.313±0.022
Means					
Salinity	2	0.278 ^b	0.314	0.282 ^a	0.313
	4	0.312 ^a	0.312	0.260 ^b	0.314
	6	0.316 ^a	0.317	0.241 ^b	0.313
Ca	0	0.308 ^{ab}	0.314	0.238 ^b	0.313
	50	0.285 ^b	0.315	0.271 ^a	0.314
	100	0.302 ^{ab}	0.314	0.257 ^{ab}	0.313
	200	0.313 ^a	0.313	0.278 ^a	0.313
Significant differences					
Salinity		**	n.s	*	n.s
Ca		*	n.s	*	n.s
Salinity*Ca		*	n.s	*	n.s

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

**₁: Represent significance difference ($P \leq 0.01$). *₁: Represent significance difference ($P \leq 0.05$).

n.s: Represent not significant difference.

4.15.5. Sodium content in fruit

The calcium, salt and interaction between calcium and salinity had significant effected on Na content in fruit. In 2021 and 2022 for LA4442, the highest values of Na content in fruit (0.077 and 0.075 respectively) were observed from interaction between 0 ppm calcium and EC 6.0 dS/m. However, in 2021, minimum Na content in fruit 0.048 was recorded from interaction between 0 ppm and EC 2.0 dS/m. Conversely, in 2022, minimum 0.045 was observed from interaction between 50 ppm calcium and EC 2.0

dS/m. The results showed that, in 2021 and 2022, in EC 2.0 dS/m, increasing calcium application did not consistently affect Na content, with the lowest concentration of Na content observed at both 0 and 200 ppm of added calcium. In contrast, in EC 4.0 dS/m, the Na content seemed to increase with calcium applications up to 100 ppm but did not further increase significantly at the highest calcium treatment of 200 ppm. On the contrary, in EC 6.0 dS/m, the presence of calcium generally showed a trend where the highest Na content was observed without any added calcium (0 ppm), and then there was a slight decrease in Na content as calcium application increased.

In 2021 for *Ufuk F1* variety, the maximum Na content 0.066 were obtained from interaction between 100 ppm calcium and EC 6.0 dS/m. while, the minimum 0.026 was recorded from interaction between 200 ppm calcium and EC 2.0 dS/m.

In 2022 the highest Na content 0.060 resulted from the combination of 0 ppm calcium with EC 6.0 dS/m. Conversely, the lowest value, 0.030, was noted when 200 ppm calcium was combined with EC 2.0 dS/m. In both years, the results indicated that the application of calcium gradually decreased the accumulation of sodium in the fruit. These results were supported by Satti and Al-Yahyai, (1995) who found that increased levels of NaCl led to higher sodium content in the fruit. In additionally calcium can mitigate the accumulation of Na^+ in fruit and leaves by reducing the uptake of sodium. The impacts of the applications on Na content in fruit was presented in Table 4.31,

Table 4.31. Effect of salinity and Ca doses on fruit Na content

Treatments		Fruit Na (%)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	0.048±0.004 ^d	0.048±0.010 ^{cd}	0.036±0.008 ^{cd}	0.037±0.004 ^f
	50	0.057±0.005 ^c	0.045±0.009 ^d	0.053±0.010 ^{bc}	0.033±0.003 ^g
	100	0.065±0.008 ^b	0.064±0.008 ^b	0.030±0.004 ^d	0.033±0.002 ^g
	200	0.050±0.004 ^d	0.052±0.006 ^{bcd}	0.026±0.005 ^d	0.030±0.002 ^h
4	0	0.064±0.011 ^b	0.058±0.010 ^{bc}	0.057±0.006 ^{ab}	0.051±0.004 ^b
	50	0.057±0.009 ^c	0.060±0.007 ^{bc}	0.055±0.007 ^{bc}	0.046±0.004 ^c
	100	0.071±0.008 ^{ab}	0.062±0.009 ^b	0.056±0.005 ^{ab}	0.043±0.003 ^d
	200	0.064±0.010 ^b	0.057±0.007 ^{bc}	0.041±0.004 ^c	0.040±0.005 ^e
6	0	0.077±0.006 ^a	0.075±0.011 ^a	0.057±0.005 ^{ab}	0.060±0.008 ^a
	50	0.072±0.011 ^{ab}	0.072±0.006 ^a	0.065±0.005 ^{ab}	0.049±0.006 ^c
	100	0.068±0.008 ^b	0.070±0.009 ^{ab}	0.066±0.011 ^a	0.048±0.005 ^c
	200	0.065±0.006 ^b	0.070±0.012 ^{ab}	0.056±0.011 ^{ab}	0.047±0.005 ^c
Means					
Salinity	2	0.055 ^c	0.052 ^b	0.037 ^c	0.033 ^c
	4	0.064 ^b	0.059 ^b	0.053 ^b	0.045 ^b
	6	0.070 ^a	0.072 ^a	0.061 ^a	0.051 ^a
Ca	0	0.063 ^b	0.060 ^b	0.050 ^a	0.050 ^a
	50	0.062 ^b	0.059 ^b	0.058 ^a	0.043 ^b
	100	0.069 ^a	0.065 ^a	0.051 ^a	0.041 ^b
	200	0.060 ^b	0.060 ^b	0.041 ^b	0.039 ^c
Significant differences					
Salinity		**	**	**	**
Ca		*	*	*	**
Salinity*Ca		*	*	n.s	*

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

**; Represent significance difference ($P \leq 0.01$). *: Represent significance difference ($P \leq 0.05$).

n.s: Represent not significant difference.

4.15.6. Calcium content in fruit tip

The occurrence of Ca of Fruit tip was significantly influenced by the levels of salinity, the concentration of calcium, and the interaction between salinity and calcium. In 2021 and 2022 for LA4442 variety, the highest values of Ca of Fruit tip (0.255 and 0.173 respectively) were obtained from interaction between 200 ppm calcium and EC 2.0 dS/m. In contrast, in 2021, the minimum Ca of Fruit tip 0.024 was found from interaction between 0 ppm calcium and EC (4.0 and 6.0 dS/m respectively). Conversely,

in 2022, the lowest value of Ca of Fruit tip 0.030 was observed found from interaction between 0 ppm calcium EC 6.0 dS/m. These results were supported by Taylor et al., (2004) when mentioned that the minimal concentration of Ca was detected at the fruit with the blossom end rot, while the maximum Ca concentration was noted at the stem end of the fruit.

During 2021 and 2022, for the Ufuk F₁ variety, the peak Ca concentration at the fruit tip (0.312 and 0.080 respectively) resulted from the combination of 200 ppm calcium and EC of 2.0 dS/m. Conversely, the minimum Ca levels in fruit tip (0.033 and 0.036 respectively) were observed when 0 ppm calcium was used with an EC of 6.0 dS/m. The results showed that calcium accumulation in fruit increased positively with higher doses of calcium, and that calcium reduced salt stress. These findings were in line with Borkowski, (1983) who found that the highest content of calcium in fresh matter was found in the smallest and the youngest fruits. The effects of the applications on the Ca of Fruit tip were displayed in Table 4.32.

4.16. Effect of salinity and Ca doses on fruit firmness

Fruits were picked at the mature-red stage. Fruit tissue firmness was measured with an (Wheel Manuel Test Stand, Model: SL J-B, S/N: 4K15C01961, Capacity: 500 N, Stroke:150 mm, PCE Instruments) machine to give full deflection for a 1-kg weight. The firmness was measured from the side of tomato fruits. In the LA4442 variety of fruit in 2021, the best value of fruit firmness 2.086 was observed with interaction between 200 ppm calcium and EC 6.0 dS/m. Whereas, lowest value of fruit firmness 1.339 was observed form interaction between 50 ppm calcium and EC 2.0 dS/m.

In 2022, the optimal fruit firmness value of 2.367 was recorded when there was an interaction between 200 ppm calcium and an EC level of 2.0 dS/m. The interaction between 0 ppm calcium and EC 6.0 dS/m resulted in the lowest recorded fruit firmness rating of 0,900. A similar result was concluded by Ho and White, (2005) who indicated that calcium application seems to increase the calcium concentration in the cell wall and, thus, enhances the fruit firmness.

The Ufuk F₁ variety showed the greatest fruit firmness values of 2.32 and 2.45 in the years 2021 and 2022, respectively. These values were seen as a result of the interaction between 200 ppm calcium and EC 6.0 dS/m. The interaction between a calcium

concentration of 0 ppm and an EC 2.0 dS/m resulted in the lowest fruit firmness values of 1.24 and 1.27 respectively. These results showed that increased calcium doses due to increased fruit firmness. Our results are agreement with Madani et al., (2015) when they found that calcium serves as a vital constituent of the cellular wall structure, effectively retarding the degradation process of cell wall polymers. Consequently, it is frequently employed to enhance fruit firmness, overall quality, and storage capabilities. These results agreed with Rab et al., (2017) they found that application of calcium also enhanced the firmness of the fruit under conditions of salinity stress. Table 4.33 displayed the effects of the treatments on fruit firmness.

Table 4.32. Effect of salinity and Ca doses on Ca of Fruit tip

Treatments		Ca of Fruit tip (%)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	0.032±0.005 ^{fg}	0.060±0.004 ^{gh}	0.059±0.002 ^g	0.044±0.005 ^e
	50	0.058±0.006 ^f	0.070±0.004 ^{fg}	0.087±0.006 ^f	0.060±0.002 ^{cd}
	100	0.127±0.012 ^{bc}	0.132±0.005 ^c	0.188±0.013 ^c	0.065±0.002 ^b
	200	0.255±0.035 ^a	0.173±0.005 ^a	0.312±0.004 ^a	0.080±0.003 ^a
4	0	0.024±0.005 ^g	0.048±0.005 ^h	0.036±0.009 ⁱ	0.037±0.002 ^f
	50	0.036±0.006 ^{fg}	0.057±0.006 ^{gh}	0.062±0.005 ^g	0.057±0.005 ^{cd}
	100	0.097±0.005 ^{de}	0.090±0.001 ^e	0.167±0.018 ^d	0.059±0.007 ^{cd}
	200	0.151±0.006 ^b	0.148±0.014 ^b	0.219±0.035 ^b	0.065±0.004 ^b
6	0	0.024±0.002 ^g	0.030±0.002 ⁱ	0.033±0.006 ⁱ	0.036±0.003 ^f
	50	0.030±0.003 ^{fg}	0.051±0.005 ^h	0.046±0.005 ^h	0.053±0.001 ^d
	100	0.061±0.006 ^{ef}	0.078±0.008 ^{ef}	0.053±0.007 ^{gh}	0.057±0.003 ^{cd}
	200	0.104±0.008 ^{cd}	0.118±0.020 ^d	0.111±0.005 ^e	0.066±0.001 ^b
Means					
Salinity	2	0.118 ^a	0.109 ^a	0.162 ^a	0.062 ^a
	4	0.077 ^b	0.086 ^b	0.121 ^b	0.055 ^b
	6	0.055 ^c	0.069 ^c	0.086 ^c	0.053 ^b
Ca	0	0.027 ^d	0.046 ^d	0.043 ^d	0.039 ^d
	50	0.042 ^c	0.059 ^c	0.065 ^c	0.057 ^c
	100	0.095 ^b	0.100 ^b	0.170 ^b	0.060 ^b
	200	0.170 ^a	0.146 ^a	0.214 ^a	0.071 ^a
Significant differences					
Salinity		**	**	**	**
Ca		**	**	**	**
Salinity*Ca		**	**	**	**

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** : Represent significance difference ($P \leq 0.01$).

Table 4.33. Effect of salinity and Ca doses on fruit firmness

Treatments		Newtons			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	1.484±0.017 ^{cd}	1.483±0.067 ^{ef}	1.24±0.06 ^g	1.27±0.10 ^f
	50	1.339±0.096 ^f	1.100±0.020 ^g	1.49±0.11 ^f	1.75±0.06 ^{cd}
	100	1.509±0.064 ^c	1.947±0.070 ^c	1.70±0.01 ^{de}	1.70±0.15 ^{cd}
	200	1.993±0.054 ^a	2.367±0.057 ^a	2.19±0.04 ^b	2.15±0.06 ^b
4	0	1.506±0.047 ^c	0.990±0.020 ^h	1.33±0.03 ^g	1.71±0.08 ^{cd}
	50	1.413±0.040 ^{def}	0.950±0.053 ^h	1.58±0.12 ^{ef}	1.40±0.22 ^{ef}
	100	1.619±0.028 ^b	1.403±0.006 ^f	1.77±0.05 ^d	1.75±0.05 ^{cd}
	200	2.033±0.045 ^a	2.197±0.038 ^b	1.93±0.07 ^c	1.91±0.03 ^c
6	0	1.503±0.076 ^c	0.900±0.060 ^h	1.69±0.06 ^{de}	1.40±0.20 ^{ef}
	50	1.386±0.107 ^{ef}	1.133±0.155 ^g	1.30±0.01 ^g	1.57±0.24 ^{de}
	100	1.725±0.061 ^b	1.553±0.047 ^e	1.82±0.07 ^{cd}	1.87±0.05 ^c
	200	2.086±0.054 ^a	2.247±0.049 ^b	2.32±0.14 ^a	2.45±0.06 ^a
Means					
Salinity	2	1.581 ^b	1.724 ^a	1.66 ^b	1.72 ^{ab}
	4	1.643 ^a	1.385 ^c	1.65 ^b	1.69 ^b
	6	1.675 ^a	1.458 ^b	1.78 ^a	1.82 ^a
Ca	0	1.498 ^c	1.124 ^c	1.42 ^c	1.46 ^c
	50	1.379 ^d	1.061 ^d	1.46 ^c	1.58 ^c
	100	1.618 ^b	1.634 ^b	1.76 ^b	1.77 ^b
	200	2.037 ^a	2.270 ^a	2.15 ^a	2.17 ^a
Significant differences					
Salinity		**	**	**	*
Ca		**	**	**	**
Salinity*Ca		*	**	**	**

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** : Represent significance difference ($P \leq 0.01$). * : Represent significance difference ($P \leq 0.05$).

4.17. Effect of salinity and Ca doses on fruit ascorbic acid (Vitamin C)

The content of ascorbic acid in tomato fruits was markedly influenced by calcium. Furthermore, the interaction between calcium and salinity was determined to have a significant impact on the tomato's ascorbic acid content. In 2021 and 2022 for LA4442 variety, the greatest values of ascorbic acid (29.32 and 19.06 respectively) observed from interaction between 200 ppm and EC 6.0 dS/m. In contrast the minimum ascorbic aside (14.53 and 9.36 respectively) were recorded from interaction between 0 ppm calcium and EC 6.0 dS/m. The results showed that calcium significantly effected on

ascorbic acid, and increased rate of calcium application approximately increased ascorbic acid, also calcium declined effected of salinity on ascorbic acid. Findings are consistent with Haleema et al., (2020) when they found that the tomato fruits that were treated with a calcium concentration of 0.75% showed the highest levels of ascorbic acid.

In 2021, for the Ufuk F₁ variety, the highest level of ascorbic acid, measuring at 25.36 resulted from the combination of 200 ppm calcium and an EC of 4.0 dS/m. Conversely, the minimum ascorbic acid content, recorded at 16.54 was noted under conditions of 0 ppm calcium and an EC of 6.0 dS/m.

In the year 2022, there was an observed rise in calcium levels in the presence of ascorbic acid, both in the absence and presence of saline conditions. However, no statistically significant differences were detected between the levels of ascorbic acid.

