T.R.
VAN YUZUNCU YIL UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF PLANT NUTRITION AND SOIL SCIENCES

EFFECTS OF SALICYLIC ACID APPLICATIONS ON PLANT GROWTH CRITERIA AND NUTRIENT UPTAKE OF LETTUCE (*Lactuca sativa*) UNDER SOME ABIOTIC STRESS CONDITIONS

Ph.D. Thesis

PREPARED BY: Salar Mohammad Ameen SALEM
SUPERVISED BY: Prof. Dr. Füsun GÜLSER

VAN-2021

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ACCEPTANCE AND APPROVAL PAGE

This thesis entitles ‘Effects of salicylic acid applications on plant growth criteria and nutrient uptake of lettuce (*lactuca sativa*) under some abiotic stress conditions’ presented by Salar Mohammad Ameen SALEM under supervision of Prof. Dr. Füsun GÜLSER in the Department of Soil Science and Plant Nutrition, has been accepted as a Ph.D. thesis according to the legislation of Graduate Higher Education on … /… / …. With unanimity member of the jury.

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Director of the institution

THESIS STATEMENT

I hereby declare that all the information in the thesis is obtained and presented within the frame of ethical behavior and academic rules, also this thesis is prepared following the thesis writing rules, furthermore, all kinds of expressions and information that do not belong to me are fully cited.

Salar Mohammad Ameen SALEM

ABSTRACT

EFFECTS OF SALICYLIC ACID APPLICATIONS ON PLANT GROWTH CRITERIA AND NUTRIENT UPTAKE OF LETTUCE (*Lactuca sativa*) UNDER SOME ABIOTIC STRESS CONDITIONS

SALEM, Salar Mohammad Ameen
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In this study, it was aimed to determine the effects of salicylic acid applications on plant growth criteria and nutrient uptake of lettuce (*Lactuca sativa*) under salt and cadmium abiotic stress conditions. Seedlings of lettuce (*Lactuca sativa*) grown in 72 pots in a pre-controlled environment were used. The experiments were carried out in 144 plastic pots with a soil capacity of 3 kg, with 3 replications in two separate times, according to the trial pattern based on full chance, in the plant growing room of Van YüzüncüYıl University, Faculty of Agriculture, Soil Science, and Plant Nutrition, under temperature, humidity, and light-controlled sterile conditions. Salicylic acid (0, 1, 2, 4 mM), cadmium (0, 40 and 80 mg kg^{-1}), and salt (0, 30 and 60 mM) were applied in the form of cadmium nitrate ($CdNO_3$) and sodium chloride (NaCl) in the growing medium. The trials were terminated at the end of 8 weeks after planting the seedlings. Plant growth parameters and macro and micro plant nutrients were determined in the harvested plant samples. As a result, in this study, more or less negative effects of increasing Cd and NaCl doses on some parameters were observed. In addition, it has been concluded that 2 mM is the optimum dose for Cd and/or NaCl applications in general. Especially in SA and Cd applications plant height, plant dry, leaf number, root diameter, chlorophyll, K, and Cd parameters and in SA and NaCl applications plant height, plant fresh weight, plant dry weight, leaf number, root length, root diameter, consumed weight, Mg, and Na parameters were influenced by SA2 dose.

Keywords: Cadmium, Lettuce, Nutrients. Plant growth parameters, Salicylic acid, Salt.

ÖZET

BAZI ABİYOTIK STRES KOŞULLARINDA SALİSİLİK ASİT UYGULAMALARININ MARULDA (*LACTUCA SATIVA*) BİTKİ GELİŞİM KRİTERLERİ VE BESİN ELEMENTİ ALIMINA ETKİSİ

SALEM, Salar Mohammad Ameen
Doktora Tezi, Toprak Bilimi ve Bitki Besleme Ana Bilim Dalı
Tez Danışmanı: Prof. Dr. Füsun GÜLSER
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Bu çalışmada bazı abiyotik stres koşullarında salisilik asit uygulamalarının marulda (*Lactuca sativa*) bitki gelişim kriterleri ve besin elementi alımına etkisi belirlenmesi amaçlanmıştır. Kontrollü koşullarıda 72 saksıda yetiştirilen marul (*Lactuca sativa*) fideleri deneme bitkisi olarak kullanılmıştır. Denemeler, 3 kg toprak kapasiteli 144 plastik saksıda, tam şansa bağlı deneme desenine göre iki ayrı dönemde ve 3 tekrarlamalı olarak Van YüzüncüYıl Üniversitesi, Ziraat Fakültesi, Toprak Bilimi ve Bitki Besleme Bölümüne ait bitki büyütme odasında, sıcaklık nem ve ışık kontrollü steril koşullarda yürütülmüştür. Salisilik asit (0, 1, 2, 4 mM), kadmiyum (0, 40 ve 80 mg kg^{-1}), ve tuz (0, 30 ve 60 mM) yetiştirme ortamlarına kadmiyum nitrat ($CdNO_3$) ve sodyum klorür (NaCl) formlarında uygulanmıştır. Denemeler fide dikimini takiben 8 hafta sonunda sonlandırılmıştır. Hasat edilen bitki örneklerinde bitki büyüme parametrelerile makro ve mikro bitki besin elementleri belirlenmiştir. Sonuç olarak bu araştırmada artan Cd ve NaCl dozlarının bazı parametreler üzerinde az veya çok olumsuz etkileri gözlenmiştir. Ayrıca genel olarak 2 mM'nin Cd ve NaCl uygulamalarında optimum doz olduğu sonucuna varılmıştır. Özellikle SA ve Cd uygulamalarında bitki boyu, bitki kuru ağırlığı, yaprak sayısı, kök çapı, klorofil, K, ve Cd parametrelerinde, SA ve NaCl uygulamalarında bitki boyu, bitki yaş ağırlığı, bitki kuru ağırlığı, yaprak sayısı, kök uzunluğu, kök çapı, tüketilen ağırlık, Mg, ve Na parametrelerinde SA2 dozu etkili bulunmuştur.

Anahtar kelimeler: Besin elementleri. Bitki büyüme parametreleri, Kadmiyum, Marul, Salisilik asit, Tuz.

ACKNOWLEDGMENT

Due to the increase in the world population, increasing industrial, agricultural activities and environmental problems brought by urbanizations have threatened natural life, especially since the second half of the twentieth century. The accumulation of solid, liquid, and gaseous pollutants in the air, water, and soil resulting from mass production and related consumption processes cause environmental pollution.

The main pollutants threatening agricultural areas in the world and our country are heavy metals and especially salinity caused by irrigation regime and water quality.

It is known that heavy metals cause many physiological and biochemical damages to living organisms. Cadmium, because of easily dissolved in water and mobility compared to others, making it the most toxic of heavy metals. In addition to causing damages in agricultural production, cadmium accumulated especially in agricultural soils, its intake by plants causes health problems for all living things in the food chain and therefore for humans.

Another important problem threatening agricultural areas is the salinity caused by poor quality irrigation water, in other words, salt accumulation in the soil. In addition to causing physiological drought by blocking the water intake of plants, high amounts of salt accumulation also have toxic effects.

Many studies have been carried out to reduce and/or eliminate the harmful effects of pollutants that adversely affect the growth and development of plants and thus cause a decrease in agricultural productivity. One of them is the application of plant growth regulators.

Salicylic acid, which usually carries a hydroxyl group or functional derivative, is a plant phenolic that is activated by abnormal changes of biotic or abiotic conditions in plants. Many studies have been carried out to show that it can eliminate physiological and biochemical negativities that may occur as a result of unsuitable environmental conditions. It has been stated by many researchers that salicylic acid in certain doses applied to plants in stressful conditions such as cadmium and salinity has positive effects on the plant morphologically and physiologically.

Our research aims to investigate the effects of exogenous salicylic acid application on lettuce (*Lactuca sativa*) seedlings on the plant growth criteria and nutrient uptake changes caused by abiotic stress induced by cadmium and salt.

I would like to acknowledge my indebtedness and render my warmest thanks to my supervisor, Prof. Dr. Füsun GÜLSER, who made this work possible. Her friendly guidance and expert advice have been invaluable throughout all stages of the thesis including planning, execution of this thesis subject and the supply of the trial plant, and so on. I greatly appreciate the freedom you have given me to find my path and the guidance and support you offered throughout my undergraduate and graduate education. I do not miss her patience and tolerance while benefiting from her precious experiences, I am very honored to work with her.

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2021
Salar Mohammad Ameen SALEM

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SYMBOLS AND ABBREVIATIONS

Some symbols and abbreviations used in this study are presented below with their explanations

Symbols	**Explanations**
°C	Degree Celsius
%	Percent
µS cm^{-1}	Micro Siemens per centimeter
dS m^{-1}	Desi Siemens per meter
mg L^{-1}	Milligram per liter
µM	Micro molar
mg	Milligram
mg kg^{-1}	Milligram per Kilogram
µg mg	Microgram per Milligram
kg	Kilogram
mM	Milli Molar
cm	Centimeter
g	Gram
mm	Millimeter
Mpa	Mega Pascal
Pcs	Pieces

Abbreviations	**Explanations**
CO_2	Carbon dioxide
Cu	Copper
Cd	Cadmium
Pb	Lead
Hg	Mercury
Zn	Zinc

Ni	Nickel
Co	Cobalt
V	Vanadium
Fe	Iron
Mo	Molybdenum
Mn	Manganese
Ag	Silver
As	Arsenic
Hg	Mercury
Sb	Antimony
Al	Aluminum
Na	Sodium
NaCl	Salt (Sodium chloride)
Ca	Calcium
K	Potassium
Cl	Chlorine
H_2O_2	Hydrogen Peroxide
ABA	Abscisic Acid
ROS	Reactive Oxygen Species
SA	Salicylic Acid
O_2	Oxygen
P	Phosphorus
N	Nitrogen
Mg	Magnesium

Abbreviations	**Explanations**
PGR	Plant Growth Regulator
ASA	Acetyl Salicylic Acid
OH	Hydroxyl
SAG	Salicylic Acid-β-glucoside
SAR	Systemic Acquired Resistance

SOD	Super Oxide Dismutase
GST	Glutathione-S-Transferase
ASA	Acetyl Salicylic Acid
LA	Lipoic Acid
GSH	Glutathione
MDA	Malone dialdehyde
NPT	Thiol
APX	Ascorbate Peroxidase
TW	Turgid Weight
RWC	Relative Water Content
DW	Dry Weight
FW	Fresh Weight
AAS	Atomic Absorption Spectroscopy
SA*Cd	Salicylic acid Cadmium Combinations
SA*S	Salicylic acid Salt Combinations

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1. INTRODUCTION

1.1. Stress in Plants

Stress is usually defined as any unfavorable external factor that exerts a disadvantageous influence on the plant. Plants are exposed to many different environmental stresses in both natural and agricultural areas. Whereas the stress on natural habitats plays a major role in the distribution of plant species, on agricultural soils it causes a decrease in potential yield in productions. In general, stress-induced damages influence plant survival, crop yield, growth (biomass accumulation), or the primary assimilation processes (CO_2 and mineral uptake), that are related to overall growth. Stress factors are classified as biotic and abiotic. Besides environmental or abiotic factors such as climate and soil (edaphic) that produce stress in plants, biotic factors (weeds, pathogens, and insect predation) can produce stress, as well (Taiz and Zeiger, 2002).

Plants are exposed to different adverse conditions that restrict their living and development conditions in their environment. There are large areas on earth such as arid zones, saline soils, north and south poles, and high mountains, and conditions that facilitate plant growth in these areas can be realized for a short time. Unsuitable conditions that affect and prevent metabolism, growth, and development in plants, such as areas, are known as stress. Plants may encounter many stress factors throughout their lives. These stress factors, which can seldom affect the plant on their own, usually occur simultaneously. Stress factors are called biotic factors, which includes competition with infectious microorganisms (fungi, bacteria, virus), pests (insect, nematode) and other organisms, and changes in the environment such as temperature, water, radiation, chemical, magnetic are called abiotic (physicochemical) factors (Gürel and Avcıoğlu, 2001).

In most studies, the concept of stress is concerned with stress tolerance which is the plant's ability to survive against an unfavorable condition. On the other hand, an unfavorable environment that is stressful for one plant may not be stressful for another. For instance, pea (*Pisum sativum*) grow best at about 20°C (Vanhala, 2016) and soybean (*Glycine max*) at about 30°C (Yin et al., 2009), as well. The pea shows signs of heat stress

much sooner than the soybean, while temperature increases. Soybean shows a higher tolerance to heat stress than the pea. Moreover, different stress factors affect plants at different levels (Taiz and Zeiger, 2002).

Plants may have acquired tolerance as a result of prior exposure to any stress, it is stated that the plant has become acclimated or its resistance has increased. Acclimation is different from adaptation. The adaptation usually refers to the level of genetically determined resistance gained through selection over many generations. Acclimation and adaptation to environmental stresses are formed as a result of interconnected events: morphological, anatomical, cellular, biochemical, and molecular level. The responses of plants to a stress factor they encounter can be grouped under two main headings, generally avoidance and tolerance (Stewart, 1996). While avoidance refers to the prevention or reduction of the entry of stress factors into plant tissues, tolerance can be defined as mechanisms to eliminate, reduce or repair the effects of stress factors (Taiz and Zeiger, 2002).

Environmental factors that plants are exposed to have a huge impact on their quality and efficiency. For efficient cultivation, it is imperative to meet the optimum environmental requirements of the plants. It is possible to classify them as climate factors, soil factors, pollutants. Any deviation that occurs in these optimum demands creates stress for that plant and result in yield decreases. Abiotic stress, which causes the average yield of plants to decrease by more than 50%, is the primary cause of agricultural product loss in the world. Abiotic stress affects plant growth and productivity by causing morphological, physiological, biochemical, and molecular changes (Pinto et al., 2004).

To meet the food needs of the world population, it is necessary to use more inputs in agricultural areas to obtain more yields per unit area. In all areas of agriculture besides measures such as quality seed, mechanization, plant breeding, it is necessary to make conscious fertilization and irrigation, as well (Önal et al., 2003).

1.2. Cadmium Toxicity

In recent years, heavy metals are among the most important factors causing environmental pollution and increasingly dangerous hazards. In the late 19th and early 20th centuries, as mining and industrial activities increased, environmental pollution of

metals became widespread. Copper, cadmium, lead, and mercury are important in terms of current mineral production worldwide (Pinto, 2004). Heavy metals in the soil may consist of various sources such as industry-originated atmospheric sludge, mining activities, domestic landfills (anthropogenic sources), and phosphate fertilizer and wastewater sludge (Williams and David, 1976). Consequently, these pollutants, derived from an increasing number of different anthropogenic sources, have seriously affected various ecosystems (Macfarlane and Burchett, 2001).