In 2021 and 2022, for the Ufuk F₁ variety, increased doses of calcium significantly impacted the ascorbic acid content. Our results agreement with result Ahmad, (2018) who found that The application of a 10 mM concentration of calcium sulphate (CaSO₄) resulted in significant improvements in total soluble solids, ascorbic acid content, and the occurrence of BER. These results agreed with Mazumder et al., (2021) who discovered that the application of a 2% calcium chloride (CaCl₂) spray resulted in an increase in the overall levels of ascorbic acid and lycopene The impact of the treatments on ascorbic acid levels was detailed in Table 4.34.

Table 4.34. Effect of salinity and Ca doses on fruit ascorbic acid (Vitamin C)

Treatments		(mg/100g)			
Salinity	Ca	LA4442		Ufuk F1	
		2021	2022	2021	2022
2	0	19.23±0.89 ^{de}	17.75±0.49 ^{ef}	19.44±1.01 ^{cd}	20.93±1.09
	50	22.43±1.52 ^{cd}	20.26±0.43 ^{cd}	18.22±1.36 ^{ef}	21.56±1.44
	100	24.02±0.65 ^{bc}	21.20±0.24 ^{bc}	22.88±0.46 ^{ab}	24.74±1.24
	200	28.29±2.78 ^a	23.84±1.75 ^a	25.03±1.86 ^a	27.99±1.75
4	0	20.08±2.96 ^{de}	18.65±1.21 ^{de}	19.04±2.00 ^{cde}	21.15±1.88
	50	19.76±2.23 ^{de}	18.33±1.43 ^{de}	21.71±1.92 ^{bc}	23.47±1.96
	100	27.13±0.34 ^{ab}	22.69±0.27 ^{ab}	23.41±1.29 ^{ab}	25.77±1.53
	200	26.75±1.92 ^{ab}	22.24±0.83 ^{abc}	25.36±0.90 ^a	27.75±1.63
6	0	14.53±2.21 ^f	14.36±1.13 ^g	16.54±2.86 ^f	18.49±1.32
	50	18.39±3.09 ^e	17.17±1.15 ^{ef}	20.10±0.59 ^{cd}	21.79±1.42
	100	16.93±0.87 ^{ef}	15.60±1.40 ^{fg}	24.01±1.16 ^{ab}	26.86±1.17
	200	29.32±2.15 ^a	24.06±1.33 ^a	25.29±0.30 ^a	28.11±1.48
Means					
Salinity	2	23.49 ^a	20.76 ^a	21.39	23.80
	4	23.43 ^a	20.48 ^a	22.38	24.54
	6	19.79 ^b	17.80 ^b	21.48	23.81
Ca	0	17.95 ^d	16.92 ^c	18.34 ^d	20.19 ^d
	50	20.19 ^c	18.59 ^b	20.01 ^c	22.27 ^c
	100	22.69 ^b	19.83 ^b	23.44 ^b	25.79 ^b
	200	28.12 ^a	23.38 ^a	25.23 ^a	27.95 ^a
Significant differences					
Salinity		**	**	n.s	n.s
Ca		**	**	**	**
Salinity*Ca		**	**	*	n.s

Values followed by similar letters under the same column are not significantly different at $P \leq 0.05$.

** : Represent significance difference ($P \leq 0.01$). * : Represent significance difference ($P \leq 0.05$).

ns: Represent not significant difference.

4.18. Colour parameters of tomato fruits

The interaction of calcium and salinity, along with their individual presence, substantially influenced the sodium levels in Colour parameters of tomato fruits (Figure 4.3). During the years 2021for LA4442 variety. The highest values of L^* , a^* and b^* (40.9, 26.5 and 27.42 respectively) were recorded from interaction between 200 ppm calcium and EC 6.0 dS/m. Conversely, in 2021 lowest value of L^* (38.42) was recorded from interaction between 0 ppm calcium and EC 2.0 dS/m. While, the minimum value

of a^* 21.79 was obtained from interaction between 50 ppm calcium and EC 2.0 dS/m. However, the smallest value of b^* 24.19 was found between interaction 100 ppm calcium and EC 2.0 dS/m. In 2022, the minimal value of L^* and a^* (38.18 and 23.02 respectively) resulted from the combination of 200 ppm calcium and EC of 2.0 dS/m. Conversely, the most reduced b^* value, 23.11, occurred with the interaction of 0 ppm calcium and an EC of 6.0 dS/m. In 2022 the highest value of L^* 39.23 was observed from interaction between 0 ppm calcium with EC 2.0 dS/m. In contrast, the maximum a^* 28.91 was noted from interaction between 50 ppm calcium with EC 6.0 dS/m. However, the greatest value of b^* 26.9 was obtained from interaction between 200 ppm with EC 6.0 dS/m. Conversely, the lowest values of L^* and a^* (38.18 and 23.02 respectively) were from interaction between 200 ppm calcium and EC 2.0 dS/m. However, minimum b^* 26.09 was observed from interaction between 200 ppm calcium and EC 6.0 dS/m.

In 2021 for Ufuk F₁, The maximum recorded values for L^* , a^* , and b^* (40.968, 25.568 and 27.54 respectively) occurred from the interaction involving 200 ppm calcium and an electrical conductivity of 6.0 dS/m. However, the minimum L^* value of 38.7 resulted from the combination of 0 ppm calcium and EC of 2.0 dS/m. On the other hand, the smallest a^* value 23.137 was observed when 0 ppm calcium was combined with EC of 4.0 dS/m. Meanwhile, the lowest b^* value, 23.919, was recorded from the interaction of 200 ppm calcium with an EC of 2.0 dS/m. in 2022, the greatest value of L^* 41.931 was observed from interaction between 0 ppm calcium with EC 4.0 dS/m. Conversely, The highest values of a^* and b^* (27.2 and 26.505 respectively) were achieved with a mix of 200 ppm calcium and an EC of 6.0 dS/m. However, The interaction between 50 ppm calcium and EC 4.0 dS/m resulted in the lowest value of L^* 40.257. In contrast, the interaction between 0 ppm calcium and EC 2.0 dS/m resulted in the lowest a^* 23.8 values. Interaction between 0 ppm and EC (2.0 and 4.0 dS/m) resulted in the lowest value of b^* 24.8.

For both genotypes in the years 2021 and 2022, the results showed that as calcium levels increased, there tended to be a slight increase in L^* value, which suggested that the fruit became lighter. However, this trend was not consistent across all levels of salinity and varied from year to year. The a^* value, indicating red to green, generally increased with higher calcium levels. This could suggest that an increase in calcium

might have correlated with a redder hue in the fruit. This trend appeared more consistent across different salinity levels and years. The b^* value, representing yellow-to-blue, fluctuated with changes in salinity and calcium. There was not a clear trend observable from the data presented. However, at higher salinity levels (6.0 dS/m), there was general increase in b^* value with increasing calcium, particularly noticeable in 2022, which could indicate that more calcium at higher salinity may lead to a yellower fruit. Senevirathna et al., (2010) discovered that the application of CaCl_2 can delay the development of fruit color in tomato by reducing the production of ethylene and slowing down the respiration rate. This, in turn, increases the shelf life of the fruits.

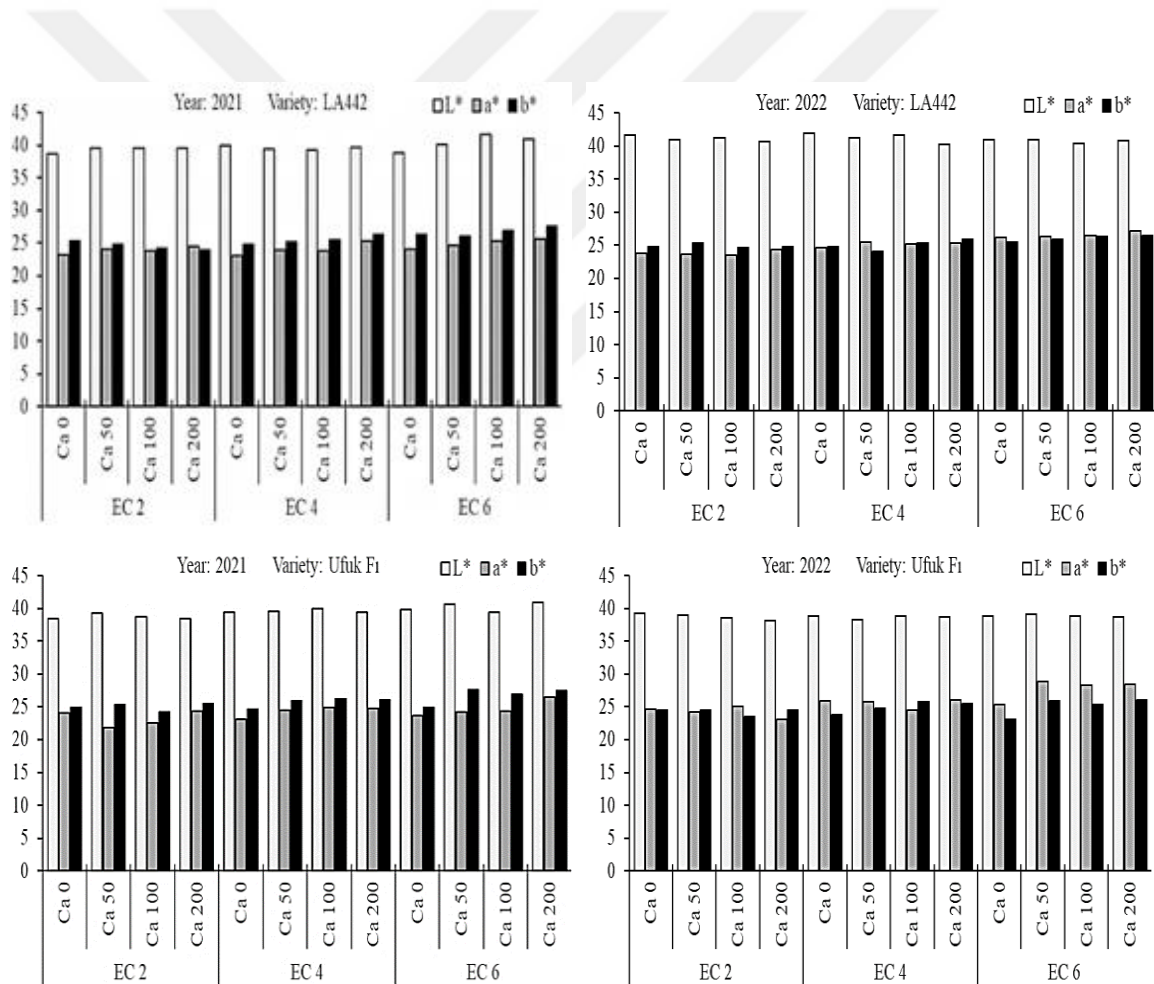


Fig. 4.3. Effect of salinity and Ca treatments on colour parameters of tomato fruits corresponding to years and genotypes

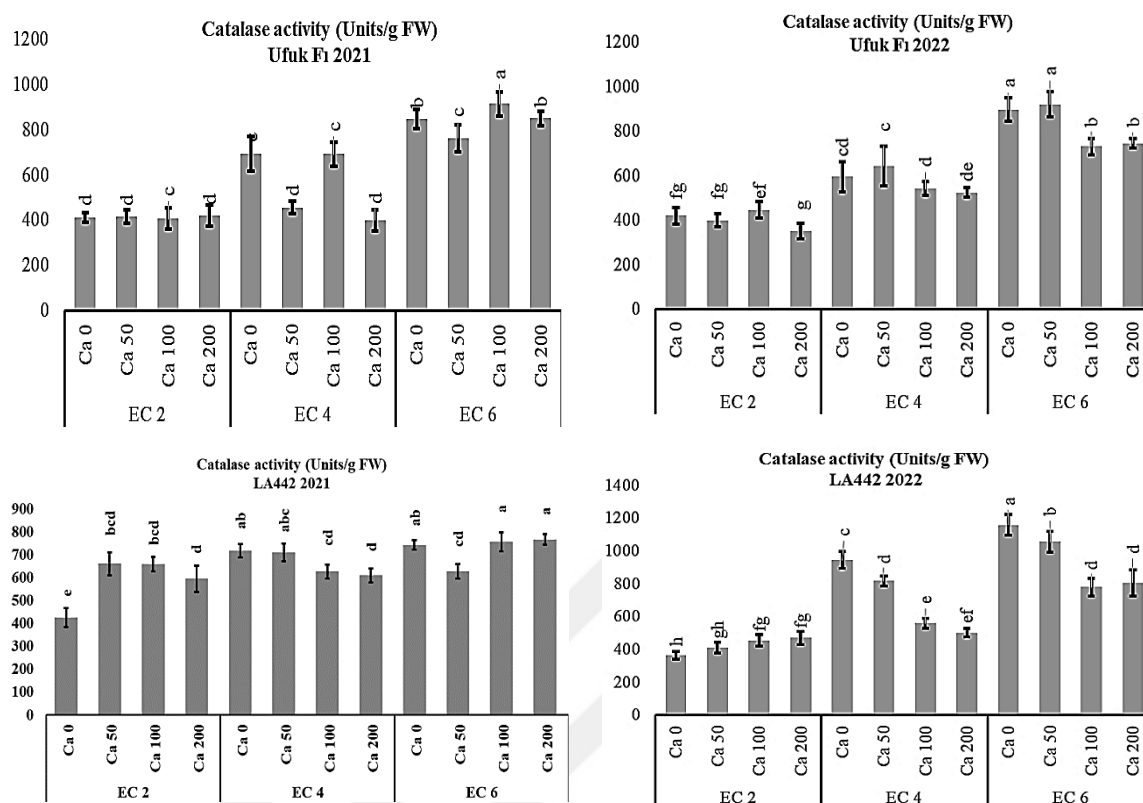
4.19. Catalase Activity (CAT)

The effects of different salinity levels and calcium concentrations had significant effect on CAT (Figure 4.4), in 2021 for Ufuk F₁ variety, the highest recorded value for CAT was 913.71 at EC 6.0 dS/m with 100 ppm calcium. However, the lowest recorded value for CAT was 399.32 at EC of 4.0 dS/m with 200 ppm calcium concentration. The results shows that At EC 2.0 dS/m, increases in calcium concentration did not show a clear pattern affecting CAT values significantly, but In EC 4.0 dS/m, increasing calcium doses led to a sharp drop in CAT values. However, this suggested that while salinity had a positive correlation with CAT values, especially at the EC 6.0 dS/m, calcium did not decrease CAT value in high salinity.

In 2022, the maximum CAT value was registered at 920.12 for an EC 6.0 dS/m when combined with 50 ppm of calcium. Conversely, the lowest CAT measurement recorded was 351.44 at an EC 2.0 dS/m with a calcium concentration of 200 ppm. The results showed that increased calcium reduced the CAT value and calcium had significantly decreased effect salt stress.

In 2021 for LA4442 variety, the highest value of CAT 767.68 was recorded from interaction between 200 ppm calcium and EC 6.0 dS/m. However, lowest value of CAT 425.79 was observed from interaction 0 ppm calcium with EC 2.0 dS/m. Applying calcium increased the CAT value, whether alone or under salt stress. These results were compatible with Mestre et al., (2012) when mentioned that increased calcium doses from 0.1 mM to 1 Mm CAT activated increased significantly. Also, the observed elevation of hydrogen peroxide (H₂O₂) levels in these fruits may be attributed to the inhibition of catalase (CAT) and ascorbate peroxidase (APX) activities. The term "BER" can be understood as the visual expression of extensive lipid peroxidation and membrane breakdown resulting from the oxidative stress observed in the presence of calcium shortage.