53 of the total 90 natural elements are considered heavy metals. Among these elements, zinc (Zn), nickel (Ni), copper (Cu), cobalt (Co), vanadium (V), and cadmium (Cd) are toxic elements, while trace elements of high or low importance are iron (Fe), molybdenum (Mo), and manganese (Mn) are important micronutrients. Silver (Ag), arsenic (As), mercury (Hg), cadmium (Cd), lead (Pb), and antimony (Sb), whose function is known as nutrients, appear to be more or less toxic for plants and microorganisms (Weast, 1984; Niess, 1999). The toxic effects of heavy metals on plant physiology and metabolism are very complex and vary depending on the type and age of the plant, the nature, and the concentration of the heavy metal (Kevreśan et al., 1998).

Heavy metals are defined as metals with a density higher than 5 g/cm^3 and some of them are biologically important. They can be used for 17 heavy metal live cells dissolved under physiological conditions for plant and animal communities within ecosystems (Weast, 1984). Among the heavy metals, zinc (Zn), nickel (Ni), copper (Cu), vanadium (V), cobalt (Co), tungsten (W), and Chromium (Cr) are non-toxic elements with low concentration. Silver (Ag), arsenic (As), mercury (Hg), antimony (Sb), cadmium (Cd), lead (Pb), and aluminum (Al), which have no known functions are less or more toxic to plants and microorganisms (Sogut et al., 2005; Beak, et al., 2006).

Heavy metals are important environmental pollutants, and their condition is particularly in lithogenic and pedogenic natural process soils, but also in mining, fossil fuel combustion, urban waste disposal, soil runoff, metalworking industries, phosphate fertilizer application, and domestic solid waste disposal sites. Anthropogenic factors depend. Domestic and industrial wastes are the source of heavy metal accumulation in the soil (Alloway, 1995). The increase of heavy metals in the environment is considered an important cause of environmental pollution (Salt and Rauser, 1995; Akinola and Ekiyoyo, 2006).

Toxicity produced by transition metals leads to neurotoxicity, hepatoxicity, and nephrotoxicity. The different solubility, absorption, transport, and chemical reactivity of these metals cause certain differences in their toxicity within the body (Stohs and Bagchi, 1995). The chemical form of heavy metals present in the soil depends on the presence of the relevant metal, pH, and other ions (Das et al., 1997). In plants with excessive amounts of heavy metals, toxicity symptoms may occur due to several interactions at the cellular level (Hall, 2002). Metals that bind to sulfhydryl groups of proteins can be caused by toxicity leading to activity inhibition or degradation of the structure (Van Assche and Clijster, 1990). Metal interaction of enzymes with ligand groups largely identifies toxicity, and inhibition of enzymes can result from masking or protein denaturation of catalytically active groups (Das et al., 1997). Also, it stimulates the formation of excessive amounts of heavy metal-free radicals and reactive oxygen species (Dietz et al., 1999; Fornazier et al., 2002). Oxidative stress occurs in plants exposed to high metal concentrations. Some antioxidant enzymes may indirectly complement the role of phytochelatins in the cellular response to metal toxicity (Mazhoudi et al., 1997.). Plants have developed complex mechanisms to control the accumulation and detoxification of metals to deal with highly toxic metals or to contain the necessary metals that meet their physiological requirements (Taiz and Zeiger, 2002). The presence of excessive essential and non-essential metals in the atmosphere, soil, and water can cause serious problems for all organisms.

Photosynthetic organisms are extremely sensitive to heavy metals. The effects of metal ions on high plants include physiological dysfunctions such as photosynthesis, respiration, water, and mineral nutrient intake. Heavy metals disrupt the water relations and water uptake pattern in plant tissue, and generally, the development and leaf growth of the whole plant is reduced (Poschenrieder and Barcelo, 1999). The synthesis of reactive forms of oxygen is induced by the deterioration of electron transport as a result of oxidative stress (Dietz et al., 1999). Heavy metals impair essential nutrient intake and distribution, including Fe uptake and transport of leaves. This metal is necessary for chlorophyll synthesis and the normal function of all processes associated with CO_2 assimilation (Krupa et al., 2002).

The presence of cadmium (Cd), a heavy metal, on agricultural land may be mainly due to abrasion from rocks, or it may be due to human activities such as industrial

activities, phosphorus fertilizers, and household wastes (Assche and Clijsters, 1990; Sanita and Gabbrielli, 1999). It can reach high levels in agricultural soils and is easily absorbed by plants (Epstein and Bloom, 2005). The high mobility of this metal in the soil-plant system also facilitates entry into the food chain (Nogawa et al., 1987). Cd, which is released as oxidizing and mobile Cd^{+2} in oxidizing conditions, degrades the soil and is easily assimilated by plants. Almost all physiological processes are impaired by the excessive absorption of plants and lipid membranes are affected (Siedlecka, 1995; Ouariti et al., 1997; Vasilev and Yordanov, 1997).

Since cadmium has higher water solubility and mobility than other metals, it is also highly absorbable by the plant. For this reason, the most dangerous heavy metal accumulation in the soil. The levels of plants being affected by heavy metal stress differ according to environmental factors and the development period of the plant. Different plant types and genotypes within the species shows different sensitivity. For example, it has been observed that vegetables with tuber roots and eaten leaves accumulate more Cd for other vegetables and durum wheat for bread wheat (Stolt et al., 2003).

Cadmium causes many physiological changes in the plant as it changes the nitrogen and carbohydrate metabolism. It inactivates enzymes in the proteins –SH groups, causing stomata closure, decreased transpiration, and disruption of chlorophyll biosynthesis (Shah and Dubey, 1995). When taken in large quantities in the plant; It causes the phytotoxic effect, chlorosis, regression in the root, and stem growth, leading the plant to death (Van Assche and Clijsters, 1990). Toxic effects of cadmium; preventing stomata opening in plant leaves, disrupting the water balance, and decreasing mineral nutrient intake. Cadmium toxicity creates oxidative stress with the production of free oxygen radicals and changes in the activities of various antioxidant enzymes (Hernandez et al., 1996; Mendelssohn et al., 2001).

Although it is important to investigate Cd as an environmental pollutant, the mechanism of toxic effects on the plant is not fully understood. Cadmium is a strong oxidative stress factor in plants. As a result, it causes several toxic symptoms in plants (Hegedűs et al., 2001).

Cd^{+2} disrupts cell metabolism and regulation in plasmatic compartments, highly toxicity (Van Assche and Clijsters, 1990), delay in growth, inhibition of photosynthesis, changes in water relations, problems in the uptake and distribution of macro and

micronutrients, outflow of cations and it causes the proliferation of free radicals (Prasad, 1995; Ramos et al., 2002).

For the plants to get the metals in the soil, they have to put them in a mobile form. Plants can make the movement of metals attached to the soil in many different ways. For example, metal chelating molecules can be secreted into the rhizosphere to dissolve the metal in the soil and make chelates. Dissolved metal ions can enter the root by extracellular (apoplastic) or intracellular (simplistic) routes (Redjala et al., 2009; Johnson et al., 2011).

Most metal ions enter the plant cells through free energy through private or general metal ion carriers or channels. Some heavy metals can easily pass through carriers localized in membranes used by other heavy metals that act as nutrients for plants (Clarkson and Lüttge, 1989). When metal ions enter the root, they are either stored or sent to shoots. Metal transport to the shoots is probably by xylems. However, metals can also be distributed to shoots through the phloem (Stephan and Scholz, 1993).

Metal ions must first pass through the cascade strip to enter the xylem tubes. Since extracellular transport is blocked, metal ions have to act intracellularly to pass this water-impermeable cell wall strip. The xylem cell wall has a high proton exchange capacity, which is expected to significantly slow down metal movement. Therefore, metal-chelate complexes such as Cd-citrate facilitate metal movements in the transpiration stream. In addition, metals can be transported in phloem by forming chelates with organic acids and phytochelatins (Salt et al., 1995). In order to counteract the toxic effects of heavy metals, a plant must either detoxify when it enters the cell by limiting its uptake into cells or improve the heavy metal metabolism (Cumming and Taylor, 1990).

Prevention processes of heavy metal toxicity by reducing cellular uptake is very limited. However, preventing heavy metal intake can be a suitable strategy for sensitive tissues such as root tip meristem. When heavy metals are deposited in the cell, they must be detoxified. This can be in the form of chelation, limitation, and precipitation depending on the metal. Cadmium is also known to be deposited in the vacuole, where phytochelatins are associated with thiol-rich peptides (Van Steveninck et al., 1992). The mechanisms for transporting the Cd and Cd-phytochelatin complex occur through the passage through the tonoplast and the accumulation of Cd in the vacuole in relation to phytochelatins (Salt and Wagner, 1993).

The most prominent features of Cd toxicity in plants are slow growth and chlorosis. Chlorosis occurs due to the interaction of toxic metals and a lack of Fe. Chlorosis resulting from excessive accumulation of Cd results from the direct or indirect interaction of this heavy metal with Fe in the leaves (Das et al., 1997). In general, Cd stress causes leaf curl and chlorosis in plants. It prevents growth in roots and shoots. Cadmium is first taken with plant roots and its toxic effects are the first in this region. Passing into tissues, Cd can alter RNA synthesis and inhibit ribonuclease activity (Shah and Dubey, 1995). Cd can also cause inhibition of nitrate reductase activity in shoots, leading to reduced nitrogen transport to shoots (Hernandez et al., 1996.).

In young barley (*Hordeum vulgare*) plants exposed to Cd stress for a long time, the formation of photosynthetic pigments has been prevented and a decrease in the content of soluble proteins has been observed (Klimentina et al., 2006). The effects of Ni, Cd, and Mo on dry weight, nitrate content, nitrate reductase, and glutamine synthetase activity, soluble protein content in sugar beet (*Beta vulgaris*) were investigated and it was concluded that the heavy metal that had the most harmful effect on these parameters was Cd. It has been determined that the amount of linoleic and linolenic acid decreases in the cell membrane of the leaves and roots of tomato seedlings applied Cd (Kevreśan et al., 1998).

1.3. Salt-Salinity

Soil salinity is one of the most important sources of abiotic stress in world agriculture, and with the increasing salinity of the soil, the increase of salt in irrigation water prevents agricultural productivity in many semi-arid and arid regions of the world. UNEP states that 20 % of the agricultural areas in the world and 50% of the cultivated areas are under salt stress (Flower and Yeo, 1995). Soil salinity; it may arise from the basic structure of the soil, the use of low-quality water, excessive water, lack of drainage, and excessive use of fertilizers. With the decrease in irrigation water every year, the decrease in quality increases the salinity of the arable land.

The problem of saline soils is gradually increasing due to low-quality irrigation water and insufficient sewage system. In clayey (loamy) soils, the formation of clay clusters by connecting sodium to the negatively charged clay renders the soil inefficient

in the cultivation of the product and causes sodicity of the soil (high sodium concentration). Since the methods that can be used to eliminate the salinity problem in the soil are strong and costly, the selection of salt-resistant plant species and their highly tolerant genotypes has been the focus of many researchers in recent years.

Salinity problem is sometimes not of soil origin but may be caused by irrigation water. Especially in agricultural production carried out in arid and semi-arid ecologies, water requirement, which cannot be met only by precipitation, is met by irrigation. There are few or more dissolved salts in all surface and groundwater that can be used as irrigation water.

In nature, plants are collected in two groups in terms of salt tolerance: halophytes (salt plants) and glycophytes (plants affected and damaged by high salt concentrations). Halophytes; are salt plants and can develop at high concentrations of salt. Although only a few plant species can live in salty conditions on earth, they cannot survive under low salt levels. Some halophytes may even withstand salt concentrations more than twice the seawater concentration.

Almost all high plants are included in glycophytes and cannot survive at high salt concentrations (Levitt, 1980). Most plants important for agriculture are glycophytes and are not tolerant of high salt concentration. Salinity causes secondary stresses such as ionic, osmotic, and oxidative stress in glycophytes (Zhu, 2001a). Sodium toxicity indicates the relationship between high salinity and ionic stress. Besides, some plant species are sensitive to the chloride anion found in saline soils. Ion toxicity is increased with alkaline pH in saline soils. The low osmotic potential of salt solutions prevents plants from getting water, resulting in physiological drought. For halophytes tolerant to sodium toxicity, osmotic stress can be an important cause of growth inhibition.

Understanding the salt tolerance mechanisms of plants can lead to growth impacts or improvements in genetic engineering. Salt tolerance studies represent an important part of basic plant physiology. These researches; allows us to understand gene regulation, ion transport, osmoregulation, and the use of mineral substances. Also, some states of salinity stress responses are associated with drought and chill stress responses (Zhu, 2001b). Plant salt tolerance studies help us understand abiotic stress tolerance mechanisms. Generally, agricultural products either avoid salt stress or show tolerance. So, these plants are either salinity resistant or have cellular arrangements for tolerance. Tolerance mechanisms are

shaped by relieving ion imbalance and osmotic stress or secondary effects caused by this stress. The chemical potential in the salt solution creates an unbalanced water potential between apoplast and simplest to maintain turgor reduction. This situation causes growth to decrease (Bohnert and Sheveleva, 1998).

Growth ceases when the turgor is lower than the initial cell wall yield. Since water potential loss is higher than the loss of turgor, it causes cellular dehydration in the plant (Taiz and Zeiger, 2002). Since NaCl is the most important cause of soil salinity, transport systems involving the use of Na^+, an osmotic solution, have been the focus of research (Hasegawa et al., 2000). According to more than 30 years of research, intracellular Na^+ balance and salt tolerance are adjusted by high [Na^+] ext that negatively affects Ca^{+2} and K^+ gain (Rains and Epstein, 1967). They compete to rise in Na^+ and K^+ transport systems. However, in salty environments, [Na^+] ext is carried more than [K^+] ext. Ca^{+2} increases K^+/Na^+ intracellular accumulation. According to the researches carried out in the last 10 years, many molecules that have survived with Na^+ and K^+ balance and have worked together with Ca^{+2} in the regulation of these transport systems have been identified.

Recently Salt-Overly Sensitive (SOS), the stress-signal pathway has been found to play an important role in the regulation of salt tolerance and ion balance. This signal path controls the Na^+ input output from the plasma membrane (Hasegawa et al., 2000; Sanders, 2000).