In 2022 the maximum CAT 1157.36 was obtained from interaction between 0 ppm calcium and 6.0 dS/m. Conversely, the lowest value of CAT 362.10 was recorded from interaction 0 ppm calcium and 2.0 dS/m. The results showed that under EC (4.0 and 6.0 dS/m), increasing calcium doses from 0 to 200 ppm led to a decline in CAT activity.



Values followed by similar letters are not significantly different at $P \leq 0.05$.

Fig. 4.4. Effect of salinity and Ca treatments on CAT of tomato fruits corresponding to years and genotypes

4.20. Peroxidase Enzyme Activity

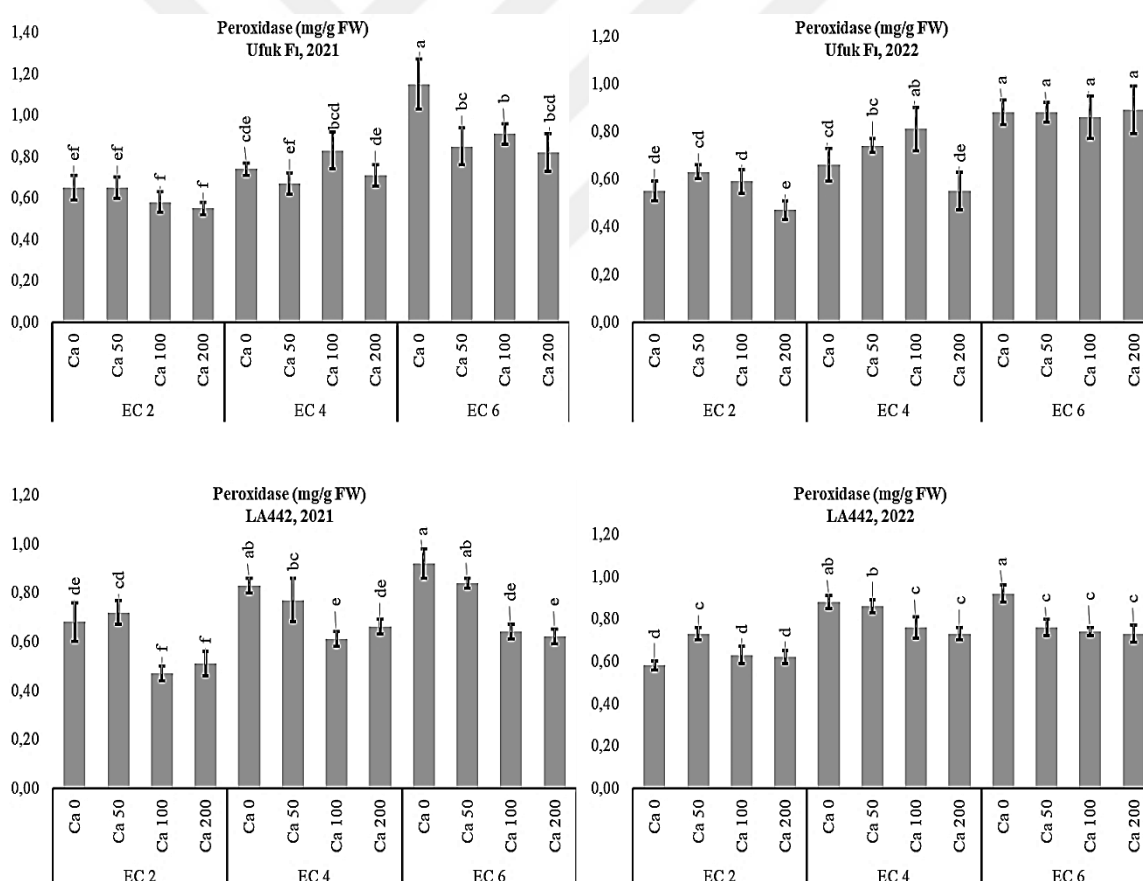
The interaction between calcium and salinity significant effect on POX (Figure 4.5). In 2021 for Ufuk F1, the highest value of POX 1.15 was obtained from interaction 0 ppm calcium and EC 6.0 dS/m. However, the lowest value of POX 0.55 was obtained from interaction 200 ppm calcium and EC 2.0 dS/m.

In 2022, the maximum POX 0.89 was recorded with the combination of 200 ppm calcium and 6.0 dS/m EC. Conversely, the minimum level of POX 0.47 resulted from the combination of 200 ppm calcium and 2.0 dS/m EC.

In 2022 for LA4442 variety, the greatest value of POX 0.92 was observed with the combination of 0 ppm calcium and 6.0 dS/m EC. Conversely, the minimum level of POX 0.47 resulted from the combination of 100 ppm calcium with 2.0 dS/m EC.

In 2022, the peak POX measurement, 0.92, was noted when 0 ppm calcium was paired with EC of 6.0 dS/m. On the flip side, the lowest POX measurement 0.58 was seen when 0 ppm calcium was added with EC of 2.0 dS/m.

In generally, the result showed that higher salinity levels tended to increase POX activity, with the highest enzyme activity having been observed at 6.0 dS/m salinity without calcium addition. Calcium addition seemed to have a less pronounced effect on POX activity, especially at high salinity levels, where the activity remained high regardless of calcium concentration. These results were supported by Jaleel et al., (2007) when mentioned that POX activity escalated in all sections of the plants subjected to both NaCl and CaCl₂ stress, in contrast to the control group. Additionally, plants under combined NaCl and CaCl₂ stress displayed higher POX activity.



Values followed by similar letters are not significantly different at $P \leq 0.05$.

Fig. 4.5. Effect of salinity and Ca treatments on pox of tomato fruits corresponding to years and genotypes

4.21. Ascorbate Peroxidase (APX) Activity

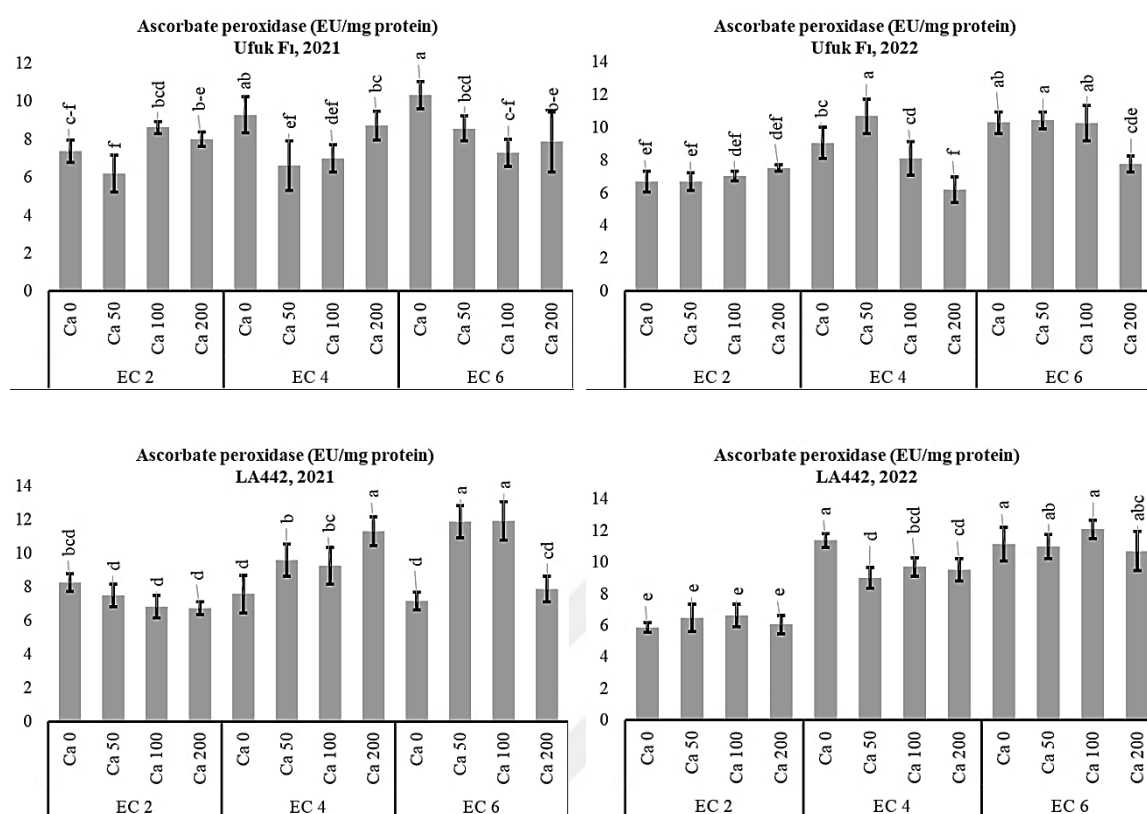
The relationship between calcium levels and salinity on peroxidase (APX) activity had significant relationships (Figur 4.6). In 2021 for Ufuk F₁, the greatest recorded value of APX, 10.33, was associated with the treatment combining 0 ppm calcium and an EC of 6 dS/m. On the other hand, the smallest recorded value of APX, 6.19, was linked to the treatment of 50 ppm calcium with an EC of 2.0 dS/m.

In 2022, the highest level of APX activity, 10.67, was documented when 50 ppm calcium was paired with an EC of 4.0 dS/m. In contrast, the lowest APX activity, again at 6.19, was seen with a higher calcium concentration of 200 ppm at the same EC of 4.0 dS/m.

In 2021 for LA4442, The highest observed APX values were recorded as (11.90 and 12.09 respectively) for EC 6.0 dS/m when it was paired with 50 and 100 ppm of calcium. In contrast, the interaction between 200 ppm calcium and EC of 2.0 dS/m resulted in the lowest observed APX values of (6.72 and 6.05 respectively).

In 2022 the greatest value of APX 12.09 was observed from interaction between calcium 100 EC 6.0 dS/m. In contrast, the minimum value of APX 5.85 was obtained with interaction between 0 ppm calcium and EC 2 dS/m.

In generally, APX activity seemed to be highest at elevated salinity levels without calcium addition. The addition of calcium tended to reduce APX activity at all salinity levels, but the effect was not linear, there were fluctuations in enzyme activity with different calcium concentrations. These findings were in line with Martínez et al., (2020) who found that documented a rise in APX enzyme activity within *S. lycopersicum* fruits and *S. chilense* leaves when subjected to conditions of elevated salinity.



Values followed by similar letters are not significantly different at $P \leq 0.05$.

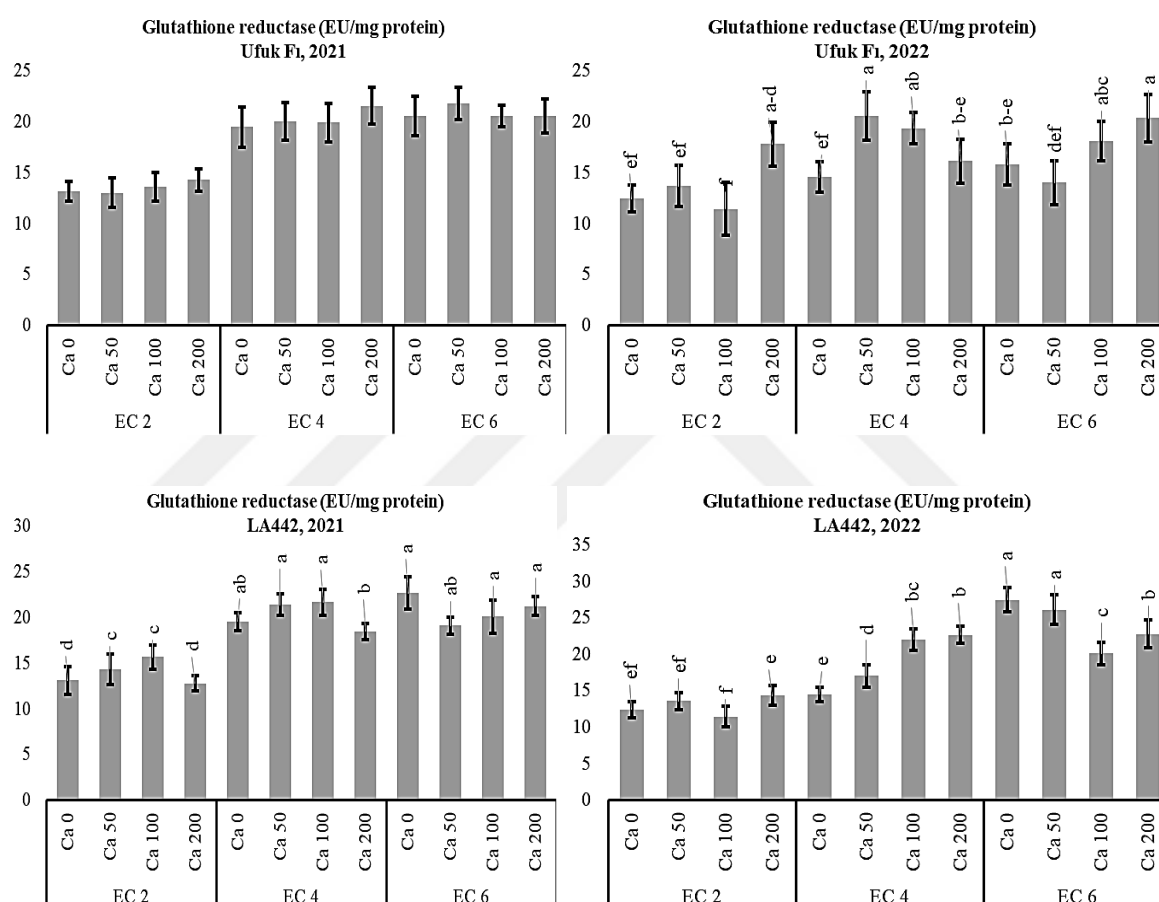
Fig. 4.6. Effect of salinity and Ca treatments on APX of tomato fruits corresponding to years and genotypes

4.22. Glutathione Reductase (GR) Activity

The calcium, salinity and interaction between salinity and calcium had significant effect on GR (Figure 4.7) For Ufuk F₁ variety in 2021, the interaction between calcium and salinity had no significant effect on GR.

In 2022, the maximum GR value was registered at 0.55 for EC 4.0 dS/m when combined with 50 ppm of calcium. Conversely, the lowest GR 11.44 was recorded from interaction between 100 ppm calcium with EC 2.0 dS/m. In 2021 and 2022 years for LA4442, the highest value of GR 22.67 and 27.47 were observed from interaction between 0 ppm calcium and EC 6.0 dS/m. However, in 2021 the minimum GR 12.78 was obtained from interaction between calcium 200 ppm and EC 2.0 dS/m. Conversely, in 2022, the minimum GR 11.44 was recorded from interaction between 100 ppm calcium with EC 2.0 dS/m. In 2021 and 2022 years, for LA4442 variety, the results showed that under EC 6.0 dS/m, increasing calcium doses led to a decrease in GR

activity. Additionally, GR activity increased with higher levels of salt. Jaleel et al., (2008) noted that the combined application of NaCl and CaCl₂ enhanced the activity of antioxidant enzymes and that CaCl₂ partially mitigated the oxidative stress induced by salinity. Murshed et al., (2014) Findings from this study indicate that treatments involving salt stress altered the activity of GR.



Values followed by similar letters are not significantly different at $P \leq 0.05$.

Fig. 4.7. Effect of salinity and Ca treatments on GR of tomato fruits corresponding to years and genotypes

4.23. Determination of Lipid Peroxidation Amount (MDA)

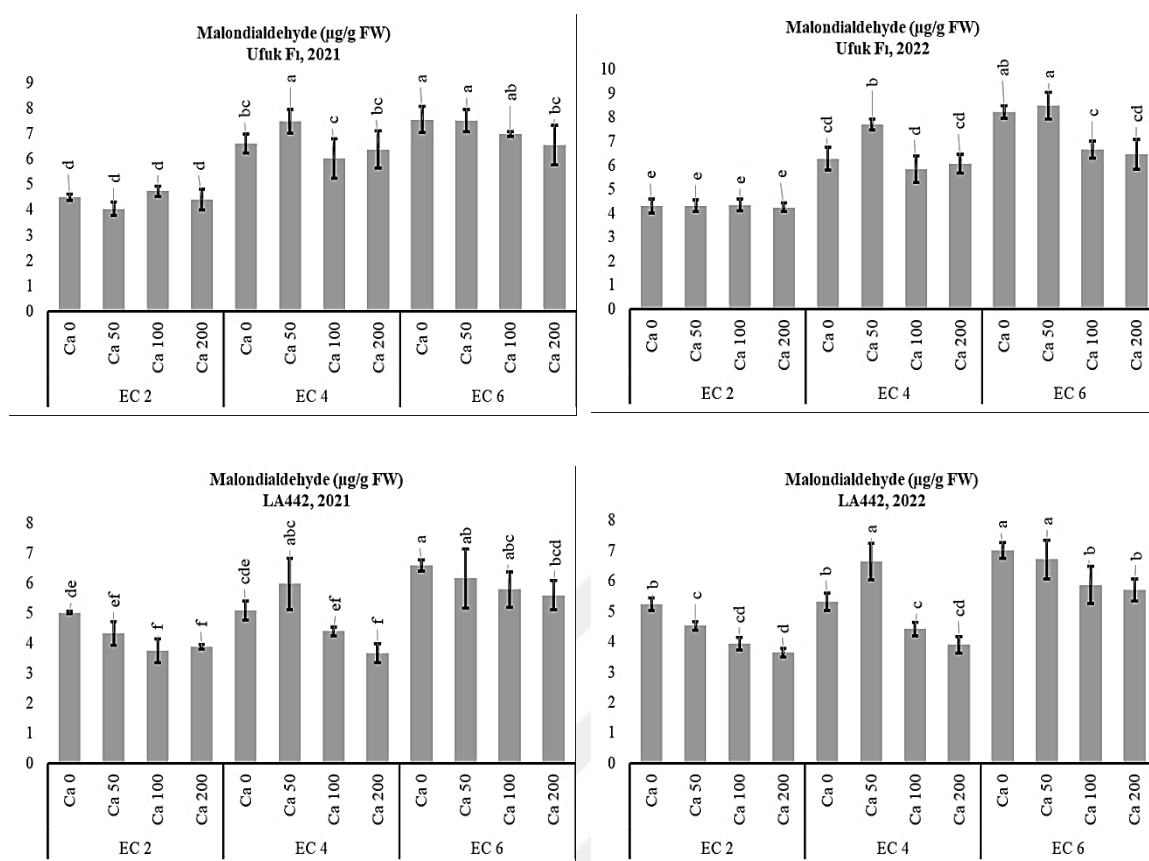
Calcium and salinity levels, as well as their combined interaction, had significantly influence the MDA. (Figure4.8). The highest value of MDA 7.55 was recorded from

interaction between 0 ppm calcium and EC 6.0 dS/m. Conversely, the lowest value of MDA 4.03 was observed from interaction between 50 ppm calcium and EC 2.0 dS/m.

In 2022, the maximum MDA 8.48 was obtained from interaction between 50 ppm calcium and EC 6.0 dS/m. However, the minimum MDA 4.23 was obtained from interaction between 200 ppm calcium and EC 2.0 dS/m.

In 2021 and 2022 years for LA4442 variety, the greatest values of MDA (6.60 and 7.00 respectively) were observed from interaction between 0 ppm calcium and EC 6.0. In contrast, in 2021, the minimum MDA 3.67 was found between interaction of 200 calcium and EC 4.0 dS/m. Conversely, in 2022, the lowest value of MDA 3.64 from interaction between 200 ppm calcium and EC 2.0.

MDA is an intermediate product in the oxidation reactions of cell membrane lipids and used in salt stress studies to determine the degree of stress damage (Gossett et al., 1994). The results showed that, in 2021 and 2022 years, for Ufuk F₁ variety, in EC 4.0 dS/m calcium decreased MAD, However in EC 6.0 dS/m increased calcium doses dropped MDA activity in fruit. In 2021 and 2022, for LA4442 variety, calcium seemed to help reduce MDA levels at lower salinities, its effectiveness diminished as salinity increased, and at high salinity levels, the impact of calcium on MDA was less. Martínez et al., (2020) found that elevating salinity levels from 40 to 80 mM resulted in higher salinity within tomato fruits. Additionally, the MDA levels were significantly elevated when NaCl was present compared to the control conditions. These results agreed with Ahmad, (2018) found that the supplementation of calcium was effective in reducing the accumulation of proline and MDA content by improving the activity of antioxidants.



Values followed by similar letters are not significantly different at $P \leq 0.05$.

Fig. 4.8. Effect of salinity and Ca treatments on GR of tomato fruits corresponding to years and genotypes

5. CONCLUSIONS AND RECOMMENDATIONS

Based on the outcomes discussed, it can be deduced that the effects of calcium doses and salt stress levels on the yield of two tomato varieties, LA4442 and Ufuk F₁. It was found that the highest marketable fruit yield and marketable fruit number were achieved with 200 ppm calcium and EC 2.0 dS/m, both in 2021 and 2022. Conversely, the lowest marketable fruit yield and marketable fruit number were observed with 0 ppm calcium and an EC of 6.0 dS/m. The study indicates that increasing calcium levels can mitigate the negative effects of salinity on both the marketable fruit yield and marketable fruit number. Similarly, marketable fruit weight was also significantly influenced by the interaction of salinity and calcium levels, with the highest marketable fruit weight recorded at 200 ppm calcium and EC 2.0 dS/m, and the lowest at 0 ppm calcium and EC 6.0 dS/m. The results suggest that calcium application is beneficial in reducing the impact of salt stress on tomato fruit yield, number, and weight. The study reveals that the total yield of tomato plants was significantly influenced by salinity and calcium doses in 2021 and 2022. The highest total yield was obtained when combined with 200 ppm calcium and EC 2.0 dS/m. In the study, the interaction between salinity and calcium doses significantly impacted the total fruit number in tomato genotypes. The LA4442 variety showed a gradual increase in fruit number with increasing calcium doses. However, the lowest fruit number was recorded in 2021 with a combination of 100 ppm calcium and EC 2.0 dS/m, and in 2022 with EC 2.0 dS/m and calcium 0 ppm. At EC 6.0 dS/m, calcium doses did not significantly affect fruit number. The Ufuk F₁ variety also showed a maximum fruit number in 2021 and 2022 with the interaction of 200 ppm calcium and EC 2.0 dS/m. At EC 6.0 dS/m, calcium doses did not significantly affect fruit number. In 2022, for the LA4442 variety, the highest values of fruit dry weight and leaf dry weight were recorded from interaction between 200 ppm calcium and 6.0 dS/m. In contrast, under EC 2.0 dS/m with 200 ppm calcium, there was a decline. For the Ufuk F₁ variety in the same year, EC 2.0 dS/m with 200 ppm calcium doses led to an increase in fruit dry weight and leaf dry weight. Conversely, the absence of calcium and EC 6.0 dS/m resulted in a decrease in both fruit dry weight and leaf dry weight. In 2021 and 2022, for both genotypes, Blossom end rot declined with increased calcium doses from 0 to 200 ppm in both saline and non-saline conditions. The highest

Blossom end rot was obtained from interaction between 0 ppm calcium and EC 6.0 dS/m. However, the lowest value of Blossom end rod was recorded from interaction between 200 ppm calcium and 2.0 dS/m. The electrical conductivity of fruit juice is significantly influenced by the interaction between calcium doses and salinity. Salinity significantly impacted the electrical conductivity of fruits juice, with higher levels of NaCl increasing conductivity but diminishing it when calcium was applied. While the pH content of the fruit juice did not change according to genotypes and years, there was no significant difference according to salt stress and calcium doses. Titratable acidity was not significantly influenced by the interaction of calcium and salinity. There was an increase in titratable acidity with salt concentration in the LA4442 variety, but not in the Ufuk F₁ variety, in both years. As a result, increased salinity led to increase titratable acidity, but the increase in calcium doses had a reducing effect. While, the pH content of the fruit juice did not change according to genotypes and years. In 2021, the highest Brix was obtained from 0 ppm calcium and EC 6.0 dS/m interaction. The lowest Brix was obtained from 200 ppm calcium and EC 2.0 dS/m interaction. Increased salt levels can be attributed to an increase in total soluble solids. However, in 2022, there was no significant difference between the effects of calcium and salt, and increased salinity did not impact the overall concentration of soluble solids. Elevation in salinity levels leads to a proportional increase in the overall concentration of soluble solids, thus mitigating crop productivity decline. Although it varies according to years and genotypes, calcium and salt stress applications caused significantly changes in leaf chlorophyll content. Leaf chlorophyll content increased with increasing calcium doses. However, leaf chlorophyll content decreased with increasing salt stress. While the highest chlorophyll content was obtained from 200 ppm Ca applications, the lowest chlorophyll content was obtained from 6 dS/m EC applications. The results suggest that calcium has a substantial effect on leaf chlorophyll content, and elevated levels of calcium reduce salinity's impact on leaf chlorophyll content. Elevated levels of calcium led to a reduction in salinity's impact on leaf chlorophyll content. Accumulation of micronutrients in tomato leaves varied according to the years, genotypes, applications and micronutrients. Fe accumulation was significantly affected by the applications. Leaf Fe content decreased with increasing Ca concentration and EC level. A significant relationship was not found between leaf Cu content and Ca and salt stress. Leaf Cu

content acted independently of salt and Ca applications. The amount of Zn was affected by Ca and salt stress applications. The highest Zn accumulation was recorded in 100 ppm Ca and EC 2.0 – 4.0 dS/m applications. Mn accumulation in the leaf varied according to years and genotypes, and generally 50-100 ppm Ca doses and EC 2.0 dS/m gave the best results. While P accumulation in tomato leaves was not affected by salt concentration, it was affected by Ca doses. In general, the highest P accumulation occurred at 100 ppm Ca doses, P accumulation was minimal at 200 ppm Ca dose. Significant relationship was not found between salt stress and P accumulation. Leaf K content was significantly affected by salt and calcium applications. Increasing Ca dose from 0 to 100 ppm also increased K accumulation, and K accumulation decreased with 200 ppm Ca application. Significant relationship was not found between salt concentration and K accumulation, and different responses occurred according to years and genotypes. Calcium accumulation in tomato leaves was significantly affected by both salt stress and Ca doses. Nonetheless, increasing salt concentration reduced calcium accumulation (especially 6.0 dS/m EC application), leaf Ca content also increased as calcium doses increased. Under high salt stress, high doses of calcium prevented the decrease in leaf Ca content. As a result, giving high doses of Ca (200 ppm) to tomato plants under salt stress provides sufficient Ca accumulation in the plant. Differences between leaf Mg content with salt stress and calcium applications resulted in different effects depending on genotypes and years. Whereas Mg accumulation in leaves was not affected by salt stress, Mg accumulation increased at low Ca doses (0 and 50 ppm). Mg accumulation was lower at 100 and 200 ppm calcium doses. Leaf Na content was significantly affected by salt and Ca applications. While Na accumulation increased at 0-100 ppm calcium doses, Na accumulation decreased at 200 ppm Ca application. However, increasing NaCl doses significantly increased Na accumulation in the leaf. The accumulation of calcium in the fruit tip, which is the principal cause of blossom end rot in tomatoes, was significantly affected by both calcium applications and salt stress. The quantity of calcium at the tip of the fruit increase as the amount of calcium provided to the plant increased. The calcium accumulation in the fruit's tip decreased as the saline level increased. A high dose of calcium (200 ppm) was effective in preventing a decrease in calcium at the fruit tip under high salt stress conditions (EC 6.0 dS/m). In the experiment, while fruit firmness was mainly affected by calcium, the

effect of salt stress on fruit firmness was slight. As the calcium dose increased, fruit firmness increased significantly. High calcium doses contributed to a further increase in fruit firmness at high salt concentrations. Calcium plays an important role in fruit firmness. Vitamin C of tomato fruits was significantly affected by salt stress and calcium applications. Conversely, the effect of calcium was more effective than salt stress. The highest vitamin C was achieved at 200 ppm Ca dose in all applications. While the effect of salt concentrations on vitamin C was not significant in the Ufuk F1 genotype, increasing salt stress caused an increase in vitamin C in the LA4442 genotype. As a result, a significant correlation was found between vitamin C and Ca in tomatoes, and as the calcium doses increased, vitamin C also increased. The interaction of calcium and salinity, along with their individual presence, substantially influenced the sodium levels in colour parameters of tomato fruits. For both genotypes in the years 2021 and 2022, the results showed that as calcium levels increased, there tended to be a slight increase in L* value, which suggested that the fruit became lighter. However, this trend was not consistent across all levels of salinity and varied from year to year. The a* value, indicating red to green, generally increased with higher calcium levels. This could suggest that an increase in calcium might have correlated with a redder hue in the fruit. Conversely, at higher salinity levels (6.0 dS/m), there is a general increase in b* value with increasing Ca, particularly noticeable in 2022, which could indicate that more Ca at higher salinity may lead to a yellower fruit. A significant effect was determined between catalase activity and salt stress in tomato fruits.

In the study, salinity stress increased the stress enzymes in tomato fruit. A significant effect was determined between catalase activity and salt stress in tomato fruits. Increased salt stress caused a significant increase in CAT activity. CAT and POX activities were lower at high calcium doses. While, the increase in salt concentration from 2.0 dS/m to 4.0 dS/m caused a significant increase in ascorbate peroxidase in fruits, the increase in APX slowed down when the salt concentration increased from 4.0 dS/m to 6.0 dS/m under high calcium doses. However, a significant increase in APX was observed in fruits under salt stress. Ascorbate peroxidase level in fruits acted independently of calcium doses. Glutathione reductase enzyme was significantly affected by salt stress. Significant relationships were not found regarding the effect of calcium doses. When the salt stress increased, glutathione reductase accumulation in

fruits also increased. In the experiment, increasing salt concentration significantly increased malondialdehyde accumulation in tomato fruits. As the salt concentration increased, the amount of malondialdehyde also increased. However, especially in cases where salt concentration is high, 100 and 200 ppm doses of calcium reduced the amount of malondialdehyde.

Considering the observations applied in the experiment as a whole, when the salt concentration of irrigation water in tomato cultivation in soilless agriculture increases to 4.0 dS/m and above, plant development, productivity and quality begin to decrease. In addition, very high yield losses due to blossom end rot occur at EC doses of 4.0 and 6 dS/m. Blossom end rot, which occurs at high salt concentrations, has been the main cause of yield loss. Under high salt stress, giving the plants more than the required dose of Ca significantly reduced the negative effects of salt stress. As a result, giving more calcium to plants in cases where salt concentration was significantly reduced the negative effects of salt stress and contributed to improvements in plant development and quality.