The cellular response to turgor reduction in osmotic regulation. Na^+ and Cl^- sensitivity is equal in the cytoplasm and organelle systems of glycophytes and halophytes. Thus, osmotic regulation takes place with the accumulation of suitable osmolites and osmoprotectants (Bohnert and Jensen, 1996; Bohnert, 1998). Na^+ and Cl^- are the most efficient osmolites for osmotic regulation and are accumulated in vacuoles to alleviate cytotoxicity (Niu et al., 1995).

The development of plant cells develops primarily with increasing vacuole volume. It is very important for cellular development that Na^+ and Cl^- facilitate osmotic regulation by accumulation in the vacuole. The movement of ions in the vacuole takes place from the apoplast membrane vesicles in the vacuole or from the plasma membrane to the tonoplast (Hasegawa et al., 2000). Ion accumulation in the vacuum can be achieved by not exposing it to toxic ions or minimizing it. However, the existence of mechanisms that contribute to this ion accumulation is not clear enough. As with the ion transport

system localized in the plasma membrane and tonoplast, a significant portion of Na^+ and Cl^- move from apoplast to vacuole. Probably the regulation of this ion transport system is necessary for the control of vacuole accumulation and plasma membrane transitions. Salt-Overly Sensitive (SOS) signal path, which is the key transport system for ion homeostasis in many plants, is very important (Hasegawa et al., 2000; Sanders, 2000).

With salinity, nutritional deficiency, ion toxicity, the metabolic imbalance caused by osmotic stress causes oxidative stress (Zhu, 2002). Ion cytotoxicity is due to the loss of functions of proteins due to the displacement of K^+ and Na^+ in biochemical reactions and conformational changes, as well as the inhibition of non-covalent interaction between amino acids.

Levitt (1980), on the other hand, interprets ion toxicity caused by salt stress as a primary effective stress factor, followed by reduced water intake, i.e. water stress and mineral substance imbalances and nutritional deterioration as secondary stress factors. Salinity causes the biosynthesis of ABA, a stress hormone, and the accumulation of reactive oxygen species (ROS) (Jia et al., 2002, Xiong and Zhu, 2003). ABA and ROS regulate ionic and osmotic homeostasis as well as the control and repair mechanism of stress destruction. Cell volume decreases with the loss of turgor under salt stress. This is done by withdrawing the plasma membrane from the cell wall (Kreps et al., 2002; Seki et al., 2002).

The reduction in chlorophyll amounts due to the disruption in the overall metabolic process has been reported by many researchers. (Cicek and Cakirlar, 2002) reported that corn and Gadallah (1999) reported decreases in chlorophyll content of leaves under salt stress in broad bean plants. Other parameters affected by stress are root and shoot dry weights, plant height, and stem diameter. In plants under salt stress, there is a significant decrease in the ability of the roots to absorb water, thereby decreasing activities such as root development and stem growth. The stems of the plants under stress decrease and their length are small compared to the control. Likewise, during the transition to the leaf area and the generative phase, flowering and fruit yield are also negatively affected. It has been reported by other researchers in many plants that there are significant reductions in dry matter and wet weights in the shoots and roots of plants under stress (Daşgan et al., 2002; Irshad et al., 2002).

Salinity stress studies consist of 4 successive categories. 1) Physiology and salt tolerance of salt toxicity: This includes all plant responses as well as cellular and metabolic responses (Greenway and Munns, 1980; Flowers and Yeo, 1995; Bohnert and Sheveleva 1998; Hasegawa et al., 2000). 2) Mechanism of salt transport in cellular membranes and longer distances in plants: This mechanism includes the molecular characterization and physiology of various ion carriers, including salt intake, and control of long-distance transport (Blumwold et al., 2000). 3) Regulation of genes expressed by salt stress (Bohnert and Yensen, 1996; Bray, 1997; Zhu et al., 1997). 4) Mutational analysis of salt stress signals and salt tolerance markers (Xiong and Zhu, 2001).

The difference in salt sensitivity is due to the difference in regulation loops or the coding of allele genes for different salt effectors. Increases in the amount of synthesis of some molecules in plants exposed to stress have shown that these substances play an important role in increasing plants' stress resistance or tolerance. Many molecules such as Ca, jasmonic acid, abscisic acid, ethylene, polyamines, and salicylic acid (SA) act as a messenger and/or signal transducer in plants (Klessig and Malamy, 1994).

As a result of the studies carried out, an increase in the amount of synthesis of these substances was found in plants that can tolerate stress factors, or by increasing the concentration of these substances in the plant with external applications, stress tolerance mechanisms were found to be activated (Senaratna et al., 2003; Korkmaz, 2005).

Salinity prevents carbon metabolism and electron transport activity in plants, as in other stress factors caused by abiotic stress factors such as high and low temperature, drought, and mineral element deficiency (Gueta-Dahan et al., 1997). Plants under salt stress close their stomata in order to reduce water loss, thus preventing the entry of CO_2 gas. As a result, CO_2 fixation decreases (Brugnoli and Lauteri, 1991; Makela et al., 1999). The light energy absorbed by electrons not used in carbon dioxide fixation is used in the activation of O_2, that is, in the synthesis of radicals (Hallewel and Gutteridge, 1985).

As explained by Choudhury et al. (2013), increasing levels of free radicals in plants under stress damage the cells, especially the membrane lipids that enter the deceleration process and disrupt cell components such as nucleic acids and chlorophyll. The chlorophyll content is also negatively affected by plants under salt stress. Factors such as disruption of general metabolic activities under salt stress and restriction in the

uptake of macronutrients such as N, P, and Mg, especially Ca and K, negatively affect chlorophyll activation (Fridovich, 1986; Davies, 1987).

Oxidative stress that develops with salt stress is directly related to the accumulation of sugars. Melted sugars start the oxidative pentose phosphate pathway and contribute to the clearance of ROS (Russell and Conn1967). Although the use of ions in osmotic regulation is preferable in the biosynthesis of organic osmolytes under osmotic stress, some plants accumulate organic osmolytes as osmotic stress tolerance. These osmolytes include proline, betaine, polyol, sugar alcohols, and soluble sugars. They act as an osmoprotectant with the stability of the quartile structures of glycine betaine and trehalose proteins. While Mannitol cleans free radicals, proline; acts as a storage source and free radical scavenger for carbon and nitrogen. All these organic osmolytes are known as osmoprotectants (Bohnert and Jensen, 1996; Chen and Murata, 2000).

Failure to use water caused by drought and salt stress increases the amount of sugar as well as causes a change in the content of organic acids (Ehret et al., 1996). As the cation/anion ratio changes in the plant under salt stress, organic acid accumulation also changes. Davies (1964) argued that the mechanism of accumulation of organic acids developed to achieve the balance of accumulated cations (K^+). If K^+ is inhibited, Na^+ takes on the same task instead, and the same mechanism develops for organic acid.

1.4. Salicylic Acid as Stress Inhibitor

Generally, for plants to complete their growth and development, some internal and external factors must play a role, and the main internal factors that regulate them are chemical in nature. Plant growth regulator (PGR) is generally called organic molecules that are synthesized in plants naturally, controlling growth and other physiological events related to it, can be effective in areas where they are transported to other parts of plants from where they occur, and show their effect even in very small amounts (Öktüren and Sönmez, 2006). These plant growth regulators that are formed within the plant and regulate growth and development are called hormones or phytohormones (plant hormones). The importance of plant growth regulators was understood at the beginning of the 19th century and it has been tried to investigate their function in agricultural products since then.

According to Barut (1995), the purposes of the use of PGRs in agriculture today are as follows; flower and fruit dilution, steel rooting, germination, fruit set, and parthenocarpy, affecting rest mechanism, sex formation, flowering, improving fruit quality, reducing pre-harvest spills, delaying aging, preservation, tissue and meristem cultures and disease and weed control (Akgül, 2008). Some of the PGRs stimulate and accelerate plant growth and development. This group, called stimulator, includes auxin, cytokinin, and gibberellins. Some of them are called inhibitors because they have effects that delay growth and development, abscisic acid and ethylene are from this group (Öktüren and Sönmez, 2006).

Plants respond to stress conditions with the balance they will establish between internal hormones and physio-biochemical changes and generally change the amount of stress plant hormones (Öktüren and Sönmez, 2006). It is stated that PGRs, which improve the plant's metal tolerance, are able to reduce metal damage in the plant when applied externally (Tassi et al., 2008).

In line with the studies conducted, the heavy metal stress of plant growth regulators on the plants; is effective in mechanisms such as the release of organic acids and carbohydrates into the rhizosphere and reduction of heavy metal intake, accumulation of heavy metals in the areas that are removed from metabolic ways such as cell walls and vacuole, increasing antioxidant enzyme activities and antioxidant molecules, repairing cell membranes. It has been demonstrated that it is alleviated (Kovacik et al., 2009; Belkhadi et al., 2010; Bashmakov et al., 2012).

Based on hormonal adaptation, various hormones have been tried to provide resistance to stress conditions and the effects of these hormones in plants under some stress conditions have been examined. It has been determined that salicylic acid, which has been widely used in researches recently changing physiological activities, and which is considered as the main source of aspirin and phytohormones, is present in all plants. Salicylic acid (SA), which is a plant phenolic, usually bearing a hydroxyl group or its functional derivative, is derived from the scientific name of the willow tree, Salix. In addition to abiotic conditions in plants, it has been determined that abnormal changes in biotic conditions occurring in plants activate salicylic acid. It has also been determined that this hormone is found intensely in necrosis and infected areas and is active in a possible stress situation (Arteca, 1996).

It is known that American Indians and Greeks used the bark and leaves of the willow tree to treat some diseases such as headaches. Acetylsalicylic acid (ASA), which was first isolated in the laboratory by a scientist named Raffaele Piria in 1828, is one of the best known and used anti-stress compounds known as aspirin (Popova et al., 1997). SA, with its chemical formula C7H6O3, is a colorless crystalline organic acid and its open formula is as follows (Figure 1.1).

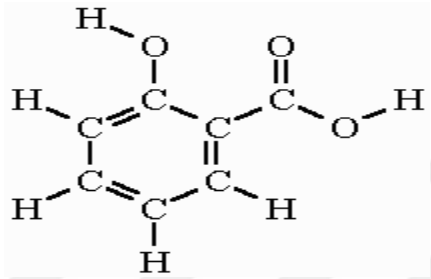

Figure 1. 1. The structural formula of salicylic acid.

Production of the first salicylic acid was started in Germany in 1874 and aspirin, the commercial name of which was acetylsalicylic acid was introduced by the Bayer cooperative in 1898. Today, it has been accepted by some scientists that salicylic acid is widely available in many plants and is an important development substance (Arteca, 1996).

SA, a phenolic compound, has recently been described as a plant hormone because of its various physiological and biochemical roles in plants (Raskin, 1992). For example, SA inhibits proteins-related pathogenesis and the inhibitory effects of heavy metals can be reduced upon germination of two rice seed varieties (Mishra and Choudhuri, 1997). SA, a secondary metabolite in the aromatic ring plant phenols group carrying hydroxyl (-OH) group, is thought to play a major role in regulating plant responses to many environmental stresses (Senaratna, 2000). The use of growth regulators to adapt plants to adverse environmental conditions such as osmotic stress and salinity is among the approaches that enable plants to develop stress resistance (Mishra and Choudhuri, 1997). SA can be regarded as an intrinsic growth regulator of phenolic compounds that help regulate physiological events in plants (Shakirova et al., 2003).

Complementary biochemical and genetic approaches for plants are used to study the signal network that adjusts natural immune responses. Based on receptor-mediated recognition, synergistic interactions between nitric oxide, reactive oxygen intermediates, and SA, the signal enhancement cycle causes biotic and abiotic stress. Alternative resistance mechanisms that act against different types of stress develop between SA and/or growth regulators. Besides, SA has been identified as an important signaling element, including establishing a response to local and systemic diseases in plants after pathogenic attacks (Alvarez, 2000). After a pathogenic attack, the level of SA usually increases and stimulates pathogenesis-related proteins, hypersensitive responses, and systemic acquired resistance development begins. During the hypersensitive response, SA emerges to regulate the delicate balance between baseline and destruction functions (Klessig and Malamy, 1994).

SA, a powerful signaling molecule, responds to specific biotic and abiotic factors in plants. It is also known that SA protects the plant from cadmium toxicity (Janda et al., 1999; Metwally et al., 2003). Externally applied SA activates various defense genes in plants. SA level increases in plants as a result of certain systemic resistance, in response to infection, ultraviolet light, and exposure to ozone, and is believed to be part of the signaling process (Rasmussen et al., 1991).

It has been suggested that there are two metabolic pathways for SA formation in plants. In these ways, it was found that the order of formation of SA β-oxidation and ortho-hydroxylation reactions are different from each other. In this regard, SA has been proven to be derived from cinnamic acid by benzoic acid in healthy and virus-inoculated tobacco plants. Accordingly, in young tomato seedlings infected with Agrobacterium tumefaciens, it was revealed that ortho hydroxylation of cinnamic acid to ortho-coumaric acid increased, followed by SA-oxidation of coumaric acid. In plants, Salicylic acid is synthesized from Shikimic acid by benzoic acid and coumaric acid (Yalpani et al., 1993; Davis, 1995) (Figure 1.2).

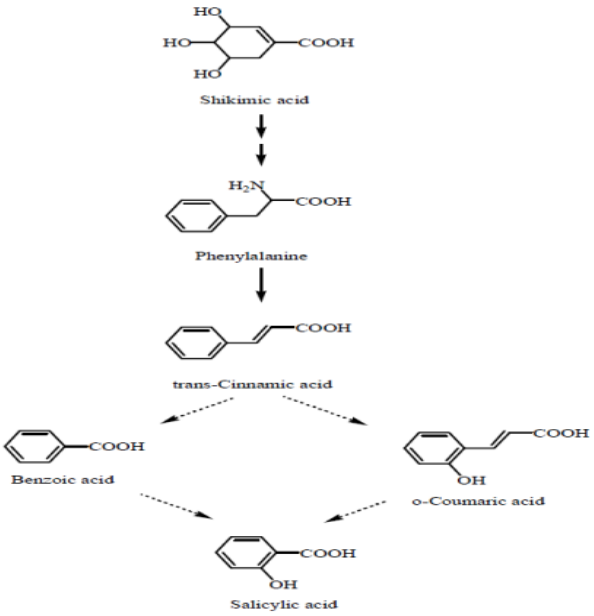

Figure 1.2. Metabolic pathway of salicylic acid biosynthesis in plants.

In plants, SA can be found in bound forms as esters and glucosides as well as metabolically active free form. SA plants are generally found in the form of salicylic acid-β-glucoside (SAG), which is a sugar compound, that is, in an inactive form (storage form). The enzyme g-glucosidase controls the signal activity of hormones in plants and regulates the free SA level in the plant by catalyzing the conversion of SA from bound form to free form (Raskin, 1995). In a tobacco study, when SA was applied to the leaves of this plant from outside, salicylic acid-β-glucosidase activity appeared in the intercellular spaces of the leaves (Davis, 1995). While a large part of SAG is located in intercellular spaces, a large part of SA is located within the cells. Because the shaping of SAG from SA occurs within the cells. This indicates that SA applied externally enters the cells directly. As a result, the view has emerged that SAG can play the role of signal that is transported to distant tissues through intercellular spaces. SAG is considered to be suitable for long-distance transport of SA. Because SAG is both more soluble than SA and less toxic (Seo et al., 1995). SA is an important endogenous compound that regulates growth and acts on metabolism in plants (Alvarez, 2000; Sakhabutdinova et al., 2003). SA has been reported to promote flowering in some plants, have a thermogenic effect (Raskin et al., 1989; Chen et al., 1993), increase thermotolerance (James et al., 1998), significantly reduce leaf

shedding (Ferrarese et al., 1996), and provide resistance to pathogens (Salisbury and Ross, 1992).

There are reports that SA has tolerated many stress factors such as (temperature, drought, and cold). As it is known, one of the important effects of stress factors on plants is leaf fall (senescence) and chlorosis is an important external indicator of leaf fall (Senaratna et al., 2000).

1.5. Interactions between Cd and SA

Plant hormones are vital to stress management. Auxins have been observed to improve the intensity of various stresses (Choudhary et al., 2013). It is stated that plant growth regulators (PGR), which improve the plant's metal tolerance, can reduce metal damage in the plant when applied externally (Tassi et al., 2008).

Exogenous applications of salicylic acid (SA) against different biotic and abiotic factors in plants have been adjusted by many researchers and are still being in the progress. In many Cd applications, the positive effect of SA, which is applied externally on the activity of antioxidant enzymes, increasing the tolerance to heavy metal stress by reducing the peroxidation of lipid molecules, especially in the roots, has been determined. This suggests that SA plays a direct or indirect role in the stress mechanism caused by Cd (Metwally et al., 2003).

With this study, salicylic acid will be applied to the lettuce plant, which must be cultivated in areas heavily contaminated with Cd and known to accumulate a high amount of Cd, which contributes to the plant's resistance mechanism against various stresses.

1.6. Interactions between NaCl and SA

Due to intensive agriculture and especially greenhouse agriculture, which is becoming widespread today, the soil becomes salty every year and restricts the growing areas of the plants or decreases the yield of the plants. Salinization caused by intensive use of soil causes adverse conditions such as weakened vegetative development and decreased yield. Different applications are tried to reduce these negative effects and increase the plant's tolerance to salt.

The resistance of plants to salinity differs from each other. In general, in vegetable groups, salt-resistance is more sensitive than other plants and for this reason, vegetables should be watered with frequent and high-quality water (Ayers and Westcot, 1989; Öztürk, 2002), (Table 1.1).

Table 1.1. Productivity changes (%) of vegetables according to salt tolerance (Kotuby et al., 1997)

Plant	Threshold		A decrease in productivity (%)					
	Soil EC dS m^{-1}	Water EC dS m^{-1}	10		25		50	
			Soil EC dS m^{-1}	Water EC dS m^{-1}	Soil EC dS m^{-1}	Water EC dS m^{-1}	Soil EC dS m^{-1}	Water ECdS m^{-1}
onion	1.2	1.0	1.8	1.2	2.8	1.8	4.3	2.9
pepper	1.5	1.0	2.2	1.5	3.3	2.2	5.1	3.4
carrot	1.0	0.7	1.7	1.1	2.8	1.9	4.6	3.1
lettuce	1.0	0.9	2.1	1.4	3.2	2.1	5.2	3.4

In many studies, plant growth regulators and vitamins have been used to minimize the negative effect of salinity on seed germination, growth, enzyme activity, and mitotic activity (Çavuşoğlu and Kabar, 2008; Tabur and Demir, 2008, 2009, 2010; Çavuşoğlu and Tabur, 2015). SA is a growth regulator that positively affects salt stress in plants, also stimulates systemic acquired (SAR) resistance against bacteria, fungi, and viral infections in plants, and causes physiological effects such as increasing nitrate reductase activity and dry matter amount in some plants. In addition, SA is used successfully against many abiotic stress factors such as high and low temperatures, water, heavy metal, frost, and drought stress (Kaydan and Yağmur, 2006).

Studies have included information about the negative effects of salt stress on plants and the use of various chemicals to reduce the salinity damage of plants, as well as information that salicylic acid reduces salt stress in various plants. Based on this information, the main purpose of the study is to investigate the response of salinity stress by using SA in lettuce (*Lactuca sativa*) plant.

Therefore, the purpose of this study is; lettuce (*Lactuca sativa*) plant, which is very sensitive to salt stress, to investigate the effect of the salicylic acid application on the salt and cadmium stresses of the plant growth criteria and nutrient uptake changes occurring during this process.

2. LITERATURE REVIEW

Zhang et al. (2014), in their study to investigate the effects of cadmium on plant development, photosynthesis, nutrients, and Cd accumulation, determined that cadmium reduces the amount of chlorophyll, and accordingly, photosynthesis and plant mass decrease, and heavy metals can reduce and increase the body water content. Since cadmium enters the plant through cation (Ca and Mg) channels or is transported with divalent cations such as Zn, Cu, Fe, and Mn are effective in their roots and an antagonistic relationship between them, and Fe and Mn concentrations decrease in the root and found that Zn and K elements are effective.

Li et al. (2014), in their study for Cd tolerance and accumulation, as the visual symptoms, the color of the roots in the control plant was white and the root colors of the treated plants were brown and black, the increasing Cd concentration and the plant Cd concentration increase in parallel, the leaf area decreases, the water content of the plant decreases.

Belkhadi et al. (2010), in their study to investigate the effect of salicylic acid on cadmium stress, decreased root and stem length, root and stem fresh weight with the application of salicylic acid (250 and 1000 μM) with Cd (50 and 100 μM) applications. They emphasized that it has not changed. They found that the increased Cd concentration in the plant prevents the transport of salicylic acid, decreases in the plant, decreases the K, Ca, Mg, and Fe concentrations in the plant with the application of Cd decreases in the leaf with the application of salicylic acid, and the salicylic acid can be used to relieve the stress of plants under Cd stress.

Correa et al. (2006), investigated the relationships between Cd toxicity and enzyme activity at different shoot endpoints in three separate plants (oats, cabbage, and lettuce). As a result, it was determined that the most sensitive change in Cd toxicity conditions was observed in enzyme activity, germination rate and plant growth were less affected.

Azizian et al. (2011), investigated the effects of lettuce plants, which were irrigated with different cadmium levels (0, 5, 10, and 20 mg L^{-1}) at different intervals (1, 2, and 4 days) in the pot experiments they conducted. As a result, irrigation water and soil

cadmium levels increased in all cadmium levels, and productivity increased at low cadmium levels. The presence of cadmium in irrigation water did not affect nutrient absorption, except iron, by the lettuce plant. High cadmium levels caused a decrease in the iron content of the lettuce plant.

Jiang et al. (2004), investigated the effect of cadmium application on the nutrient content of the shoots and roots of the Indian mustard plant. Cd $(NO_3)_2$ at 0, 50, 100, 150, and 200 mg Cd kg^{-1} levels were applied to the environment where the Indian mustard plant was grown. Cadmium accumulation in shoot and root increased with increasing cadmium levels in the soil. It has been determined that cadmium accumulation is higher in the roots than in shoots.

Hassan et al. (2005), in their study using two kinds of paddy plants; investigated the effect of cadmium toxicity on plant development, antioxidative enzyme activity, lipid peroxidation level. Cadmium stress caused a decrease in chlorophyll content and plant height. As an indicator of lipid peroxidation, MDA content increased due to cadmium increase in leaves. Increased cadmium in the root and stem caused a decrease in SOD, POD, and CAT enzyme activities.

Correa et al. (2006), tried to determine the effect of cadmium applied to lettuce, cabbage, and oat plant on wet weight, germination rate, and antioxidative enzyme activity in plants. In the experiment, 0, 6.25, 12.5, and 50 mg kg^{-1} Cd was applied to the plants. As a result, the effect of cadmium applications on lettuce, cabbage, and oat plants on plant biomass was found to be negative. Enzyme activities (catalase, peroxidase, superoxide dismutase, and glutathione reductase) were found to increase significantly compared to control.

Haghighi et al. (2010), investigated its effect on the development of lettuce and antioxidative enzyme activity by applying increasing levels of humic acid and cadmium to the lettuce plant grown in aquatic culture. Humic acid levels were applied as 0, 100, 1000 mg L^{-1}, and cadmium levels as 0, 2, 4 mg L^{-1}, respectively. As a result, it was found that the application of cadmium caused a decrease in fresh weight in the leaves of the lettuce plant, increased enzyme activity, and increased cadmium level in the leaves. However, the addition of humic acid to the nutrient solution reduced the absorption of cadmium by the plant relative to the increased cadmium concentration.

Monteiro et al. (2012), investigated the effect of increasing rates of cadmium applications (0, 1, 10, and 50 μM) on cadmium accumulation and enzyme activity in the roots and leaves of the lettuce plant. It has been determined that SOD and catalase activities increase with the addition of cadmium in the leaves where cadmium accumulation is lower than the roots. Researchers reported that due to the toxic effect, SOD and peroxidase activity increased in the root, whereas glutathione reductase activity did not change in both plant organs.

Dias et al. (2013), examined the toxic effects of cadmium on the photosynthetic system in lettuce plants. The effects of 0, 1, 10, and 50 μM cadmium application levels on rubisco activity, CO_2 extraction rate, plant growth, and nutrient uptake were investigated, respectively. In the study, cadmium at the level of 10 and 50 μM caused a decrease in rubisco activity and a decrease in the rate of carbon dioxide extraction. In addition, nutrient intake and dry matter content were negatively affected by cadmium.

Ivanova et al. (2008), examined the role of salicylic acid against changes in cadmium caused by cadmium leaves. First, they divided the corn leaves into two groups and applied SA and pure water. Later, they made the Cd application necessary by using three different doses. In the study, low-stress effects in salicylic acid pretreatment groups and high-stress effects in cadmium groups that were not pretreated were observed. These high-stress effects; biochemical and physiological changes. Changes in the fatty acid profile were found to be insignificant compared to the non-pre-treated groups. It has been reported that in groups where salicylic acid pretreatment has not been applied, a strong decrease in trienoic fatty acid and an increase in saturated fatty acids have been observed and the 18:0 to 18:3 ratios have deteriorated in this way. It was concluded that SA plays a protective role in membrane lipids in corn plants treated with Cd.

Kaydan and Yağmur (2006), in their study on wheat and green lentils, different salicylic acid doses (0, 1.281 mg da^{-1}, 128.1mg da^{-1}, 12.810 g da^{-1}) and their application forms (seed and leaf spraying) studied the effects on yield and yield components. According to the results obtained in the research; It was determined that the application methods on yield and yield components except plant height were not effective in the wheat trial, but salicylic acid doses increased all the features except for fertile spike count and thousand weight per square meter. The highest grain yield was obtained from 276.58 kg da^{-1} to 128.1 mg da^{-1} salicylic acid dose and the grain yield per unit area was

determined to be 24.8%. In the lentil experiment, it has been determined that the number of plants per square meter, plant height, and thousand-grain weight, salicylic acid doses, and application methods are not effective. It has been determined that with the increase of salicylic acid doses, the total number of branches, the number of seeds in the plant, the grain yield in the plant and the grain yield per unit area, the total number of branches in the plant, and the number of seeds in the plant were affected by the application of salicylic acid in the form of seeds and leaves. It was determined that the highest unit area grain yield was obtained in 141.60 mg da^{-1} and 128.1 mg da^{-1} salicylic acid dose and foliar application.

Krantev et al. (2008), investigated the role of cadmium in the corn plant to reduce the negative effects of pretreatment with SA against oxidative stress damages and negative effects on photosynthesis. Cadmium caused a drop in root and shoot dry weight, chlorophyll content, and growth parameters in the plant. Again, cadmium led to changes in many parameters related to oxidative stress. Proline caused an increase in hydrogen peroxide and lipid peroxidation levels. In SA pretreated groups, growth parameters, root and shoot dry weight and decrease in chlorophyll content decreased. Again, the decrease in the parameters related to oxidative stress decreased. These data lead to the idea that salicylic acid has a protective role against oxidative stress damage and the effects on photosynthesis in plants under cadmium stress pretreated with SA.

Popova et al. (2009), investigated the effects of SA pre-soaking on Cd (0, 0.5, 1, 2, and 5 μM) toxicity in seedlings of Pea (*Pisum sativum*). When SA was added to the growing medium, the CO_2 assimilation in the plant increased for 1 and 2 μM Cd but decreased at other concentrations. Overall, enzyme activity decreased with increasing Cd concentration. Lipid peroxidation and peroxidase activity decreased in seedlings with SA pretreatment. In contrast, the amount of proline and electrolyte flow increased more in SA pre-treated seedlings. FAME (fatty acid methyl esters) showed an increase in the concentration of 2 μM Cd in SA pre-treated seedlings. In seedlings without SA, linolenic acid (18: 3) decreased. SA pretreatment led to an increase in the amount of linoleic acid (18: 2) for only 0.5 μM Cd. In seedlings without SA pre-application at a concentration of 2 μM Cd, an increase in the amount of the same fatty acid was observed.

In another study, Belkhadi et al. (2010), investigated the effects of SA and Cd toxicity on plant growth, lipid peroxidation, and fatty acid composition in flax (*Linum*

usitatissimum) plants. It was determined that Cd accumulation increased in roots and shoots and plant growth was preserved when SA was applied. Cd decreased the content of total lipids and chlorophyll in the leaves while increasing the amount of MDA. However, the opposite result was found in the leaves with SA. The dose of fatty acids in Cd, which is 50 μM, increased by 16: 0 and 18: 0. The values of 18:- 2 and 18:- 3 increased at all doses of Cd, but decreased by 18:- 1. SA application lowered 18:- 1 while increasing 18:- 2 and 18:- 3.