6. REFERENCES

- Abbasi, N. A., Zafar, L., Khan, H. A., and Qureshi, A. A. 2021. Effects of naphthalene acetic acid and calcium chloride application on nutrient uptake, growth, yield, and postharvest performance of tomato fruit. *Pak. J. Bot.*, 45, 1581–1587.
- Abdelhameed, A., El-Hady, A., and others. 2018. Response of tomato plant to foliar application of calcium and potassium nitrate integrated with different phosphorus rates under sandy soil conditions. *Egyptian Journal of Soil Science*, 58(1), 45–55.
- Adams, P. 1990. Effect of salinity on the distribution of calcium in tomato (*Lycopersicon esculentum*) fruit and leaves. In *Plant Nutrition—Physiology and Applications* (pp. 473–476). Springer.
- Adams, P. & Ho, L. 1993. Effects of environment on the uptake and distribution of calcium in tomato and on the incidence of blossom-end rot. *Plant Soil* 154, 127–132.
- Adams, P., and Ho, L., C. 1989. Effects of constant and fluctuating salinity on the yield, quality and calcium status of tomato. *J. Horti. Sci.*, 64: 725–732.
- Adilu, G., S., and Gebre, Y., G. 2021. Effect of salinity on seed germination of some tomato (*Lycopersicon esculentum* Mill.) varieties. *Journal of Aridland Agriculture*, 7, 76–82.
- Aghofack-Nguemezi, J., Tatchago, V., and others. 2010. Effects of fertilizers containing calcium and/or magnesium on the growth, development of plants and the quality of tomato fruits in the western highlands of Cameroon. *International Journal of Agricultural Research*, 5(10), 821–831.
- Agius, C., von Tucher, S., and Rozhon, W. 2022. The effect of salinity on fruit quality and yield of cherry tomato. *Horticulturae*, 8(1). 59.
- Ahmad, N. U. R. F. B. 2018. Use of Calcium Sulphate in Alleviating Salinity Effects in Tomato (*Lycopersicon esculentum* Mill.). Universiti Putra Malaysia, in fulfilment of the requirements for the degree of Master of Science.
- Ahmed, N., Mahmud, N., Zaman, M. A., Ferdous, Z., & Halder, S. 2017. Effect of Different Salinity Level on Tomato (*Lycopersicon esculentum*) Production under Climate Change Condition in Bangladesh. *Annual Research & Review in Biology*, 13(3), 1–9.
- Aişe, D., Erdal, S. and Elif, D. S. 2014. Çiçek Burnu Çürüklüğü ve Oluşum Nedenleri. GAP Tarımsal Araştırma Enstitüsü Müdürlüğü, Şanlıurfa Harran Üniversitesi Ziraat Fakültesi Toprak Bilimi ve Bitki Besleme Bölümü, Şanlıurfa. Sayı: 361.
- Aktas, H., Karni, L., Chang, D. C., Turhan, E., Bar-Tal, A., and Aloni, B. 2005. The suppression of salinity-associated oxygen radicals production in pepper (*Capsicum annuum*) fruit by manganese, zinc and calcium in relation to its sensitivity to blossom-end rot. *Physiologia Plantarum* 123.
- Alam, S., N. 1999. Nutrient uptake by plants under stress conditions. In: *Handbook of Plant and Crop Stress*, ed. M. Pessarakli, pp. 227–243. New York: Marcel Dekker.
- Al-Bayati, A. S., and Majeed, H. H. 2022. Response of Tomato (*Lycopersicon esculentum*) to NP Organic Fertilizer (Rich in Phosphorus) and Calcium. *SABRAO Journal of Breeding and Genetics*, 54(5), 1223–1230.
- Ali, M. Y., Sina, A. A. I., Khandker, S. S., Neesa, L., Tanvir, E. M., Kabir, A., Khalil, M. I., and Gan, S. H. 2020. Nutritional composition and bioactive compounds in tomato and their impact on human health and disease: A review. *Foods*, 10(1), 45.

- Ananthanarayana, R., & Hanumantharaju, T. H. 1992. Interactions of Ca and Mg with other plant nutrients. In H. L. S. Tandon (Ed.).
- Anil, A. S., Sharma, V. K., Barman, M., Datta, S. P., Bandyopadhyay, K. K., Singh, P. K., and Chobhe, K. A. 2020. Effect of calcium and boron on biomass yield and nutrients uptake by tomato (*Solanum lycopersicum*). *Indian Journal of Agricultural Sciences*, 90(6). 1176–1179.
- Anjum, S., Hamid, A., Ghafoor, A., Tahira, R., Shah, S. Z. A., Awan, S. I., Ahmad, K. S. 2020. Evaluation of biochemical potential in tomato (*Solanum lycopersicum*) germplasms. *Pak. J. Agric. Sci.* 57, 177–187.
- Anonim, 2021. Tarım Ürünleri Piyasalar. <https://arastirma.tarimorman.gov.tr>.
- Anonymous, 2021. Tomato production. <https://www.fao.org/faostat/en/#data/QCL>.
- Armstrong, M. J., and Kirkby, E. A. 1979. Estimation of potassium recirculation in tomato plants by comparison of the rates of potassium and calcium accumulation in the tops with their fluxes in the xylem stream. *Plant Physiology*, 63(6), 1143–1148.
- Ashraf, M. I., Sajad, S., Hussain, B., Sajjad, M., Adnan, M., and Ismail, M. 2018. Foliar Application Effect of Boron, Calcium and Nitrogen on Vegetative and Reproductive Attributes of Tomato (*Solanum lycopersicum* L.). *J. Agri. Sci. Food Res.* 9, 1.
- Assunção, N. S., Silva, N. O., Fernandes, F. L., Aquino, L. A., and Fernandes, M. E. 2020. Physico-chemical characteristics and productivity of tomato plants in function of nitrogen sources and doses. *Biosci. j.(Online)*. 1274–1282.
- Atanasoff, D. 1934. Is bitter pit of apples a virus? *Journal of Phytopathology* 13, 1–8.
- Azaizah, H., Gunse, B., and Steudle, E. 1992. Effects of NaCl and CaCl₂ on water transport across root cells of maize (*Zea mays* L.) seedlings. *Plant Physiology* 99: 886–894.
- Barker, A.V., Ready, K. M. 1994. Ethylene evolution by tomato stressed by ammonium nutrition. *J. Am. Soc. Hort. Sci.* 119, 706–710.
- Barman, M., Shukla, L. M, Datta, S. P., and Rattan, R. K. 2014. Effect of applied lime and boron on the availability of nutrients in an acid soil. *Journal of Plant Nutrition* 37(3): 357-73.
- Bar-Tal, A., and Pressman, E. 1996. Root restriction and potassium and calcium solution concentrations affect dry-matter production, cation uptake, and blossom-end rot in greenhouse tomato. *Journal of the American Society for Horticultural Science*, 121(4), 649–655.
- Batey, T. 1971. Manganese and boron deficiency. Trace elements in soils and crops. Technical Bulletin, 21. Her Majesty's Stationary Office, London, pp: 137-148.
- Beckles, D. M. 2012. Factors affecting the postharvest soluble solids and sugar content of tomato (*Solanum lycopersicum* L.) fruit. *Postharvest Biology and Technology* 63: 129–140.
- Bergmann, W. 1992. Nutritional Disorders of Plants: Development, Visual and Analytical Diagnosis. Gustav Fischer Verlag, Jena, Germany.
- Bhattarai, D. R., and Gautam, D. M. 2006. Effect of harvesting method and calcium on postharvest physiology of tomato. *Nepal Agric. Res. J.* 7, 37-41.
- Bielinski, S., McAvoy, E., Ozores-Hampton, M., Vallad, G., Dittmar, P., Susan W., Smith, H., and Olson, S. 2014. “Chapter 12. Tomato Production.” IFAS Extension University of Florida. IFAS Extension, 2013. Web. 26 Aug.

- Binti ahmad, N. F. 2018. Use of calcium sulphate in alleviating salinity effects in tomato (*Lycopersicon esculentum* Mill.). Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science.
- Birgin, Ö., Akhoundnejad, Y., and Dasgan, H., Y. 2021. The effect of foliar calcium application in tomato (*solanum lycopersicum* L.) under drought stress in greenhouse conditions. *Applied Ecology and Environmental Research*, 19(4), 2971–2982.
- Bolarin, M. C., Cuartero, E. G., Cruz, V., and Cuartero, J. 1993. Salinity tolerance in four wild tomato species using vegetative yield-salinity response curves. *J. Am. Soc. Hort. Sci.* 116: 286-290.
- Bonomelli, C., de Freitas, S. T., Aguilera, C., Palma, C., Garay, R., Dides, M., Brossard, N., & Brien, J. A. 2021. Ammonium Excess Leads to Ca Restrictions, Morphological Changes, and Nutritional Imbalances in Tomato Plants, Which Can Be Monitored by the N/Ca Ratio. *Agronomy*, 11(7), 1437.
- Boone, R. S., Sams, C. E., and Conway, W. S. 1997. Yield and Disease Resistance of Six Tomato Cultivars Grown in Two Media and Three Calcium Concentrations. *HortScience*, 32(3), 470B--470.
- Borkowski, J. (1983). Study on the calcium uptake dynamic by tomato fruits and blossom-end rot control. *Symposium on the Use of Fertilizers in Protected Vegetable Production* 145, 222–229.
- Bramlage, W. J., and Weis, S. A. 2004. Postharvest fruit quality and storage life in relation to mineral nutrients. *New York State Fruit Quarterly* 12, 11–12.
- Brooks, C. 1914. Blossom-end rot of tomato. *Phytopathology* 4, 345–374.
- Buczek, J., & Leonowicz-Babiak, K. 1971. The effects of calcium to magnesium ratio on the increments of dry weight and protein content in tomato. *Acta Societatis Botanicorum Poloniae*, 40(4), 557–567.
- Bush, D. S. 1995. Calcium regulation in plant cells and its role in signaling. *Annu. Rev. Plant Physiol. Plant Mol. Biol.* 46, 95-122.
- Cakmak, I., and Romheld, V. 1977. Boron deficiency-induced impairments of cellular functions in plants. *Plant and Soil* 193, 71–83.
- Çakmak, I., Atli, M., Kaya, R., Evliya, H., Marschner, H. 1994. Association of High Light and Zinc Deficiency in Cold-Induced Leaf Chlorosis in Grapefruit and Mandarin Trees. *J. Plant Physiol.*, 146: 355-360.
- Cakmak, I., Marschner, H. 1992. Magnesium Defficiency and Hilight Intensity Enhance Activities of Superoxide Dismutase, Ascorbate Peroxidase and Glutathione Reductase in Bean Leaves. *Plant Physiol.*, 98:1222-1226.
- Carne, W. M., and Martin, D. 1934. Apple investigations in Tasmania. Miscellaneous notes, I.I. Virus theory of bitter pit. *Bulletin of CSIRO [Australia]* 7, 203–214.
- Carvajal, M., Martinez, V., and Cerda, A. 1999. Influence of magnesium and salinity on tomato plants grown in hydroponic culture. *Journal of Plant Nutrition*, 22, 177-190.
- Charles, W. A., and Shomakher, P. B. 2005. Blossom-end rot of tomato, pepper and watermelon. *Plant Pathology Extension*. North Carolina State University Publication. College of Agriculture and Life Sciences.
- Chiu, T. E., and Bould, C. 1977. Sand-culture studies on the calcium nutrition of young apple trees with particular reference to bitter pit. *Journal of Horticultural Science* 52, 19–28.

- Çiçek, N. and Çakırlar, H. 2002. The effect of salinity on some physiological parameters in two maize cultivars, *Bulg. J. Plant physiol.* 28(1–2): 66–74.
- Cramer, G. R. 2002. Sodium-calcium interactions under salinity stress. In *Salinity. Environment-Plants-Molecules*, eds. A. L'äuchli, and U. L'üttge, pp. 205–227: Dordrecht, the Netherlands: Kluwer.
- Cruz, V., and Cuartero, J. 1990. Effect of salinity at several developmental stages of six genotypes of tomato (*Lycopersicon spp*). In: Cuartero J., Gomez-Guillamon M., Fernandez-Munoz R. Edition, Malaga, Spain, 81-86.
- Cuartero, J., & Fernández-Muñoz, R. (1998). Tomato and salinity. *Scientia Horticulturae*, 78(1–4), 83–125.
- Cuartero, J. R., and Fernandez, M. 1999. Tomato and salinity. *Sci. Hortic.* 78:83-125.
- Cuartero, J., Soria, T., 1997. Productividad de tomates cultivados en condiciones salinas. *Actas de Horticultura* 16, 214±221.
- Dasgan, H. Y., Aktas, H., Abak, K., & Cakmak, I. 2002. Determination of screening techniques to salinity tolerance in tomatoes and investigation of genotype responses. *Plant Science*, 163(4), 695–703.
- Davenport, R., James, R. A., Zakrisson-Plogander, A., Tester, M., and Munns, R. . 2005. Control of sodium transport in durum wheat. *Plant Physiology* 137: 807–818.
- De Freitas, S. T., Amarante ,C. V. T., Labavitch, J. M., and Mitcham, E. 2010. Cellular approach to understand bitter pit development in apple fruit. *Postharvest Biology and Technology* 57, 6–13.
- Dekock, P. C., Hall, A., Inkson, R. H. E., & Alan Robertson, R. 1979. Blossom-end rot in tomato. *Journal of the Science of Food and Agriculture*, 30(5), 508–514.
- Dela-Fuente, R. K., Tang, P. M., and Guzman, C. C. 1986. Pant growth substances, 1985: Plant-environment interactions. Wilkinsin, R.E. (Ed.). Proceedings of the 12th International Conference on Plant Growth Substances, August 26-31, 1985, Madison Avenue, New York, USA., pp: 227.
- Dilmaçınal, T., Koyuncu, M. A., Aktaş, H. ve Bayindir, D. 2011. The effects of several postharvest treatments on shelf life quality of bunch tomatoes. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 39(2), 209-213.
- Dorais, M., Dorval, R., Demers, D., Micevic, D., Turcotte, G., Hao, X., Papadopoulos, A. P., Ehret, D. L., & Gosselin, A. 1998. Improving tomato fruit quality by increasing salinity: effects on ion uptake, growth and yield. XXV International Horticultural Congress, Part 1: Culture Techniques with Special Emphasis on Environmental Implications- 511, 185–196.
- Dorais, M., Papadopoulos, A. P., and Gosselin, A. 2001. Influence of electric conductivity management on greenhouse tomato yield and fruit quality. *Agronomie* 21:367-383.
- Durukan, H., & Demirbas, A. 2018. The effects of different salt doses on yield and nutrient uptake of tomato plant. *Sci. Pap. Ser. A Agron*, 61(1), 71–76.
- Ebert, G., Eberle, J., Ali-Dinar, H., and Ludders, P. 2002. Ameliorating effects of Ca (NO₃)₂ on growth, mineral uptake and photosynthesis of NaCl stressed guava seedlings (*Psidium guajava* L.). *Sci Hort.*;93:125-135.
- Ehret, 1986. Translocation of calcium in relation to tomato fruit growth. *Ann Bot* 58: 679–688.
- Ehret, D. L., Ho, L. C. 1986. The effects of salinity on dry matter partitioning and fruit growth in tomato grown in nutrient film culture. *J. Horti. Sci.* 61, 361±367.