Mohsenzadeh et al. (2011), SA's study on the mitigating effect of cadmium (100 μM) on corn (*Zea mays*) seedlings; Negative effects on seedling growth, shoot and root fresh weight, proportional water content (RWC), chlorophyll amount decreased, free proline, dissolved sugar content and lipid peroxidation were observed at a lower rate. It was observed that SA (500 μM) significantly reduced the inhibitory effects of cadmium on corn (*Zea mays*) seedlings.

Ahmad et al. (2011), examined the healing effects of SA on Cd toxicity in their study on mustard plants (*Brassica Juncea*). In the study, while the value of proline decreased when Cd was applied, the value of proline increased when Cd was applied together with SA. MDA and H_2O_2 values increased with Cd doses but decreased when SA was applied. It was seen in this study that SA weakened the negative effects of Cd and improved oxidative damage.

Moradkhani et al. (2012), in the study of sunflower (*Helianthus anuus*) plants, the values of fatty acids decreased as Cd concentrations increased. Trunk and root length, leaf, root, stem fresh weight decreased with Cd concentrations and increased with SA applications.

Saidi et al. (2013), in a study on bean (*Phaseolus vulgaris*) seedlings, the healing effect of SA application against increased Cd concentrations were investigated. While the amount of chlorophyll and carotenoid decreased in the leaves of the bean (*Phaseolus vulgaris*) when Cd was applied, an increase was observed with SA application. Since SA administration reduces the amount of MDA, it has been reported that oxidative damage is alleviated.

Turhan et al. (2014), examined the effect of different salinity levels (1.60, 2.87, 4.14, 5.41, 6.68, and 7.95 dS m^{-1}) on garlic. In the study, they investigated the total dry matter, total soluble solids, total sugar, total acid, vitamin C, and protein values in plants. As a

result of the study, they found that salinity had a statistically significant effect on the yield and quality of the plant. It was determined that the plant yield, total sugar, and acid content were not affected up to 2.87 dS m^{-1} salinity and the content of soluble solids and protein to 4.14 dS m^{-1}. It is determined that the garlic plant can be grown in soils with salinity up to 4.14 dS m^{-1} considering all parameters.

In Yeter et al. (2015), they examined the effects of the application of different saline waters with different washing rates on the germination and development of alfalfa. Within the scope of the study, 3 different salt waters (0.25 dS m^{-1}, 1.5 dS m^{-1} and 3.0 dS m^{-1}) were used in 4 different washing rates (10%, 20%, 35% and 50%). As a result of the study, it was determined that salinity and washing rate were effective on plant yield and the salinity threshold of the plant was 1.5 dS m^{-1}.

In their study, Aydın and Atıcı (2015), the effect of salt concentration on germination and seedling development of different plants; The effects of salt (NaCl) stress on germination and seedling development of wheat (*Triticum aestivum* cv. *Bezostaya*), tomato (*Lycopersicon lycopersicum* cv. H55711), beans (*Phaseolus vulgaris sp. sphearicus*) and corn (*Zea mays* cv. *Hido*) species have been reported to have different effects. Due to the increase in salt concentration, both germination and seedling development was significantly prevented in all cultivars.

Baath et al. (2017), conducted that a study to determine the effect of salinity on pepper plants and used 5 different salt concentrations (3, 3.5, 6, 8, and 10 dS m^{-1}) in the study. As a result of the study, it was determined that the increase in salinity caused an increase in germination time and the increase in irrigation water salinity caused a decrease in photosynthesis, stomatal conductivity, fruit weight, and water use efficiency.

In their study, Çanakçı and Munzuroğlu (2004), investigated the mutual effects of 50 ppm acetylsalicylic acid (ASA) and 1% NaCl on the weight and wet-dry weight change, pigment and protein amount in cuttings from one-week-old bean seedlings grown in greenhouse conditions. Trial solutions were applied to the cut body ends of steels through a closed system. According to the results obtained; In terms of wet weight increase, no statistically significant difference was found between steels that were treated with 50 ppm ASA and steels belonging to the control group, while the wet weight loss in steels with 50 ppm ASA + 1% NaCl treated was less than 1% NaCl treated steels. As the water content of steels exposed to salt stress is lower than that of ASA treated steels, it

has been determined that ASA application reduces the amount of dry matter. 50 ppm ASA, control, 50 ppm of chlorophyll b and total pigment II in the steels where the water content is in the form of control, 50 ppm ASA, 50 ppm ASA + 1% NaCl, 1% NaCl according to the groups and respectively, respectively. It was determined that the amount of chlorophyll a and total pigment I in the form of ASA + 1% NaCl, 1% NaCl were in the form of control, 50 ppm ASA, 50 ppm ASA + 1% NaCl, 1% NaCl according to the groups. As a result, against the osmotic effect of acetylsalicylic acid by salt; They determined that wet weight loss, chlorophyll b, and total pigment II breakdown in steels are prevented at certain rates and also reduces protein breakdown due to stress in steels.

In his study, El-Tayeb (2005), investigated the effect of applying 0, 50, 100, 150, and 200 mM NaCl to barley seeds, where 1 mM salicylic acid solution was applied before planting. It has been found that increased NaCl level reduces the germination percentage and decreases the growth parameters (fresh and dry weight), potassium, calcium phosphorus, and sugar content in both root and leaves, the content of leaf relative water and photosynthetic pigments (Chlorophyll a, b and carotenoids). In contrast, Na determined that soluble sugars and proteins, free amino acids containing proline content and lipid peroxidation level, and peroxidase activity increased together. He also found that the electrolyte leak in the leaves increased with the salt level. The salicylic acid application increases leaf relative water content, fresh and dry weights, photosynthetic pigments, soluble saccharides, phosphorus content, and peroxidase activity in seedlings, whereas Na^+, soluble protein content, lipid peroxidation level, electrolyte leakage significantly decreased with the salicylic acid application under saline conditions. As a result, it has been revealed that the applied salicylic acid causes high protective reactions for photosynthetic pigments, causing a pre-stimulated reaction to salt stress and ensures membrane integrity promoting plant growth.

In their study, Szalai et al. (2005), examined the effect of salicylic acid content on corn stress in corn (*Zea mays*) plants. Two-week corn plants were applied 50 or 100 mM NaCl for seven days and after the 1st, 3rd, and 7th days, salicylic acid and antioxidant enzyme activity were analyzed in leaves and roots. In the study, it was determined that there was no change in the level of free and bounded salicylic acid in the maize plants where 100mM NaCl was applied, the total product decreased after seven days, there was glutathione -5-transferase and guaiacol peroxidase activities increased.

Qing-Mao et al. (2007), investigated the effect of leaf and root SA pretreatment on salt stress in their study in cucumber. They determined that the application of 50 mg L^{-1} SA from leaf and root increased the sugar content by 110.4 % and the proline content by 82.2 %, and also increased the activity of superoxide dismutase, peroxidase, and catalase and water content while reducing malondialdehyde and electrolyte leakage. In addition, they found that salicylic acid pretreatment made significant improvements in growth parameters such as plant height, stem diameter and total mass in NaCl stressed plants. As a result, they reported that salicylic acid administration may have important effects on cucumber seedling's NaCl tolerance through osmatic regulation, water balance, antioxidation, and membrane stability.

Rafique et al. (2011), in their work; the effects of dipping pumpkin seeds into SA and ASA solutions on 10 dS m^{-1} salt concentration and seedling growth were investigated. SA (15 and 30 mg L^{-1}) and ascorbic acid (30 mg L^{-1}) applications significantly affected seedling fresh weight, protein content, protease, and nitrate reductase activity in both saline and unsalted conditions. Pre-germination applications reduced the severity of salt stress and the best result was obtained from 30 mg L^{-1} SA and ascorbic acid applications, which gave the best seedling growth, fresh and dry weight results under both saline and salt-free conditions. As a result, ascorbic acid and SA applications have been reported to be successful in improving the negative effect of salt stress on the pumpkin.

Baran et al. (2014), examined the effects of salicylic acid application on soybean (*Glycine max*) yield and quality parameters have grown under salinity effect. In this study, the effects of 5 different salt concentrations (50, 75, 100, 125, 150 mM) and 5 different salicylic acid doses (0.1, 0.25, 0.5, 0.75, and 1.0 mM) on yield quality parameters of soybean (*Glycine max*) They were examined. As a result of the study, it was found that the increase in salinity caused a decrease in the chlorophyll content of the plant, but it also increased the proline and MDA values in the plant. It has been determined that the application of salicylic acid increases the exhaustion resistance against salt stress and the effect of salinity stress decreases in the case of 1mM salicylic acid application.

Dadaşoğlu et al. (2014), conducted research on the bean plant to determine the effects of salicylic acid application on salinity. 5 different salts (0.0, 50, 100, 150 and 200 mM) and 5 different salicylic acid doses (0.0 (control), 0.1, 0.25, 0.50, 0.75 and 1.00 mM) were used in the study. They investigated the effects of salicylic acid applications on

germination in bean (*Phaseolus vulgaris*) seeds. As a result of the study, it was determined that germination in the bean plant decreased in the case of high salinity conditions and high salicylic acid dosage.

Akçalı (2014), in his thesis, investigated the effects of lipoic acid (LA) and SA application on certain proteome and biochemical parameters in canola seedlings exposed to salt stress; It stated that salt stress reduces root and stem growth, ascorbate, and glutathione (GSH) content, while MDA increases the content of cysteine, proline, and thiol (NPT) and activities of antioxidant enzymes such as SOD, CAT, guaiacol POD and ascorbate peroxidase (APX). NaCl alleviated the stimulated reduction in the seedling growth of SA and LA applied externally and stated that it also decreased MDA contents. There was no change in the content of proline in SA and LA treatment. SA and LA applications under salt stress indicated that while increasing the cysteine content, it decreases the thiol content. He stated that while ascorbate content decreased more in LA application in areas with salt stress, they did not see a significant effect in the salicylic acid application. It has been stated that only salicylic acid application increases the glutathione content in salt applied areas, while both LA and SA applications applied externally to increase the guaiacol POD and CAT activities and cause a decrease in APX activity. The results stated here determined that LA could be effective in increasing the seedling growth of plants exposed to salt stress in a short time.

3. MATERIALS AND METHODS

The research was conducted in the growing room of the Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Van YüzüncüYıl University. lettuce (*Lactuca sativa*) was used as an experimental plant in the research.
Temperature, humidity, light, and sterilization controls were carried out in the growing room. Seedlings were grown in the growing room under controlled conditions which were adjusted to 45-55 % humidity, 16 hours light and 8 hours dark photoperiod, 25±1 °C temperature, and 10.000 Lux/Daylight intensity during growth and development.

3.1. Research Plan

The research was conducted in three replications in 72 pots as factorial design, research repeated in two years, in order to more understand the effects of salicylic acid on Cd and NaCl stresses two years the same experiment was adjusted. For both experiments total of 144 lettuces (*Lactuca sativa*) seedlings were sown in 144 pots with 3 kg capacity and loamy soil used as experiment soil. The same experiment was established two times, the first experiment on 16th November 2017 was set for eight weeks, under normal growth conditions, and pots were irrigated regularly. The second experiment (the same experiment is repeated) started on 22nd March 2018 for eight weeks again in the same place, with the same cultivation medium, and the same plant was used, also, the same optimum growth conditions were established regarding light and irrigation. Both experiments were completed after eight weeks and the lettuce plants were harvested, and the same measurements and analyses carried out for the first and second experiments.

Three different doses of cadmium (0- 40-80 mg kg^{-1}) (Cd0: 0 g, Cd1: 0.1862 g, and Cd2: 0.3724 g) as $CdNO_3$ and three different doses of salt (0-30-60 mM) (NaCl0: 0 g, NaCl1: 5.256 g, and NaCl2: 10.512 g) as NaCl respectively been used. Also, salicylic acid was (0-1-2-4 mM) (SA0: 0 g, SA1: 0.414 g, SA2: 0.828 g, and SA3: 1.656 g) to be four doses used (Demirkiran et al., 2007), separately applied to each pot. The salicylic acid solution was prepared by dissolving solid salicylic acid in distilled water and shaking for 6 hours, at the end three different doses were prepared. Lettuce (*Lactuca sativa*)

(yedikule marul) kind as plant material for both experiments used. Cadmium and salt solutions applied in the soil one week before planting, however, salicylic acid applied as a solution one week after planting.

3.2. Fertilization and Irrigation

As the basic fertilization, each pot applied $(NH_4)\ 2SO_4$, TSP, and K_2SO_4 (300 mg kg^{-1} nitrogen, 150 mg kg^{-1} phosphorus (P_2O_5), and 200 mg kg^{-1} potassium (K_2O) respectively. The manual irrigation system was used, for our research pot lettuce plants, irrigation was depending on the plant needed for water, also, distilled water regularly was used as irrigation water.

3.3. Laboratory Analysis

All laboratory works and analyses were carried out at the Plant Nutrition and Soil Science Department, Agriculture faculty building, University of Van YüzüncüYıl.

3.4. Sample Preparation

3.4.1. Soil

After harvesting, soil inside pots was removed and transferred to a suitable tray, then by placing in a current air soil samples dried out at a temperature no more than 30°C, until all soil samples get dried this process was continued. After removing all fibrous from dried soil samples, then the soil sample was crushed/ground separately and passed through a 2.36 mm mesh sieve.

3.4.2. The plant

After collected plant samples from pots, for washing and cleaning plant samples water trays been used, then plant samples washed under running tap water, washing was carried out very quickly to the minimized loss of constituents, then all plant samples dried

out by using paper tissues and putting in the oven at 40°C for 2 days. Finally, plant samples ground to make a powder from them and to be used.

3.5. Chemical and Physical Analysis of Soil and Plant Samples

3.5.1. Soil texture

Soil texture analysis was determined by the “Bouyoucos hydrometer” method (Demiralay, 1993)

3.5.2. Soil pH

The soil reaction was determined in a 1: 2.5 soil-water mixture with a glass electrode pH-meter. (Jackson, 1964). 72 soil samples were tested for pH, soil samples then let passed through 2.36mm sieve mesh size. As 1: 2.5 soil-water mixture prepared then put into shaker for 30 minutes, finally, the pH electrode was installed.

3.5.3. Electrical conductivity

Soil salinity was determined by measuring the electrical conductivity in a 1: 2.5 soil-water mixture using a conductivity instrument. (U.S. Salinity Laboratory Staff, 1954).

3.5.4. Lime content ($CaCO_3$)

Lime content was determined by Scheibler calcimeter method (Alison and Moodie, 1965).

3.5.5. Organic matter content

The organic carbon (OC) value in the soil was determined by the “Walkley-Black”

3.5.6. Soil phosphorus content

According to the Olsen method, the phosphorus passed into the extract solution was determined by molybdophosphoric blue color method (Olsen and Watanabe, 1957).

3.5.7. Soil macro and micronutrients contents

The analysis of extractable Ca, Mg, and Na elements were made by using AAS with ammonium acetate extraction solution. The analysis of extractable Zn, Fe, Mn, Cd, Mn, and Cu elements were made by using AAS with a DTPA-TEA extraction solution recommended for calcareous soils (Lindsay and Norvell, 1978).

3.5.8. Chlorophyll

At the end of the experiment, in the week of harvesting, plant chlorophyll was determined by using the chlorophyll meter (Spad-502 plus).

3.5.9. Leaf osmotic potential

To determining the leaf osmotic potential, at the end of the experiment (in the week of harvesting), one leaf was taken from each pot/ plant, and extracts were prepared by using Jones and Turner's (1978) method. Vapour–pressure osmometer (Vapro Osmometer) was used to determine the osmolality (-MPa).

3.5.10. Relative water content

At the beginning of the spike (in the week of harvesting), leaves taken from plants were immediately weighed to the fresh weights (FW), after 4 hours leaving inside water leaves re-weighing to get turgor weight (TW), finally, the leaf samples were put in a 60 ^{o}C air circulation drying cabinet for 24 hours and their dry weights (DW) were determined (Dhanda and Stehil 1998). Relative water content was calculated by following equation.

RWC = (FW– DW)/ (TW– DW) × 100

3.5.11. Determination of plant macro and micronutrients contents

In the plant samples: Nitrogen; Kjeldahl method, phosphorus spectrophotometer and vanado molybdo yellow color method, and (Ca, Mg, Na, K, Cd, Fe, Cu, Zn, Mn) contents of the extracts obtained after dry combustion was determined by atomic absorption spectrophotometer (Thermo ICE 3000 series) (Kacar and İnal, 2008). Macro and micronutrients uptake of plants was calculated by multiplying the dry weight of harvested plants by nutrient concentration values of plants.

3.5.12. Plant cadmium content

Plant root and leaf samples were treated with a mixture of nitric and perchloric acid using a double acid extraction method (3: 1 ratio), Cd content was analyzed by atomic absorption spectrophotometer (Thermo ICE 3000 series) (Kacar, 1994). Cd uptake in plants was calculated by multiplying the dry weight of harvested plants by Cd concentration values.

3.6. Morphological Measurements in Plant Samples

3.6.1. Plant height (cm/ plant)

The distance between the root top and the peak of the harvested plant was measured with the help of a ruler.

3.6.2. Plant fresh and dry weights (g / plant)

At the end of the experiment, plant harvested were weighed on sensitive scales and their fresh weights were determined; the same samples were then dried to a constant weight in a 65 ºC oven for 48 hours, and then their dry weight was taken.

3.6.3. Stem diameter (cm / plant)

The diameter of the stem was determined as cm with the help of a caliper.

3.6.4. Number of leaves (pcs / plant)

At the end of the experiment, the number of leaves was measured as the number/ plant by counting all leaves on the plant.

3.6.5. Root fresh and dry weights (g / plant)

At the end of the experiment, plant root was weighed on sensitive scales and their fresh weights were determined; the same samples were then dried to a constant weight in a 65 ºC oven for 48hours, and then their dry weight was taken.

3.6.6. Root length and diameter (cm)

The area from the root top to the root end of the plant was measured by tape (± 0.5) in cm. The diameter of the root was determined as cm with the help of a caliper.

3.6.7. Consumable weight (g /plant)

At the end of the experiment, the plant's yellowed, deteriorated, rotten, non-renewable, and very hardened leaves were removed, and re-weighing to determine consumable weight.

3.6.8. Number of scrap leaves (pcs)

Leaves of plants taken from each pot were not considered to be economical.

3.7. Statistical Analysis

Statistical analysis of the findings was carried out using variance analysis using the SPSS software package program as factorial design and the results were grouped according to Duncan multiple comparison tests (SPSS, 2018).

3.8. Sample Treatments

The experiment was conducted using loamy soil with cadmium, salt, and salicylic acid in the plots growing lettuce, which is consist of 8 treatments replicated in 3 replications.

Plant growth characteristics in the harvested plants (plant height (cm), plant diameter (cm), plant fresh and dry weight (g), stem length and diameter (cm), number of leaves, root fresh and dry weights (g), root length and diameter (cm), consumable weight (g), number of discarded leaves, osmotic potential, chlorophyll, and relative water content (RWC) were measured. In addition, macro and micro plant nutrients (cadmium, nitrogen, phosphorus, potassium, magnesium, calcium, manganese, iron, copper, and zinc) were measured.

Table 3.1. Applications and doses used in the experiment

Salicylic Acid and Cadmium	Salicylic Acid and Salt
SA0 Cd0	SA0 Salt0
SA0 Cd1	SA0 Salt1
SA0 Cd2	SA0 Salt2
SA1 Cd0	SA1 Salt0
SA1 Cd1	SA1 Salt1
SA1 Cd2	SA1 Salt2
SA2 Cd0	SA2 Salt0
SA2 Cd1	SA2 Salt1
SA2 Cd2	SA2 Salt2
SA3 Cd0	SA3 Salt0
SA3 Cd1	SA3 Salt1
SA3 Cd2	SA3 Salt2



Figure 3.1. A general view from the day the trial seedlings were planted.



Figure 3.2. An overview of the trial pattern before harvest.



Figure 3.3. General view of salicylic acid and salt treated plants.



Figure 3.4. General view of salicylic acid and salt treated plants.

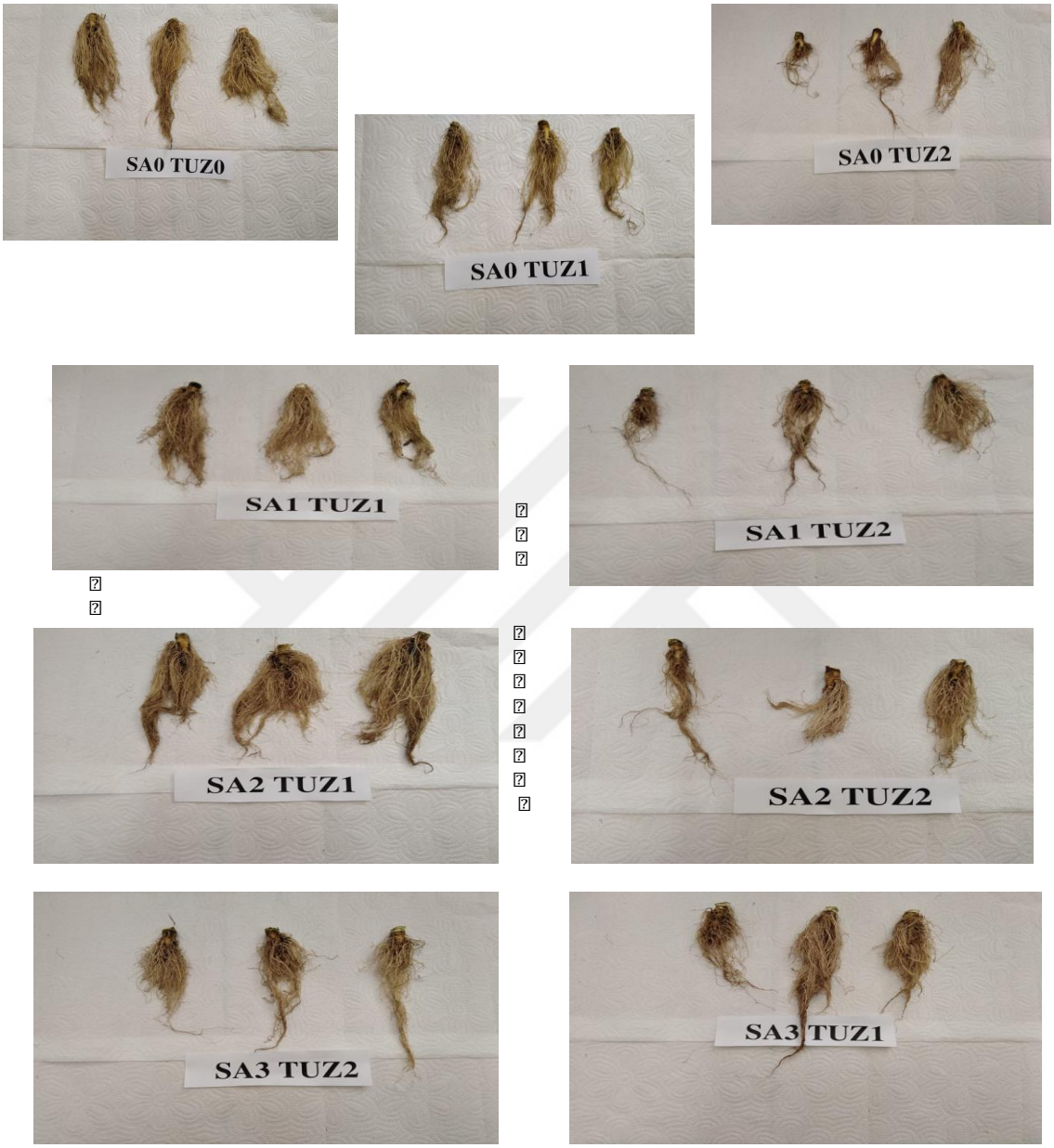

Figure 3.5. General view of salicylic acid and salt treated plant roots.



Figure 3.6. General view of salicylic acid and cadmium treated plants.



Figure 3.7. General view of salicylic acid and cadmium treated plant.



Figure 3.8. General view of salicylic acid and cadmium treated plant.

Table 3.2. Some chemical and physical properties of soil used in the experiment

Texture	pH	EC	$CaCO_3$	OM	P	Ca	Mg	K	Fe	Cu	Zn	Mn
		dS /m	%	%	mg kg^{-1}							
Loamy	7.81	0.36	3.86	1.32	5.50	3034	405	298	5.58	0.81	0.58	29.84

The experiment soil was loamy, slightly alkaline, non-saline, moderately limely, insufficient in terms of organic matter, phosphorus and zinc content, and sufficient for other nutrients.

4. RESULTS AND DISCUSSIONS

4.1. Soil Measurements for Cd and Salt Applications

4.1.1. Soil measurements for Cd and SA applications

Changes in soil physical parameters under Cd and SA applications were given in (Table 4.1) for the first and second experiments. Soil pH values increased by increasing SA doses in both experiments. These increases were found significant ($P < 0.05$) for the second experiment. By SA applications soil EC values decreased compared to control at 1% level statistically (Table 4.1) in both experiments. Increasing Cd doses had no effects on soil investigated parameters.

In the first experiment, soil pH values shown changes between 7.3 to 7.7 and were around neutral ranges (Table 4.1). SA*Cd value is important at the 1% level ($P < 0.01$) (Table 4.2). In the second experiment, the pH was also found about 7.3 to 7.6 as high as the first experiment (Table 4.1). SA applications value is important at 5% level ($P < 0.05$). In the first experiment the highest EC values were obtained from SA0*Cd0; SA0*Cd1 and SA0*Cd2 as 721.667; 655.33 and 649.333 $\mu S\ cm^{-1}$, respectively.

The lowest values were obtained from SA2*Cd0 and SA2*Cd1 as 417.667 and 472.333 $\mu S\ cm^{-1}$. In the second experiment, the highest EC values were determined from SA2*Cd2 and SA0*Cd0 as 641.667 and 603.667 $\mu S\ cm^{-1}$, respectively. The lowest values were obtained from SA2*Cd0 as 418.333 $\mu S\ cm^{-1}$ (Table 4.1).

Table 4.1. The effects of different salicylic acid and Cd applications on soil pH and EC with Duncan letters

	SA	Cd			SA means
		0	1	2	
First Experiment Ph	0	7.333 b	7.330 b	7.687 a	7.450
	1	7.493 ab	7.643 a	7.307 b	7.481
	2	7.287 b	7.483 ab	7.567 a	7.446
	3	7.507 ab	7.607 a	7.473 ab	7.529
	Cd means	7.405 B	7.516 A	7.508 AB	
	SA	Cd			SA means
		0	1	2	
Second Experiment pH	0	7.377 b	7.440 ab	7.423 ab	7.413 B
	1	7.483 ab	7.507 ab	7.413 ab	7.468 AB
	2	7.370 b	7.477 ab	7.477 ab	7.441 B
	3	7.543 ab	7.567 a	7.530 ab	7.547 A
	Cd means	7.443	7.498	7.461	
	SA	Cd			SA means
		0	1	2	
First Experiment EC µS cm^{-1}	0	721.667 a	655.333 b	649.333 b	675.444 A
	1	642.667 b	534.667 de	514.333 ef	563.889 B
	2	417.667 g	472.333 f	574.000 cd	488.000 C
	3	532.667 de	615.667 bc	511.333 ef	553.222 B
	Cd means	578.667	569.500	562.250	
	SA	Cd			SA means
		0	1	2	
Second Experiment EC µS cm^{-1}	0	603.667 ab	574.333 a-c	578.000 a-c	585.333 A
	1	562.333 bc	532.333 b-d	511.000 cd	535.222 B
	2	418.333 e	473.000 de	641.667 a	511.000 B
	3	537.667 b-d	522.667 cd	514.333 cd	524.889 B
	Cd means	530.500	525.583	561.250	

a, b, c, d, e, f Superscripts with the same letters at each treatment are not significantly different, the mean values indicated by different letters are important for own lines and columns.

Table 4.2. The variance analysis results on the effects of different salicylic acid and Cd applications on pH and EC

		pH		EC	
S. O. V.	DF	MS	F	MS	F
		First Experiment			
SA	3	0.013	0.88 NS	54483.87	79.52**
Cd	2	0.046	3.04 NS	812.19	1.19 NS
SA* Cd	6	0.080	5.32**	15430.82	22.52**
Error	24	0.0151		685.13	
		Second Experiment			
S. O. V.	DF	MS	F	MS	F
SA	3	0.029	3.54*	9432.37	5.43**
Cd	2	0.009	1.09	4483.69	2.58
SA* Cd	6	0.004	0.54	13118.17	7.56**
Error	24	0.0083		1736.16	

The F value indicated by ** is important at the 1% level (P <0.01).
The F value indicated by * is important at the 5% level (P <0.05).