- Ekinci, M., ESR.,İNGÜ, A., Dursun, A., Yildirim, E., Turan, M., Karaman, M. R., & Arjumend, T. 2015. Growth, yield, and calcium and boron uptake of tomato (*Lycopersicon esculentum* L.) and cucumber (*Cucumis sativus* L.) asaffected by calcium and boron humate application in greenhouse conditions. *Turkish Journal of Agriculture and Forestry*, 39(5), 613–632.
- El Habbasha, S. F., and Ibrahim, F. M. 2015. Calcium: Physiological Function, Deficiency and Absorption. *Int.J. ChemTech Res.* 2015,8 (12),pp 196-202.
- El-Enany, A. E. 2001. Calcium enhancement of shoot organogenesis in salinity-stressed tomato explants. *Acta Agronomica Hungarica*, 49(1), 35–42.
- El-Mogy, M. M., Garchery, C., & Stevens, R. 2018. Irrigation with salt water affects growth, yield, fruit quality, storability and marker-gene expression in cherry tomato Section B Soil and plant science.
- FAOSTAT, 2017. *Food and Agricultural Organization of the United Nations. Statistical Databases*, at <http://www.fao.org>
- Farahani, H., Valadabadi S., Khalvati, M. 2009. interactive effects of P supply and drought on root growth of the mycorrhizal coriander (*Coriandrum sativum* l.). *J Plant breed Crop Sci* 1(5):217–222.
- Fawzy, Z. F., & others. 2019. Adverse positive effect of salinity stress on tomato fruit quality. *Acta Scientific Agriculture*, 3, 66–69.
- Forghani, A., Forghani, A. H., Altafi, M., Hashemi Majd, K., & Sofalian, O. 2021. The effects of different sources of potassium and calcium on yield and ionic balance of tomato under salinity stress in hydroponic cultivation. *Nova Biologica Reperta*, 8(3), 206–219.
- Fouda, K. F., El-Hadidi, E. M., El-Shazly, M. M., & Hegazy, H. M. 2020. Interaction effect of compost, boron and phosphorien on tomato quality and yield. *Plant Archives*, 20(1), 1509–1515.
- Francois, L. E., and Maas, E. V. 1993. Crop response and management on salt-affected soils. In: M. Pessarakli (ed). *Handbook of plant and Crop stress*.Marcel Dekker. Inc., pp: 149-181.
- Freitas, S. T., Handa, A. K., Wu, Q., Park, S., and Mitcham, E. J. 2012. Role of pectin methylesterase in cellular calcium distribution and blossom-end rot development in tomato fruit. *Plant Journal* 71, 824–835.
- Ganeshamurthy, A. N., Kalaivanan, D., & Satisha, G. C. 2016. Management of vegetable crops in acid soils of India. *Innovations in Horticultural Sciences*, 559–584.
- Gerçekcioğlu, R., Asarkaya, U., and Özatasever, Ö. 2019. Ziraat'kiraz Çeşidinde Bor Uygulamasının Verim ve Meyve Kalitesine Etkisi. *Gaziosmanpaşa Bilimsel Araştırma Dergisi*, 8(3), 120-129.
- Gholamnejad, S., Haghighi, M., Etemadi, N., & Shariatmadari, H. 2020. Fortification of tomato with Ca and its effects on the fruit quality, calcium status and nutraceutical values of tomato in different NO₃: NH₄ ratios. *New Zealand Journal of Crop and Horticultural Science*, 48(4), 228–243.
- Ghoname, A., El-Bassiouny, A. M., Abdel-Mawgoud, A. M. R., El-Tohamy, W. A., & Gruda, N. 2012. Growth, Yield and Blossom-End Rot Incidence in Bell Pepper as Affected by Phosphorus Level and Amino Acid Applications. *Gesunde Pflanzen*, 64(1).
- Gillaspy, G., Ben-David, H., and Gruissem, W. 1993. Fruits: a developmental perspective. *Plant Cell* 5, 1439–1451.

- Giuffrida, F., Cassaniti, C., Malvuccio, A., & Leonardi, C. 2017. Effects of salt stress imposed during two growth phases on cauliflower production and quality. *Journal of the Science of Food and Agriculture*, 97(5), 1552–1560.
- Giuffrida, F., Martorana, M., Leonardi, C. 2009. How sodium chloride concentration in the nutrient solution influences the mineral composition of tomato leaves and fruits. *HortScience*, 44, 707–711.
- Gossett, D.R., Millhollon, E.P., Lucas, M.C. 1994. Antioxidant response to NaCl stress in salt tolerant and salt sensitive cultivars of cotton. *Crop Sci.* 34: 706-714.
- Grabarek, Z. 2011. Insights into modulation of calcium signaling by magnesium in calmodulin, troponin C and related EF-hand proteins. *Biochimica et Biophysica Acta (BBA)-Molecular Cell Research*, 1813(5), 913–921.
- Gransee, A., & Führs, H. 2013. Magnesium mobility in soils as a challenge for soil and plant analysis, magnesium fertilization and root uptake under adverse growth conditions. *Plant and Soil*, 368, 5–21.
- Gunes, A., Alpaslan, M., & Inal, A. 1998. Critical nutrient concentrations and antagonistic and synergistic relationships among the nutrients of NFT-grown young tomato plants. *Journal of Plant Nutrition*, 21, 2035-2047.
- Habibi, N., Sediqui, N., Terada, N., Sanada, A., & Koshio, K. 2021. Effects of salinity on growth, physiological and biochemical responses of tomato. *J. Int. Soc. Southeast Asian Agric. Sci*, 27(2), 14–28.
- Hadi, M. R., & Karimi, N. 2012. The role of calcium in plants' salt tolerance. *Journal of Plant Nutrition*, 35(13), 2037–2054.
- Hadi, M. S., Conway, W. S., and Sams, C. E. 1996. Effects of calcium on yield and incidence of blossom-end rot of three tomato cultivars. *HortScience*, 31(4), 672d--672.
- Hagassou, D., Francia, E., Ronga, D., & Buti, M. 2019. Blossom end-rot in tomato (*Solanum lycopersicum* L.): A multi-disciplinary overview of inducing factors and control strategies. *Scientia Horticulturae*, 249, 49–58.
- Hajer, A. S., Malibari, A. A., Al-Zahrani, H. S., and Almaghrabi, O. A. 2006. Responses of three tomato cultivars to sea water salinity. Effect of salinity on the seedling growth. *African J. Biotech.* 5(10): 855-861.
- Haleema, B., Rab, A., Hussain, S. A., Sajid, M., Arif, M., Shah, S. T., & Basit, A. 2020. Influence of calcium concentrations and sources on the fruit quality of tomato (*Lycopersicon esculentum* mill) at different storage conditions. *Fresenius Environmental Bulletin*, 29(3), 1866–1877.
- Halvin, J. L., and Soltanpour, P. N. 1980. A nitric acid plant tissue digest method for use inductively-coupled plasma spectrometry. *Commun. Soil Sci. and Plant Anal.* 11: 969-80.
- Hao, X. and Papadopoulos, A. P. 2002. Growth, photosynthesis and productivity of greenhouse tomato cultivated in open or closed rockwool
- Hao, X., & Papadopoulos, A. P. 2004. Effects of calcium and magnesium on plant growth, biomass partitioning, and fruit yield of winter greenhouse tomato. *HortScience*, 39(3), 512–515.
- Hao, X., & Papadopoulos, A., P. 2003. Effects of calcium and magnesium on growth, fruit yield, and quality in a fall greenhouse tomato crop grown on rockwool. *Canadian Journal of Plant Science*, 83, 903-912.

- Hartman, P. L., Mills, H. A., and Jones J. J. B. 1986. The influence of nitrate: ammonium ratios on growth, fruit development, and element concentration in 'Floradel' tomato plants. *J. Am. Soc. Hort. Sci.* 111, 487–490.
- Hasanuzzaman, M., Nahar, K., Alam, M., Bhowmik, P. C., Hossain, M., Rahman, M. M., Prasad, M. N. V., Ozturk, M., Fujita, M., & others. 2014. Potential use of halophytes to remediate saline soils. *BioMed Research International*.
- Hirschi, K. D. 2004. The calcium conundrum. Both versatile nutrient and specific signal. *Plant Physiol* 136:2438–2442.
- Ho, L. C., Hand, D. J., and Fussell, M. 1999. Improvement of tomato fruit quality by calcium nutrition. *Acta Hort.* 463–468.
- Ho, L.C., and White, P. J. 2005. A cellular hypothesis for the induction of blossom end rot in tomato fruit. *Annals of Botany* 95, 571–581.
- Hoagland, D. R., Arnon, D. I. 1950. The Waterculture method for growing plants without soil. California Agriculture Experiment Station Circular, 347 p.
- Hochmuth, G. J., & Hochmuth, R. 2009. Blossom-end rot in bell pepper: causes and prevention. *SL*, 284, 5.
- Horie, T., Karahara, I., & Katsuhara, M. 2012. Salinity tolerance mechanisms in glycophytes: An overview with the central focus on rice plants. *Rice*, 5(1), 1–18.
- Howladar, and Rady. 2012. Effects of calcium paste as a seed coat on growth, yield and enzymatic activities in NaCl stressed-pea plants. *African J. Biotech.* 11(77): 14140-14145.
- Husain, S., Von Caemmerer, S., and Munns, R. 2004. Control of salt transport from roots to shoots of wheat in saline soil. *Func. Plant Biol.* 31: 1115-1126.
- Hussein, M. M., El-Faham, S. Y., & Alva, A. K. 2012. Pepper plants growth, yield, photosynthetic pigments, and total phenols as affected by foliar application of potassium under different salinity irrigation water.
- Ilyas, M., Ahmad, M., Hussain, Z., Saeed, A., Begum, F., Khan, M. I., Shah, S., & others. 2021. Interactive effect of calcium and magnesium on the growth and yield of tomato (*Lycopersicon esculentum* L.). *Pure and Applied Biology (PAB)*, 5(4), 876–882.
- Ishii, T., Matsunaga, T., and Hayashi, N. 2001. Formation of rhamnogalacturonan II borate dimer in pectin determines cell wall thickness of pumpkin tissue. *Plant Physiology*. 126 (4): 1698–1705.
- Islam, M. Z., Mele, M. A., Baek, J. P., and Kang, H. M. 2016. Cherry tomato qualities affected by foliar spraying with boron and calcium. *Hortic. Environ. Biotechnol*, 57(1), 46–52.
- Islam, M. S., Zakaria, M., Hossain, M. M., Mia, M. A. B., & Karim, A. 2019. Effect of potassium on yield, quality and shelf life of tomato. *Bangladesh Journal of Agricultural Research*, 44(4), 659–668.
- Ismail, A., Takeda, S., and Nick, P. 2014. Life and death under salt stress: Same players, different timing? *J Exp Bot* 65: 2963–2979
- Jakobsen, S. T. 1979. Interaction between phosphate and calcium in nutrient uptake by plant roots. *Communications in Soil Science and Plant Analysis*, 10(1–2), 141–152.
- Jaleel, C. A., Manivannan, P., Kishorekumar, A., Sankar, B., Gopi, R., and Panneerselvam, R. 2007. Alterations in osmoregulation, antioxidant enzymes and indole alkaloid levels in *Catharanthus roseus* exposed to water deficit. *Colloids and Surfaces B: Biointerfaces*, 59: 150-157.

- Jaleel, C. A., Manivannan, P., Sankar, B., Kishorekumar, A., & Panneerselvam, R. 2007. Calcium chloride effects on salinity-induced oxidative stress, proline metabolism and indole alkaloid accumulation in *Catharanthus roseus*. *Comptes Rendus Biologies*, 330(9), 674–683.
- Jayaramaiah, R., Nataraja, A., Kumar, B. T. N., & Pramod, G. 2018. Effect of Calcium Metalosate on Growth and Yield of Tomato (*Lycopersicon esculentum* Mill.). *Int. J. Curr. Microbiol. App. Sci*, 7(10), 1371–1375.
- Johnson, R.W., Dixon, M. A., Lee, D. R. 1992. Water relations of the tomato during fruit growth. *Plant Cell Environ.* 15, 947–953.
- Jonson, N., Nonami, H., and Matan, E. 1992. reported that individual fruit weight decreased with increased salinity due to the reason of high salinity lowering the water potential in the plant which will reduce the water flow into the fruit and therefore the rate of fruit expansion.
- Kabata-Pendias, A., and Pendias, H. 1992. Trace Elements in Soils and Plants. 2nd Edn., CRC Press, Boca Raton, Fla, ISBN-10: 0849366437.
- Kada. M. D., Sahnoune, M., and Belkhodja, M. 2022. Morphological and Physiological Responses of Tomato Varieties Under Saline Environment.
- Karaman, M. R., Turan, M., Yıldırım, E., Güneş, A., Esringü, A., Demirtaş, A., Gürsoy, A., Dizman, M., Tutar, A., and Kılınç, H. 2012. Ca ve B-humat bileşiklerinin domates (*Lycopersicon Eesculentum* L.) bitkisinin verim parametreleri ile klorofil ve stoma geçirgenliği üzerine etkilerinin belirlenmesi. *SAÜ Fen Edebiyat Dergisi*, pp:177-185.
- Kaya, M. D, Ipek, A., and Ozturk, A. 2003. Effects of different soil salinity levels on germination and seedling growth of safflower (*Carthamus tinctorius* L.). *Turk J Agric For.* 27:221–227.
- Kayees, M. O., Hasanuzzaman, M., Rahman, M. W., Uddin, M. J., & Islam, M. R. 2016. Identification of tomato (*Lycopersicon esculentum* L.) genotypes for salt tolerance during emergence. *Int. J. Biosci*, 9(4), 297–304.
- Kazemi, M. 2014. Effect of foliar application of humic acid and calcium chloride on tomato growth. *Bull. Environ. Pharmacol. Life Sci.* 3(3): 41- 46.
- Keskin, G. 2013. Tomato and tomato paste situation - outlook: 2012/2013 (In Turkish), Agricultural economics and policy development institute TEPGE Publication No:219.
- Khan, F., Narayan, S., Prajapati, M. K., & Narayan, R. 2017. Calcium Deficiency Disorders and their Management in Vegetables. *University of Agricultural Sciencesand Technology of Kashmir*.
- Koike, S., and Smith, R. 2010. Calcium deficiency disorders hit vegetable crops in central coast. Copyright{copyright} 2015 Regents of the University of California, Agriculture and Natural Resources.
- Korkmaz, A., Karagöl, A., & Akinoğlu, G. 2017. The effects of CaCl₂ on fruit yield, quality and nutrient contents of tomato under NaCl stress conditions. *Eurasian Journal of Soil Science*, 6(1), 84–91.
- Korkmaz, N., & Aşkın, M. A. 2013. Effects of calcium and boron foliar application on pomegranate (*Punica granatum* L.) fruit quality, yield, and seasonal changes of leaf mineral nutrition. III International Symposium on Pomegranate and Minor Mediterranean Fruits 1089, 413–422.