4.1.2. Soil measurements for Salt and SA applications

Changes in soil physical parameters under Salt and SA applications were given in (Table 4.3) for the first and second experiments. In salt applications, increasing NaCl doses increased soil pH values only in the second experiment significantly at the 5% level (P <0.01). In the first experiment, slight increases in pH values were determined in SA3 doses. Similarity increasing NaCl doses increased soil EC values in both experiments. By adding SA doses soil EC decreased, especially at the SA2 level. In the first experiment, soil pH values were changes between 7.4 to 7.7 and are around neutral ranges (Table 2.1). For the second experiment, pH values were increased to 8 as more alkaline. SA value is important at the 5% level (P <0.05) (Table 4.3).

In the first and second experiments, the highest EC values were obtained from SA3*S2 as 2054.667 and 2347.667 μS cm^{-1}. For the lowest values were obtained from SA2*S0 as 543.667 and 562.667 μS cm^{-1} respectively (Table 4.3). In this result, when salt was applied, the EC values increased gradually. While increasing the Salt concentration, EC values also increased, but by adding the salicylic acid concentration of

salt decreases, especially at SA2. It seems there are correlations between EC and SA increase.

Table 4.3. The effects of different salicylic acid and salt applications on soil pH and EC with Duncan letters

	SA	Salt			SA means
		0	1	2	
First Experiment pH	0	7.593 b	7.653 ab	7.500 b	7.582
	1	7.550 b	7.933 a	7.553 b	7.679
	2	7.473 b	7.667 ab	7.733 ab	7.624
	3	7.573 b	7.540 b	7.463 b	7.526
	Salt means	7.548 B	7.698 A	7.563 B	
	SA	Salt			SA means
		0	1	2	
Second Experiment pH	0	7.717 b-d	7.667 b-d	7.477 d	7.620 B
	1	8.073 a	7.890 a-c	7.947 ab	7.970 A
	2	7.900 a-c	7.933 ab	7.727 b-d	7.853 A
	3	7.820 a-c	7.600 cd	7.583 dc	7.668 B
	Salt means	7.878 A	7.773 AB	7.683 B	
	SA	Salt			SA means
		0	1	2	
First Experiment EC µS cm^{-1}	0	643.333 f	1211.333 cd	1945.000 a	1266.556 B
	1	576.667 f	1109.667 de	1920.333 a	1202.222 B
	2	543.667 f	1013.667 e	1314.667 bc	957.333 C
	3	645.000 f	1470.000 b	2054.667 a	1389.889 A
	Salt means	602.167 C	1201.167 B	1808.667 A	
	SA	Salt			SA means
		0	1	2	
Second Experiment EC µS cm^{-1}	0	590.667 e	1173.667 d	2409.667 a	1391.333 B
	1	587.333 e	1219.333 d	2155.000 b	1320.556 B
	2	562.667 e	1226.667 d	1615.667 c	1135.000 C
	3	581.667 e	1710.000 c	2347.667 a	1546.444 A
	Salt means	580.583 C	1332.417 B	2132.000 A	

a, b, c, d, e, f Superscripts with the same letters at each treatment are not significantly different, the mean values indicated by different letters are important for own lines and columns.

Table 4.4. The variance analysis results on the effects of different salicylic acid and salt applications on pH and EC

		pH		EC	
S. O. V.	DF	MS	F	MS	F
		First Experiment			
SA	3	0.037	1.50 NS	297946.44	24.70**
Salt	2	0.082	3.27 NS	4366999.0	361.99**
SA* Salt	6	0.048	1.91 NS	80583.44	6.68**
Error	24	0.025		12063.92	
		Second Experiment			
S. O. V.	DF	MS	F	MS	F
SA	3	0.238	8.20**	262139.19	24.61**
Salt	2	0.113	3.89 *	7222961.08	678.11**
SA*Salt	6	0.016	0.58 NS	160405.94	15.06**
Error	24	0.029		10651.61	

The F value indicated by ** is important at the 1% level (P <0.01).
The F value indicated by * is important at the 5% level (P <0.05).

4.2. Plant Measurements

4.2.1. Interactions between Cd and SA

In this study on lettuce (*Lactuca sativa*) seedlings, the effects of salicylic acid (SA) concentrations applied to seedlings on the response to different cadmium (Cd) concentrations were investigated. In general, as the cadmium concentrations applied to the seedlings increase, both the morphological and physiological parameters of the seedlings have been observed to decrease in both the salicylic acid application and the control groups (Ivanova et al., 2008). Similar results have been reported in different plants treated with cadmium (Metwally, et al., 2003; Ashraf et al., 2003). However, the differences between salicylic acid-treated and non-treated groups on some parameters were not found statistically significant.

Table 4.5. The effects of different salicylic acid and Cd applications on plant growth criteria with Duncan letters

	SA	Cd			SA means
		0	1	2	
First Experiment Plant Height (cm)	0	22.833 a	17.000 d	19.500 cb	19.778 A
	1	22.833 a	19.833 b	14.400 e	19.022 AB
	2	19.667 b	17.167 cd	18.500 c-d	18.444 AB
	3	22.167 a	16.667 de	14.500 e	17.778 B
	Cd means	21.875 A	17.667 B	16.725 B	
	SA		Cd		SA means
		0	1	2	
Second Experiment Plant Height (cm)	0	20.000 b	18.400 bc	15.667 c	18.022 C
	1	21.467 ab	19.400 bc	20.800 b	20.556 B
	2	20.200 bc	21.633 ab	22.967 ab	21.600 B
	3	26.000 a	25.933 a	21.033 b	24.322 A
	Cd means	21.917	21.342	20.117	
	SA		Cd		SA means
		0	1	2	
First Experiment Plant Fresh Weight (g)	0	55.400 a-c	69.100 a	20.933 f	48.478 A
	1	65.133 a	46.367 b-d	39.567 c-e	50.356 A
	2	57.700 a-c	29.467 d-f	27.267 ef	38.144 B
	3	60.467 ab	16.900 f	12.867 f	30.078 B
	Cd means	59.675 A	40.458 B	25.158 C	
	SA		Cd		SA means
		0	1	2	
Second Experiment Plant Fresh Weight (g)	0	30.433 b-d	24.567 cd	19.733 d	24.911 B
	1	36.667 a-d	32.700 b-d	50.200 a	39.856 A
	2	38.767a-c	32.500 b-d	41.900 a-c	37.722 A
	3	46.367 ab	41.133 a-c	30.200 b-d	39.233 A
	Cd means	38.058	32.725	35.508	
	SA		Cd		SA means
		0	1	2	
First Experiment Plant Dry Weight (g)	0	2.767 b-d	4.300 ab	2.200 d	3.089 B
	1	4.700 ab	4.333 ab	4.100 a-d	4.378 A
	2	4.200 a-c	3.533 a-d	4.100 a-d	3.944 AB
	3	5.267 a	2.200 d	2.300 cd	3.256 B
	Cd means	4.233 A	3.592 AB	3.175 B	
	SA		Cd		SA means
		0	1	2	
Second Experiment Plant Dry Weight (g)	0	2.967 c	2.267 de	1.567 f	2.267 C
	1	2.833 c	2.600 cd	2.867 c	2.767 B
	2	3.900 a	2.833 c	2.133 e	2.956 B
	3	4.233 a	3.333 b	2.100 e	3.222 A
	Cd means	3.483 A	2.758 B	2.167 C	

Table 4.5. The effects of different salicylic acid and Cd applications on plant growth criteria with Duncan letters (continued)

	SA	Cd			SA means
		0	1	2	
First Experiment Leaf Number Plant^{-1}	0	16.667 a-c	16.000 a-c	19.000 a	17.222 AB
	1	16.333 a-c	16.000 a-c	14.667 c	15.667 B
	2	18.000 ab	17.000 a-c	17.667 a-c	17.556 A
	3	15.667 bc	16.000 a-c	15.333 bc	15.667 B
	Cd means	16.667	16.250	16.667	
	SA	Cd			SA means
		0	1	2	
Second Experiment Leaf Number Plant^{-1}	0	9.667 b	13.000 a	12.000 a	11.556 B
	1	13.333 a	12.333 a	13.000 a	12.889 A
	2	13.000 a	12.333 a	12.667 a	12.667 A
	3	13.333 a	13.333 a	11.333 ab	12.667 A
	Cd means	12.333	12.750	12.250	
	SA	Cd			SA means
		0	1	2	
First Experiment Plant Diameter (cm)	0	6.760 bc	6.090 cd	7.850 ab	6.900 B
	1	7.693 a-c	7.620 a-c	6.330 bc	7.214 AB
	2	9.010 a	7.687 a-c	6.780 bc	7.826 A
	3	8.637 a	4.807 d	6.863 bc	6.769 B
	Cd means	8.025 A	6.551 B	6.956 B	
	SA	Cd			SA means
		0	1	2	
Second Experiment Plant Diameter (cm)	0	4.160 ed	4.650 dc	4.443 c-e	4.418 B
	1	5.967 a	5.063 bc	5.247 a-c	5.426 A
	2	5.900 ab	5.353 a-c	4.837 cd	5.363 A
	3	5.313 a-c	3.740 e	4.570 c-e	4.541 B
	Cd means	5.335 A	4.702 B	4.774 B	

a, b, c, d, e, f Superscripts with the same letters at each treatment are not significantly different, the mean values indicated by different letters are important for own lines and columns.

Plants' growth parameters Cd and SA applications and Duncan letters were given in (Table 4.5) for the first and second experiments. In the first experiment, for all plant growth parameters, the values were gradually decreased with increasing Cd concentrations. The lowest values were obtained in Cd applications in general. There were not correlative relations between SA*Cd applications. The highest values for plant height were obtained in SA0*Cd0 and SA1*Cd0 as 22.833 cm. The lowest values were determined in SA1*Cd2 and SA3*Cd2 as 14.400;14.500 cm. The highest values for plant

The variance analysis on the effects of different salicylic acid and Cd applications on plant growth criteria were given in (Table 4.5 and Table 4.6). The plant growth parameters decreased gradually, either stem (Table 4.5) and root developments (Table 4.6). There were significant differences between the mean values of plant height, dry weight, and the number of leaves as compared to the control groups, which was statistically important (P<0.05) for the first experiment. Plant height, fresh weight, dry weight, and stem diameter were important (P<0.05), the number of leaves was more important (P<0.01) for the second experiment. SA applications slightly alleviate the Cd effects for first and second experiments on plant height, fresh weight, stem diameter (P<0.05), and the number of leaves (P<0.01).

The values for different Cd applications, the plant height, fresh weight, and stem diameter were found important (P<0.05) for the first experiment. For the second experiment, plant dry weight and stem diameter were significant at (P<0.05).

For the second experiment plant dry weight and the number of leaves were important (P<0.05) and plant diameter was more important in 1% level (P<0.01).

Table 4.6. The variance analysis results in the effects of different salicylic acid and Cd applications on plant growth criteria

		Plant Height		Plant Fresh Weight		Plant Dry Weight		Leaf Number		Plant Diameter	
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
First Experiment											
SA	3	6.50	3.48*	805.6	8**	3.25	3.18*	9.06	3.3*	1.99	2.71NS
Cd	2	90.23	48.31**	3589	35.64**	3.41	3.33NS	0.69	0.25NS	6.96	9.45**
SA*Cd	6	13.94	7.47**	579.4	5.75**	3.3	3.22*	3.39	1.24NS	3.98	5.41**
Error	24	1.867		100.7		1.025		2.75		0.736	
Second Experiment											
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
SA	3	61.19	10.06**	449.8	5.63**	1.46	35.85**	3.25	3.09*	2.54	11.16**
Cd	2	10.14	1.67NS	85.38	1.07NS	5.21	127.8**	0.86	0.82NS	1.44	6.33**
SA*Cd	6	12.56	2.06NS	175.3	2.2NS	0.71	17.39**	4.34	4.11**	0.71	3.12*
Error	24	6.084		79.847		0.04		1.055		0.227	

The F value indicated by ** is important at the 1% level (P <0.01).
The F value indicated by * is important at the 5% level (P <0.05).

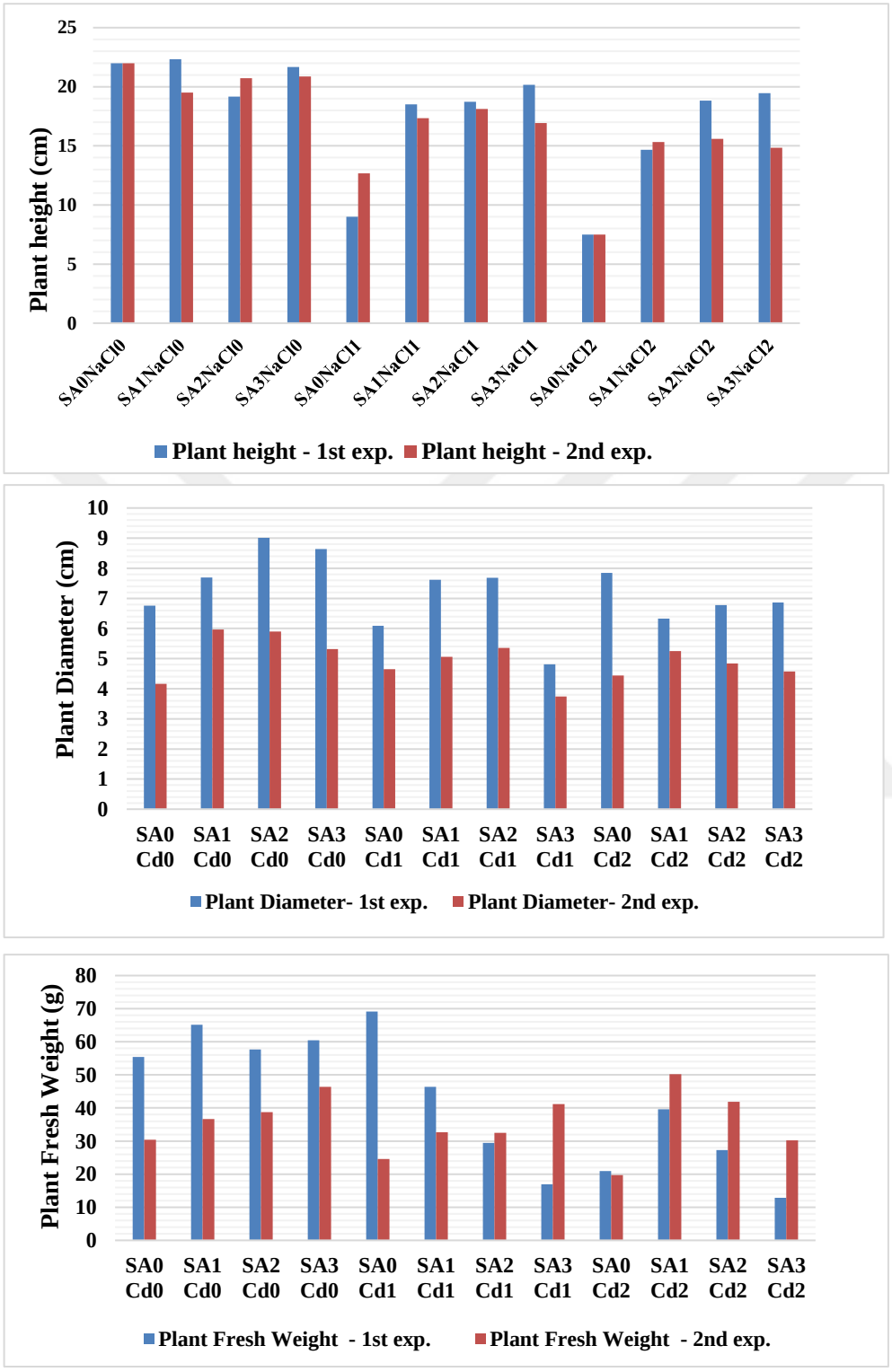

Figure 4.1. Effects of different Cd and SA doses on plant height, plant fresh weight, and plant diameter.