- Krishna, R., Karkute, S. G., Ansari, W. A., Jaiswal, D. K., Verma, J. P., & Singh, M. 2019. Transgenic tomato for abiotic stress tolerance: status and way ahead. 3 Biotech, 9(4), 1–14.
- Küçükçelik, B. 2013. The Impact of Applying Various Calcium Dosages on Tomato Cultivars Grown in Perlite and Grape Marc: A Study on Blossom-End Rot and Fruit Cracking. Namık Kemal University, Graduate School of Natural and Applied Sciences, Department of Horticulture, Main Science Division.
- Kumar, S., Kumar, R., and Singh, P. 2021. Impact of foliar spray of calcium and magnesium on quality and nutrient uptake of tomato (*Lycopersicon esculentum* L.) in north west Himalayas. *Annals of Biology*, 37(2) 229-234.
- Lavanya, G., and Bahadur, V. 2021. Economics of Effect of Calcium and Boron on Growth, Yield and Quality of Cherry Tomato (*Solanum lycopersicum* var. *cerasiforme*) Under Shade Net Condition. *Ind. Journal. Pure App. Biosci.* 9(2), 232-239.
- Li, H., Liu, Y., Zhou, J. 2019. Effect of anti-transpiration on growth and magnesium, potassium and calcium uptake in tomato plant. *Agricultural Research in the Arid Areas*.
- Liebisch, F., Max, J. F. J., Heine, G., & Horst, W. J. 2009. Blossom-end rot and fruit cracking of tomato grown in net-covered greenhouses in Central Thailand can partly be corrected by calcium and boron sprays. *Journal of Plant Nutrition and Soil Science*, 172(1), 140–150.
- Lolaei, A., Rezaei, M. A., Raad, M. K., and Kaviani, B. 2012. Effect of Calcium Chloride on Growth and Yield of Tomato under Sodium Chloride Stress. *Journal of Ornamental and Horticultural Plants*. 2(3): 155-160.
- Loomis, W. D., and Durst, R. W. 1992. Chemistry and biology of boron. *BioFactors*. 3, 229–239.
- Lopez-Bucio, J., la Vega, O. M., Guevara-Garcia, A., & Herrera-Estrella, L. 2000. Enhanced phosphorus uptake in transgenic tobacco plants that overproduce citrate. *Nature Biotechnology*, 18(4), 450–453.
- Lucas, R. E. 2015. Potassium nutrition of vegetable crops. *The Role of Potassium in Agriculture*, 489–498.
- Lutts, S., Kinet, J. M., Bouharmont, J. 1996. NaCl-Induced Senescence in Leaves of Rice (*Oryza sativa* L.) Cultivars Differing in Salinity Resistance. *Annals Of Botany*, 78: 389- 398.
- Madani, B. M., Wall, A., Mirshekari, A., Bah and Mohamed, M. T. M. 2015. Influence of calcium foliar fertilization on plant growth, nutrient concentrations, and fruit quality of papaya. *Hort. Technol.* 25: 496-504.
- Madhavi, D. L., and Salunkhe, D. K. 1998. Tomato. In: Salunkhe, D.K. and Kadam, S.S. (eds.) *Handbook of Vegetable Science and Technology: Production, Composition, Storage and Processing*. Marcel Dekker, New York, pp.171–201.
- Manaa, A., Faurobert, M., Valot, B., Bouchet, J. P., Grasselly, D., Causse, M., & Ahmed, H. B. 2013. Effect of salinity and calcium on tomato fruit proteome. *OMICS: A Journal of Integrative Biology*, 17(6), 338–352.
- Manivannan, P., Jaleel, C.A. Sankar, B. Somasundaram, R. Murali, P.V. Sridharan, R. and Panneerselvam, R. 2007. Salt stress mitigation by calcium chloride in *Vigna radiata* (L.) Wilczek. *Acta Biologica Cracoviensia Series Botanica*, 49: 105-109.
- Marschner, H. 2011. Mineral Nutrition of Higher Plants. San Diego: Academic Pres.

- Marschner, P. 2012. Marschner's Mineral Nutrition of Higher Plants, 3. Ed. Academic Press, London.
- Martínez, J. P., Fuentes, R., Faruías, K., Lizana, C., Alfaro, J. F., Fuentes, L., Calabrese, N., Bigot, S., Quinet, M., & Lutts, S. 2020. Effects of salt stress on fruit antioxidant capacity of wild (*Solanum chilense*) and domesticated (*Solanum lycopersicum* var. *cerasiforme*) tomato. *Agronomy*, 10(10), 1481.
- Masarirambi, M. T., Oseni, T. O., Shongwe, V. D., Mhazo, N., & others. 2011. Physiological disorders of Brassicas/Cole crops found in Swaziland: A review. *African Journal of Plant Science*, 5(1), 8–14.
- Mashhady, A. S., Sayed, H. I., and Heikal, M. S. 1982. Effect of soil salinity and water stress on growth and content of nitrogen, chloride and phosphate of wheat and triticale. *Plant and Soil* 68:207-216.
- Mazumder, M. N. N., Misran, A., Ding, P., Wahab, P. E. M., and Mohamad, A. 2021. Preharvest foliar spray of calcium chloride on growth, yield, quality, and shelf life extension of different lowland tomato varieties in Malaysia. *Horticulturae*, 7(11), 466.
- Mengel, K. and Kirkby, E. 2001. Principle of plant nutrition. 5 th Ed: international potash institute, bern switzerland.
- Mengel, K., and Kirkby, E. A. 1978. Principles of Plant Nutrition, 3rd ed.; International Potash Institute: Bern, Switzerland.
- Mestre, T. C., Garcia-Sanchez, F., Rubio, F., Martinez, V., & Rivero, R. M. 2012. Glutathione homeostasis as an important and novel factor controlling blossom-end rot development in calcium-deficient tomato fruits. *Journal of Plant Physiology*, 169(17), 1719–1727.
- Michailidis, M., Karagiannis, E., Tanou, G., Samiotaki, M., Tsiolas, G., Sarrou, E., and Molassiotis, A. 2020. Novel insights into the calcium action in cherry fruit development revealed by high-throughput mapping. *Plant Mol. Biol.* 104, 597–614.
- Milagres, C.d.C., Maia, J.T.L.S., Ventrella, M.C., Martinez, H.E.P. 2019. Anatomical changes in cherry tomato plants caused by boron deficiency. *Braz. J. Bot.* 42, 319–328.
- Minoia, S., Petrozza, A., D'Onofrio, O., Florence, P., and Mosca, C. 2010. A new mutant genetic resource for tomato crop improvement by TILLING technology. *BMC research notes*. 3(1): p. 69.
- Mitchell, J. P., Shennan, C., Grattan, S. R., & May, D. M. 1991. Tomato fruit yields and quality under water deficit and salinity. *Journal of the American Society for Horticultural Science*, 116(2), 215–221.
- Mizrahi, Y. 1982. Effect of salinity on tomato fruit ripening. *Plant Physiology*, 69(4), 966–970.
- Montesano, F., & van Iersel, M. W. 2006. NaCl Stress in Hydroponic Tomatoes Can Be Alleviated by Calcium. *HortScience*, 41(4), 999C-999.
- Morard, P., Pujos, A., Bernadac, A., & Bertoni, G. 1996. Effect of temporary calcium deficiency on tomato growth and mineral composition. *Journal of Plant Nutrition*, 19, 115-127.
- Murshed, R., Lopez-Lauri, F., & Sallanon, H. 2014. Effect of salt stress on tomato fruit antioxidant systems depends on fruit development stage. *Physiology and Molecular Biology of Plants*, 20, 15–29.

- Needham, P. 1973. Nutritional disorders. In: The U.K. Tomato Manual. Grower Books, London.
- Netondo, G. W., Onyango, J. C., and Beck, E. 2004. Sorghum and salinity: II. Gas exchange and chlorophyll fluorescence of sorghum under salt stress. *Crop Sci.* 44(3): 806–811.
- Niu, X.L., Ma, W.F., Chen, G.M., Liang, J, Zhang, H. Y. 2018. Effect of foliar spraying calcium fertilizer on mineral elements contents in gold silk jujube. *Econ. For. Res.* 36: 141-146.
- Nizam, R., Hosain, M. T., Hossain, M. E., Islam, M. M., & Haque, M. A. 2019. Salt stress mitigation by calcium nitrate in tomato plant. *Asian Journal of Medical and Biological Research*, 5(1), 87–93.
- Nonami, H., Fukuyama, T., Yamamoto, M., Yang, L., & Hashimoto, Y. 1995. Blossom-end rot of tomato plants may not be directly caused by calcium deficiency. *Acta Horticulturae*, 396, 107-114.
- Nukaya ,A., Goto, K., Jang, H., Kano, A., and Ohkawa, K. 1995. Effect of K/Ca ratio in the nutrient solution on incidence of blossom-end rot and gold specks of tomato fruit grown in rockwool. *ActaHortic.*396.13.
- Nukaya, A., Goto, K., Jang, H., Kano, A., & Ohkawa, K. 1994. Effect of NH₄-N level in the nutrient solution on the incidence of blossom-end rot and gold specks on tomato fruit grown in rockwool. *International Symposium on Growing Media & Plant Nutrition in Horticulture* 401, 381–388.
- Nzanza, B. 2008. Yield and quality of tomato as influenced by differential Ca, Mg and K nutrition. University of Pretoria.
- Ouhibi. C., Attia, H., Rebah, F., Msilini, N., Chebbi, M., Aarouf, J., Urban, L. and Lachaal, M. 2014. Salt stress mitigation by seed priming with UV-C in lettuce plants: Growth, antioxidant activity and phenolic compounds. *Plant Physiol Biochem* 83: 126–133.
- Paiva, E.A.S., Sampaio, R.A. & Martinez, H.E.P. 1998. Composition and quality of tomato fruit cultivated in nutrient solution containing different calcium concentrations. *J. Plant Nutr.* 21, 2653-2661.
- Palta, J. P., and Lee–Stadelmann, O. Y. 1983. Vacuolated plant cells as ideal osmometer: Reversibility and limits of plasmolysis, and estimation of protoplasm volume in control and water-stress-tolerant cells. *Plant, Cell Environ.* 6:601–610.
- Papadopoulos, A. P. 2003. Effects of calcium and magnesium on growth, fruit yield and quality in a fall greenhouse tomato crop grown on rockwool. *Canadian Journal of Plant Science*, 83(4), 903–912.
- Parvin, K. 2013. Mitigation of salt stress in tomato by exogenous application of calcium. Department of Agricultural Botany, Sher-e-Bangla Agricultural University.
- Parvin, K., Ahamed, K. U., Islam, M. M., Haque, M. N., Hore, P. K., Siddik, M. A., & Roy, I. 2015. Reproductive behavior of tomato plant under saline condition with exogenous application of calcium. *Mid East J Sci Res*, 23, 2920–2926.
- Pasternak, D., Twersky, M., and De Malach, Y. 1979. Salt resistance in agricultural crops. In: Mussell H., Staples R.C. (Eds.), *Stress Physiology in Crop Plants*. Wiley, New York. 127-142.
- Patel, N. T., Guptab, A., and Pandey, A. N. 2010. Salinity tolerance of *Avicennia marina* (Forssk.) Vierh. from Gujarat coasts of India. *Aquatic Botany* 93: 9–16.

- Petro, and Turza, M. 1986. Flavor of tomato and tomato products. *Food Reviews International*. 2(3): p. 309-351.
- Peyvast, G., Olfati, J. A., Ramezani-Kharazi, P., & Kamari-Shahmaleki, S. 2009. Uptake of calcium nitrate and potassium phosphate from foliar fertilization by tomato. *Journal of Horticulture and Forestry*, 1(1), 7–13.
- Pinto, M. C. X., Kihara, A. H., Goulart, V. A. M., Tonelli, F. M. P., Gomes, K. N., Ulrich, H., & Resende, R. R. 2015. Calcium signaling and cell proliferation. *Cellular Signalling*, 27(11), 2139–2149.
- Plese, L. P. M., Tiritan, C. S., Yassuda, E. I., Prochnow, L. I., Corrente, J. E., & Mello, S. C. 1998. Efeitos das aplicações de cálcio e de boro na ocorrência de podridão apical e produção de tomate em estufa. *Scientia Agrl*, 55, 144–148.
- Poovaiah, B. W., and Reddy, A. S. N. 1987. Calcium messenger systems in plants. *CRC Crit. Rev. Plant Sci*. 6:47–102.
- Poovaiah, B. W., and Reddy, A. S. N. 1993. Calcium and signal transduction in plants. *CRC Crit. Rev. Plant Sci*. 12(3):185–211.
- Posada, F. C., and Rodriguez, C. A. 2009. Reducing negative effects of salinity in tomato (*Solanum lycopersicum* L.) plants by adding leonardite to soil. *Acta Hort.*, 821: 113-139.
- Rab, A., & Haq, I. 2012. Foliar application of calcium chloride and borax influences plant growth, yield, and quality of tomato (*Lycopersicon esculentum* Mill.) fruit. *Turkish Journal of Agriculture and Forestry*, 36(6), 695–701.
- Rab, A., Sajid, M., Ahmad, N., Nawab, K., & Ali, S. G. 2017. Foliar calcium application ameliorates salinity-induced changes of tomato crop grown in saline conditions. *Sarhad Journal of Agriculture*, 33(4), 540–548.
- Rabie, R. K. and Kumazawa, K. 1988. Breeding Tomato for salt tolerance: Variations in ion concentrations associated with response to salinity. *J. Amer. Soc. Hort. Sci*. 118(3):405-408.
- Rafat, S., and Rafiq, A. 2009. Vegetative Growth and Yield of Tomato as Affected by the Application of Organic Mulch and Gypsum under Saline Rhizosphere. *Pak. J. Bot.* 41(6): 3093-3105.
- Rahman, M. M., Hossain, M., Hossain, K. F. B., Sikder, M. T., Shammi, M., Rasheduzzaman, M., Hossain, M. A., Alam, A. K. M. M., & Uddin, M. K. 2018. Effects of NaCl-salinity on tomato (*Lycopersicon esculentum* Mill.) plants in a pot experiment. *Open Agriculture*, 3(1), 578–585.
- Rajabipour, A., Zarietard, M. R., Dodd, G. T., & Norris, E. R. 2004. Tensile strength and relaxation of tomato skin by a loop technique. *International Agrophysics*, 18(2).
- Raleigh, S. M., and Chucka, J. A. 1944. Effect of nutrient ratio and concentration on growth and composition of tomato plants and on the occurrence of blossom-end rot of the fruit. *Plant Physiol.* 19,671–678.
- Ramon, A. M., Carpena-Ruiz, R.O., and Garate, A. 1990. The effects of short-term deficiency of boron on potassium, calcium and magnesium distribution in leaves and roots of tomato (*Lycopersicum esculentum* L.) plants. *Dev. Plant Soil Sci.*, 41: 287-290.
- Reitz, N. F., and Mitcham, E. J. 2021. Lignification of tomato (*Solanum lycopersicum*) pericarp tissue during blossom-end rot development. *Scientia Horticulturae*, 276, 109759.

- Reitz, N. F., Shackel, K. A., & Mitcham, E. J. 2021. Differential effects of excess calcium applied to whole plants vs. excised fruit tissue on blossom-end rot in tomato. *Scientia Horticulturae*, 290, 110514.
- Reitz, N. F., K. A. Shackel, and E. J. Mitcham. 2020. Differential effects of excess calcium applied to whole plants vs. excised fruit tissue on blossom-end rot in tomato. Department of Plant Sciences, University of California, Davis, CA 95616, USA. *Scientia Horticulturae* 290.
- Rekha, C., Poornima, G., Manasa, M., Abhipsa, V., Devi, J. P., Kumar, H., T., V., & Kekuda, T. R. P. 2012. Ascorbic acid, total phenol content and antioxidant activity of fresh juices of four ripe and unripe citrus fruits. *Chemical Science Transactions*, 1(2), 303-310.
- Rani, P., Sharma, M. K., Rani, S., Kumar, N., & Sharma, S. K. 2017. Effect of Different Saline Environments on Flowering Time, Chlorophyll Content and Photochemical Efficiency of Tomato. *Annals of Biology*, 33(1), 86–93.
- Saberi, A. R., Aishah, H. S., Halim, R. A., and Zaharah, A. R. 2011. Morphological responses of forage sorghums to salinity and irrigation frequency. *African J. Biotech.* 10(47): 9647-9656.
- Safi, A., Rachid, G., El-Fadel, M., Doummar, J., Abou Najm, M., and Alameddine, I. 2018. Synergy of climate change and local pressures on saltwater intrusion in coastal urban areas: effective adaptation for policy planning, *Water Int.* 43, 145-164.
- Sainju, U. M., Dris, R., Singh, B., & others. 2003. Mineral nutrition of tomato. *Food Agric. Environ.* 1(2), 176–183.
- Sajid, M., Ullah, I., Rab, A., Shah, S. T., Basit, A., Bibi, F., Ahmad, M., & others. 2020. Foliar application of calcium improves growth, yield and quality of tomato cultivars. *Pure and Applied Biology (PAB)*, 9(1), 10–19.
- Sakamoto, Y., Watanabe, S., Nakashima, T., & Okano, K. 1999. Effects of salinity at two ripening stages on the fruit quality of single-truss tomato grown in hydroponics. *The Journal of Horticultural Science and Biotechnology*, 74(6), 690–693.
- Sandoval-villa, m., guertal, e.a. & wood, c.w., 2001. Greenhouse Tomato response to low ammonium-nitrogen concentrations and duration of ammonium-nitrogen supply. *J. Plant nutr.* 24, 1787-1798.
- Santos, A., dos, N., Silva, Ê. F., de, F., Silva, G., F., Bezerra, R. R., & Pedrosa, E. M. R. 2017. Concentração de nutrientes em tomate cereja sob manejos de aplicação da solução nutritiva com água salobra 1. *Revista Ciência Agronômica*, 48, 576–585.
- Sardans, J., and Peñuelas, J. 2015. Potassium A neglected nutrient in global change. *Glob. Ecol. Biogeogr.* 24, 261–275.
- Sarkar, D., Ghosh S., Batabyal, K., Mandal, B., and Chattopadhyay, A. P. 2015. Liming effects on extractable boron in six acidic soils. *Communications in Soil Science and Plant Analysis* 46(10): 1320-25.
- Sati, F., & Qubbaj, T. 2021. Effect of calcium chloride postharvest treatment in combination with plant natural substance coating on fruit quality and storability of tomato (*Solanum lycopersicum*) fruits during cold storage. *Journal of Applied Botany and Food Quality*, 94, 100–107.
- Satti, S. M. E., & Al-Yahyai, R. A. 1995. Salinity tolerance in tomato: Implications of potassium, calcium, and phosphorus. *Communications in Soil Science and Plant Analysis*, 26(17–18), 2749–2760.

- Saure, M. C. 2014. Why calcium deficiency is not the cause of blossom-end rot in tomato and pepper fruit—A reappraisal. *Scientia Horticulturae* 174, 151–154.
- Saure, M. C. 2001. Review: Blossom-end rot of tomato (*Lycopersicon esculentum* Mill.)-A calcium- or a stress-related disorder? *Sci. Hort.* 90:193–208.
- Saleh, S., Liu, G., Liu, M., Liu, W., Gruda, N., & He, H. 2019. Reducing the salinity impact on soilless culture of tomatoes using supplemental Ca and foliar micronutrients. *Acta Scientiarum Polonorum Hortorum Cultus*, 18(3), 187–200.
- Scrase-Field, S. A. M. G., and Knight, M. R. 2003. Calcium: Just a chemical switch? *Current Opinion in Plant Biology* 6, 500–506.
- Senevirathna, P. A. W. A. N. K., Daundasekera, W. A. M. 2010. Effect of postharvest calcium chloride vacuum infiltration on the shelf life and quality of tomato (cv. 'Thilina'). *Ceylon J. Sci.* 39, 35–44.
- Shalhevet, J., & Yaron, B. 1973. Effect of soil and water salinity on tomato growth. *Plant and Soil*, 39(2), 285–292.
- Shankar, A., Reddy, R. V. S. K., Sujatha, M. and Pratap, M. 2013. Genetic variability studies in F₁ generation of tomato (*Solanum lycopersicum* L.). *Journal of Agriculture and Veterinary Science* 4(5): 31-34.
- Shao, X., Hou, M., and Chen, J. 2013. Effects of EM-calcium spray on Ca uptake, blossom-end rot incidence and yield of greenhouse tomato (*Lycopersicon esculentum*). *Research on Crops* 14: 1159–1166.
- Singh, J., Sastry, E. V., & Singh, V. 2012. Effect of salinity on tomato (*Lycopersicon esculentum* Mill.) during seed germination stage. *Physiology and Molecular Biology of Plants*, 18(1), 45–50.
- Sonneveld, C., & Voogt, W. 1985. Growth and cation absorption of some fruit-vegetable crops grown on rockwool as affected by different cation ratios in the nutrient solution. *Journal of Plant Nutrition*, 8(7), 585–602.
- Soria, T., Cuartero, J., & Romero-Aranda, R. 2000. Yield and fruit quality of salinised tomato plants with enhanced Ca fertilization. *International Symposium on Techniques to Control Salination for Horticultural Productivity* 573, 35–41.
- Sousa, G. G., de Sousa, H. C., Lessa, C. I. N., Goes, G. F., Freire, M. H., de Souza, M. V. P., Gomes, S. P., & Schneider, F. 2023. Production of watermelon seedlings in different substrates under salt stress. *Revista Brasileira de Engenharia Agricultura Ambiental*, 27, 343–351.
- Sridevi, G. 2020. Effect of different salinity levels on plant growth parameters of tomato. *An Asian Journal of Soil Science*, 15(2), 97–100. <https://doi.org/10.15740/HAS/AJSS/15.2/97-100>.
- Sturiao, W. P., Martinez, H. E. P., Oliveira, L. A., Jezler, C. N., de Jesus Pereira, L., Ventrella, M. C., & do Carmo Milagres, C. 2020. Deficiency of calcium affects anatomical, biometry and nutritional status of cherry tomato. *South African Journal of Botany*, 132, 346–354.
- Su, H., Gollack, D., Zhao, C., and Bohnert, H.J. . 2002. The expression of HAK-type K⁺ transporters is regulated in response to salinity stress in common ice plant. *Plant Physiol.* 129(4): 1482–1493.
- Suzuki K., Shono, M., Egawa, Y. 2003. Localization of calcium in the pericarp cells of tomato fruit during the development of blossom-end rot. *Protoplasma* 222, 149–156.
- Tabatabaiean, J. 2014. Effect of calcium nutrition on reducing the effects of salinity on tomato plant. *American Journal of Plant Nutrition and Fertilization Technology*,

- 4(1), 11–17.
- Tabatabaie, S. J., Gregory, P. J., and Hadley, P. 2004. Uneven distribution of nutrients in the root zone affects the incidence of blossom end rot and concentration of calcium and potassium in fruits of tomato. *Plant and Soil* 258: 169–178.
- Tadesse, T., & Nichols, M. A. 2003. The effect of conductivity on the yield and quality of sweet pepper (*Capsicum annuum* L.). *International Symposium on Managing Greenhouse Crops in Saline Environment* 609, 197–199.
- Tanveer, K., Gilani, S., Hussain, Z., Ishaq, R., Adeel, M., & Ilyas, N. 2020. Effect of salt stress on tomato plant and the role of calcium. *Journal of Plant Nutrition*, 43(1), 28–35.
- Taylor, I. B. 1986. Biosystematics of tomato. In: Atherton, J.G. and Rudish, J. (eds.) *The Tomato Crop: A Scientific Basis for Improvement*. Chapman and Hall, London.
- Taylor, M. D., Locascio, S. J., & Alligood, M. R. 2004. Blossom-end rot incidence of tomato as affected by irrigation quantity, calcium source, and reduced potassium. *HortScience*, 39(5), 1110–1115.
- Tejashvini, A. 2018. Growth and yield attribute as influenced by calcium foliar nutrition under poly-house condition. *Int. J. Pure Appl. Biosci.* 6, 952–957.
- Tejashvini, A., and Subbarayappa, C.T. 2021. Interactive effect of calcium and boron on growth, yield and nutrient uptake by tomato (*Lycopersicon esculentum* L.). *International Journal of Chemical Studies*, 9(1), 976–979.
- Terraza, S. P., Romero, M. V., Peena, P. S., Madrid, J. L. C., Verdugo, S. H. 2008. Efecto del calcio y potencial osmótico de la solución nutritiva en la pudrición apical, composición mineral y rendimiento de tomate. *Interciencia* 33, 449–456.
- Thimmaiah, S. K. 1999. *Standard Methods of Biochemical Analysis*, Kalyani Publishers, Noida, 1999.
- Tripler, C. E., Kaushal, S. S., Linkens, G. E., Walter, M. T. 2009. Patterns in potassium dynamics in forest ecosystems. *Ecol. Lett.* 451–466.
- Tsadilas, C. D., Kassioti, T., and Mitsios, I. K. 2005. Influence of liming and nitrogen forms on boron uptake by tobacco. *Communications in Soil Science and Plant Analysis* 36: 701–08.
- Tuna, A. L., Kaya, C., Ashraf, M., Altunlu, H., Yokas, I., & Yagmur, B. 2007. The effects of calcium sulphate on growth, membrane stability and nutrient uptake of tomato plants grown under salt stress. *Environmental and Experimental Botany*, 59(2), 173–178.
- Turhan, A. 2020. The effect of saline water application on tomato fruit yield and some quality parameters. *Fresenius Environmental Bulletin*, 29(6).
- Turhan, A., Kuşçu, H., Demir, A. O., & others. 2015. Effect of irrigation water salinity on yield, fruit characteristics and water use efficiency of cucumber. *Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi*, 32(3), 29–38.
- Tüzel, I. H., Tüzel, Y., Gül, A., & Eltez, R. Z. 2000. Effects of EC level of the nutrient solution on yield and fruit quality of tomato. *V International Symposium on Protected Cultivation in Mild Winter Climates: Current Trends for Sustainable Technologies* 559, 587–592.
- Varis, S., and George, R. A. T. 1985. The influence of mineral nutrition on fruit yield, seed yield, and quality in tomato. *J. Hort. Sci.* 60, 373–376.
- Viets, F.G. 1965. Diagnose des Ca-Ernährungszustandes und der Blütenend- faule bei Buschtomate. *Gartenbauwiss.* 55, 209–212.

- Vinh, T. D., Yoshida, Y., Ooyama, M., Goto, T., Yasuba, K., & Tanaka, Y. 2018. Comparative analysis on blossom-end rot incidence in two tomato cultivars in relation to calcium nutrition and fruit growth. *The Horticulture Journal*, 87(1), 97–105.
- Vitart, V., Baxter, I. Doerner, P., and Harper, J. F. 2001. Evidence for a role in growth and salt resistance of a plasma membrane H^+ -ATPase in the root endodermis. *The Plant Journal* 27: 191–201.
- Voogt, W. 1998. The growth of beefsteak tomato as affected by K/Ca ratios in the nutrient solution. Glasshouse Crops Research Station Naaldwijk, the Netherlands.
- Warrence, N. J., Bauder, J. W., & Pearson, K. E. 2002. Basics of salinity and sodicity effects on soil physical properties. Department of Land Resources and Environmental Sciences, Montana State University-Bozeman, MT, 129, 1–29.
- White, P. J. 2001. The pathways of calcium movement to the xylem, *Journal of Experimental Botany*, vol. 52 (pg. 891-899).
- White, P. J., and Broadley, M. R. 2003. Calcium in plants. *Annals of Botany* 92, 487–511.
- Wilcox, G. E., Hoff, J. E., & Jones, C. M. 1973. Ammonium Reduction of Calcium and Magnesium Content of Tomato and Sweet Corn Leaf Tissue and Influence on Incidence of Blossom End Rot of Tomato Fruit1. *Journal of the American Society for Horticultural Science*, 98(1), 86–89.
- Wills, R. B. H., & Tirmazi, S. I. H. 1979. Effect of calcium and other minerals on ripening of tomato. *Functional Plant Biology*, 6(2), 221–227.
- Winsor, G. W. 1973. Nutrition. In: *The U.K. Tomato Manual*. Grower Books, London.
- Wissuwa, M., gamat, g., ismail, M. 2005. Is root growth under phosphorus deiciency affected by source or sink limitations? *J exp bot* 56(417):1943–1950.
- Langenhoven, P. 2018. Hydroponic tomato production in soilless culture. *Indian Horticultural Congress*, February 13.
- Wu, Z., Liang, F., Hong, B., Young, J. C., Sussman, M. R., Harper, J. F., Sze, H. 2002. An endoplasmic reticulum-bond Ca^{2+}/Mn^{2+} pump, ECA1, supports plant growth and confers tolerance to Mn^{2+} stress. *Plant Physiology*, 130: 128–137.
- Yamauchi, T., Hara, T., and Sonoda, Y. 1986. Effects of boron deficiency and calcium supply on the calcium metabolism in tomato plant. *Plant Soil*, 93: 223-230.
- Yan, B. and Ying, H. 2018. Effect of Soil Magnesium on Plants. *IOP Conf.ser: Earth Environ. Sci.* 170 0221.
- Yang, Y., and Guo, Y. 2018. Elucidating the molecular mechanisms mediating plant salt-stress responses. *New Phytol* 217: 523–539.
- Yasar, F., Uzal, O. 2020. Effect of calcium applications on ion accumulation in different organs of pepper plant under salt stress. In *BIO Web of Conferences* (Vol. 17, p. 00231). EDP Sciences.
- Yılmaz, C., Yetişir, H., and Sarı, N. 2002. Bazı Kimyasal Uygulamalarının Lital Marul (*Lactuca Sativa L.*) Çeşidinde Baş Oluşumu Üzerine Etkileri. *Alatarım* 1 (2), 36.
- Yoshida, Y., Irie, N., Vinh, T. D., Ooyama, M., Tanaka, Y., Yasuba, K., & Goto, T. 2014. Incidence of blossom-end rot in relation to the water-soluble calcium concentration in tomato fruits as affected by calcium nutrition and cropping season. *Journal of the Japanese Society for Horticultural Science*, 83(4), 282–289.
- Zhai, Y., Yang, Q., & Hou, M. 2015. The Effects of saline water drip irrigation on tomato yield, quality, and blossom-end rot incidence---A 3a Case Study in the South of China. *PloS One*, 10(11), e0142204.

- Zhang, P., Senge, M., & Dai, Y. 2016. Effects of salinity stress on growth, yield, fruit quality and water use efficiency of tomato under hydroponics system. *Reviews in Agricultural Science*, 4, 46–55.
- Zhang, P., Senge, M., Yoshiyama, K., Ito, K., Dai, Y., & Zhang, F. 2017. Effects of low salinity stress on growth, yield, and water use efficiency of tomato under soilless cultivation. *農業農村工学会論文集*, 85(1), I\15--I\21.
- Zhang, P., Senge, M., & Dai, Y. 2017. Effects of salinity stress at different growth stages on tomato growth, yield, and water-use efficiency. *Communications in Soil Science and Plant Analysis*, 48(6), 624–634.
- Zhu Q., Ozores-Hampton M., Li, Y. C., Morgan, K. T., Liu, G., and Mylavarapu, R. S. 2018. Effect of phosphorus rates on growth, yield, and postharvest quality of tomato in a calcareous soil. *Hort. Sci.*52:1406–1412. doi: 10.21273/ HORTSCI12192-17.
- Zhu, C., Kinet, J. M., and Lutts, S. 2001. Characterization of rice (*Oryza sativa* L.) F-3 populations selected for salt resistance. I-Physiological behavior during vegetative growth. *Euphytica*. 121: 251-263.
- Zhu, J., K. 2002. Salt and drought stress signal transduction in plants. *Annu Rev Plant Biol* 53: 247–273.