The highest values for root length were obtained from SA1*Cd0; SA0*Cd0 and SA2*Cd0 as 14.000; 13.667 and 13.500 cm. The lowest was found in SA3*Cd2 as 6.900 cm. The highest root weights were found in SA3*Cd0 and SA3*Cd1 as 12.250 and 9.467 g. whereas, the lowest values were measured in SA0*Cd1 and SA2*Cd1 as 1.267 and 1.333 g. The highest measurements were recorded in SA2*Cd0 and SA1*Cd2 as 10.780 and 9.500 cm. The lowest values were obtained in SA0*Cd1 and SA3*Cd1 as 5.683 and 5.990 cm (Table 4.7).

Plant and root lengths (cm), diameters (cm), fresh and dry weights (g), the number of leaves, consumable weight, the number of discarded leaves were determined. While there was an increase in values of these morphological parameters by increasing SA, in general, Cd has shown negative effects as reported in many studies (Ramos et al., 2002; Klimentina et al., 2006). Zhang et al. (2014), reported that the Cd reduces plant growth in general due to a decrease in photosynthesis. Li et al. (2014) also showed that an increase in Cd concentration leads to a decreased in the leaf area, the water content of the plant.

Although there was a significant increase in root and shoot parameters by using solely SA, there were no correlative changes in SA*Cd applications. Belkhadi et al. (2010), is also reported that there is no change in root and stem length, root and stem fresh weight, and plant water content with application of salicylic acid with Cd, due to the prevention of transport of SA at the presence of Cd. On the other hand, Syed et al., 2007 reported that SA, reduces the Cd permeability of the membranes or maintaining their integrity and may alleviate the inhibitory effects of Cd on the expansion of root cells as a result of cross-linking of cell wall components (Ashraf et al., 2003; Choudhury et al., 2013).

Table 4.7. The effects of different salicylic acid and Cd applications on root growth parameters with Duncan letters

	SA	Cd			SA means
		0	1	2	
First Experiment Root Length (cm)	0	13.667 a	9.833 c-d	12.333 a-c	11.944 AB
	1	14.000 a	12.000 a-c	13.000 ab	13.000 A
	2	13.500 a	9.500 cd	9.000 cb	10.667 B
	3	9.367 dc	8.433 d	6.900 d	8.233 C
	Cd means	12.633 A	9.942 B	10.308 B	
	SA	Cd			SA means
		0	1	2	
Second Experiment Root Length (cm)	0	17.000 a	15.100 ab	11.867 ab	14.656
	1	11.300 ab	13.267 ab	14.067 ab	12.878
	2	16.633 ab	13.733 ab	12.600 ab	14.322
	3	16.733 ab	10.367 ab	9.200 b	12.100
	Cd means	15.417 A	13.117 AB	11.933 B	
	SA	Cd			SA means
		0	1	2	
First Experiment Root Weight (g)	0	1.900 c	1.267 c	2.367 c	1.844 B
	1	1.967 c	2.933 c	2.733 c	2.544 B
	2	1.867 c	1.333 c	2.567 c	1.922 B
	3	12.250 a	9.467 b	3.900 c	8.539 A
	Cd means	4.496 A	3.750 AB	2.892 B	
	SA	Cd			SA means
		0	1	2	
Second Experiment Root Weight (g)	0	1.200 b	1.167 b	1.167 b	1.178 B
	1	1.600 ab	1.400 ab	2.800 ab	1.933 AB
	2	2.000 ab	1.900 ab	2.967 a	2.289 A
	3	1.667 ab	2.300 ab	1.433 ab	1.800 AB
	Cd means	1.617	1.692	2.092	
	SA	Cd			SA means
		0	1	2	
First Experiment Root Diameter (cm)	0	6.477 d-f	5.683 f	7.897 c-e	6.686 B
	1	7.413 d-f	8.190 b-d	9.500 a-c	8.368 A
	2	10.780 a	7.920 c-e	6.267 ef	8.322 A
	3	9.707 ab	5.990 f	7.787 c-e	7.828 A
	Cd means	8.594 A	6.946 B	7.863 A	
	SA	Cd			SA means
		0	1	2	
Second Experiment Root Diameter (cm)	0	5.170 b	6.303 ab	6.240 ab	5.904 B
	1	7.810 a	7.660 a	7.560 a	7.677 A
	2	7.967 a	7.447 a	7.833 a	7.749 A
	3	7.240 a	6.200 ab	6.167 ab	6.536 B
	Cd means	7.047	6.903	6.950	

a, b, c, d, e, f Superscripts with the same letters at each treatment are not significantly different, the mean values indicated by different letters are important for own lines and columns.

Table 4.8. The variance analysis results in the effects of different salicylic acid and Cd applications on root growth criteria

		Root length		Root weight		Root diameter	
S. O. V.	DF	MS	F	MS	F	MS	F
			First Experiment				
SA	3	37.95	11.16**	94.05	47.96**	5.51	6.31**
Cd	2	25.57	7.52**	7.73	3.94*	8.18	9.36**
SA* Cd	6	3.89	1.15NS	16.44	8.39**	8.30	9.51**
Error	24	3.399		1.96		0.87	
			Second Experiment				
S. O. V.	DF	MS	F	MS	F	MS	F
SA	3	13.07	0.86NS	1.93	2.93NS	7.29	7.51**
Cd	2	37.64	2.47NS	0.85	1.29NS	0.07	0.07NS
SA* Cd	6	16.98	1.12NS	0.78	1.19NS	0.84	0.87NS
Error	24	15.21		0.66		0.97	

The F value indicated by ** is important at the 1% level (P <0.01)
The F value indicated by * is important at the 5% level (P <0.05)

Plants' physiological parameter measurements for Cd vs SA applications were given in (Table 4.9) and variance analysis results were given in (Table 4.10) for the first and second exp. Increasing Cd concentrations leads to a decrease in consumed weight valued gradually from 54.443 to 17.400 g for the first experiment (P< 0.01). The highest values for consumed weight were shown in SA1*Cd0; SA0*Cd2; SA2*Cd0 and SA3*Cd0 as 56.100;54.433;52.600 and 52.260 g, respectively. The lowest values were obtained in SA3*Cd1 and SA3*Cd2 as 9.467 and 17.400 g. SA applications generally show the highest values (p<0.05). It seems there were no significant correlations between SA and Cd applications (p<0.01). In the second experiment the highest values for plant consumed weight were shown in SA1*Cd2; SA3*Cd0 and SA3*Cd1 as 46.900; 46.600 and 41.367 g. The lowest value was SA0*Cd2 as 19.083 g, it was shown that the lowest value was recorded from the Cd2 application, one of the highest values was obtained in SA1*Cd1 applications at (p<0.05).

The highest values for chlorophyll content were obtained as 52.680 and 50.013 μg mg^{-1} in SA3*Cd0 applications, the lowest values were in SA0*Cd0 and SA3*Cd2 as 38.847 and 40.720 μg mg^{-1}. For the second experiment, the highest chlorophyll content

values were obtained in SA3*Cd2 and SA0*Cd2 as 54.933 and 53.800 μg mg^{-1}, the lowest values were recorded in SA3*Cd1; SA2*Cd2 and SA0*Cd0 as 41.567; 41.933 and 42.867 μg mg^{-1}. While SA concentrations were increased, the chlorophyll contents were increased for the first and second experiments, as well ($p<0.05$). Chlorophyll contents were also increased with increases in Cd concentrations for the first and second experiments ($p<0.05$). However, there were no correlations were found for chlorophyll contents under interaction in SA and Cd. Cd1 and Cd2, there were correlations of gradually increase in chlorophyll contents either first or second experiments ($p<0.01$; $p<0.05$ respectively). It shows that SA applications alleviate the negative effects of Cd on chlorophyll contents.

For the first experiments, the highest relative water content values (RWC) were calculated in SA3*Cd0; SA3*Cd1; SA2*Cd0 and SA0*Cd0 as 87.553; 87.127; 86.603, and 86.273, the lowest values were determined in SA0*Cd2; SA1*Cd1 and SA1*Cd2 as 78.460; 78.573 and 79.633. In the second experiment, the highest RWC values were calculated in SA3*Cd0 and SA3*Cd1 as 87.993; 87.967, the lowest values were seen in SA0*Cd2; SA1*Cd1 and SA1*Cd2 as 77.910; 78.593, and 78.677.

The highest wastrel leaves weights of the plant were recorded in SA0*Cd2 and SA1*Cd2 as 3.000 and 1.667, the lowest values were found in SA2*Cd0 and SA3*Cd0 with 0.000 and 0.333 for the first experiments. For the second experiment, the highest wastrel leaves weights of the plant were recorded in SA2*Cd0; SA1*Cd1 and SA2*Cd2 with 1.333 and, the lowest values were found in SA1*Cd2 and SA3*Cd2 as 0.000 and 0.333 (Table 4.9). Wastrel leaves weights were decreased gradually for both Cd1 and Cd2 concentrations for the first experiments.

As indicated consumed and wastrel leaves weight, the production of lettuce under Cd-induced stress has been investigated. While at higher Cd concentrations the consumed weights are decreased, the wastrel weights are increased i.e. the productions were decreased.

Azizian et al. (2011) focused on the productivity of lettuce plants at different Cd concentrations. They reported that productivity increase at low Cd concentrations, as well. Another study, Correa et al. (2006), reported that Cd concentrations negatively affect lettuce biomass as we reported.

Table 4.9. The effects of different salicylic acid and Cd applications on consumed weight, chlorophyll, relative water content, and wastrel leaves with Duncan letters

	SA	Cd			SA means
		0	1	2	
First Experiment Consumed Weight (g)	0	42.433 a-c	19.067 de	54.433 ab	38.644 A
	1	56.100 a	43.033 a-c	33.667 b-d	44.267 A
	2	52.600 ab	35.700 a-d	30.500 cd	39.600 A
	3	52.267 ab	9.467 e	17.400 de	26.378 B
	Cd means	50.850 A	26.817 B	34.000 B	
	SA		Cd		SA means
		0	1	2	
Second Experiment Consumed Weight (g)	0	26.100 cd	24.367 cd	19.083 d	23.183 B
	1	36.367 a-c	32.567 a-d	46.900 a	38.611 A
	2	38.367 a-c	29.900 b-d	34.500 a-c	34.256 A
	3	46.600 a	41.367 ab	28.533 b-d	38.833 A
	Cd means	36.858	32.050	32.254	
	SA		Cd		SA means
		0	1	2	
First Experiment Chlorophyll µg mg^{-1}	0	38.847 d	42.593 b-d	42.213 cd	41.218 B
	1	41.987 cd	47.400 a-c	48.067 a-c	45.818 A
	2	44.700 b-d	45.153 b-d	50.013 a	46.622 A
	3	52.680 ab	42.113 cd	40.720 cd	45.171 A
	Cd means	44.553	44.315	45.253	
	SA		Cd		SA means
		0	1	2	
Second Experiment Chlorophyll µg mg^{-1}	0	42.867 c	43.000 c	53.800 ab	46.556
	1	43.667 c	45.933 a-c	47.367 a-c	45.656
	2	44.533 bc	48.233 a-c	41.933 c	44.900
	3	48.733 a-c	41.567 c	54.933 a	48.411
	Cd means	44.950 B	44.683 B	49.508 A	
	SA		Cd		SA means
		0	1	2	
First Experiment Relative Water content %	0	86.273 a	80.690 cd	78.460 de	81.808 C
	1	83.370 b	78.573 e	79.633 de	80.526 D
	2	86.603 a	82.277 bc	80.150 de	83.010 B
	3	87.553 a	87.127 a	83.887 b	86.189 A
	Cd means	85.950 A	82.167 B	80.533 C	
	SA		Cd		SA means
		0	1	2	
Second Experiment Relative Water content %	0	86.270 a	80.327 cd	77.910 e	81.502 C
	1	83.283 b	78.593 de	78.677 de	80.184 D
	2	86.070 a	83.160 b	81.157 bc	83.462 B
	3	87.993 a	87.967 a	83.233 b	86.398 A

Table 4.9. The effects of different salicylic acid and Cd applications on consumed weight, chlorophyll, relative water content, and wastrel leaves with Duncan letters (continued)

First Experiment Wastrel Leaves Weight	Cd means	85.904 A	82.512 B	80.244 C	
	SA		Cd		SA means
		0	1	2	
	0	0.667 bc	1.333 bc	3.000 a	1.667 A
	1	0.667 bc	1.000 bc	1.667 ab	1.111 AB
	2	0.000 c	1.000 bc	1.333 bc	0.778 B
	3	0.333 bc	0.667 bc	1.000 bc	0.667 B
	Cd means	0.417 B	1.000 B	1.750 A	
	SA		Cd		SA means
		0	1	2	
Second Experiment Wastrel Leaves Weight	0	1.000	1.000	0.667	0.889
	1	1.000	1.333	0.000	0.778
	2	1.333	0.667	1.333	1.111
	3	0.667	1.000	0.333	0.667
	Cd means	1.000	1.000	0.583	

a, b, c, d, e, f Superscripts with the same letters at each treatment are not significantly different, the mean values indicated by different letters are important for own lines and columns.

In the leaves, chlorophyll content was found to be slightly higher as the Cd concentration increased in the groups that had treated and untreated SA compared to the control. In some studies, it was reported that the chlorophyll content was decreased by Cd concentration due to increased pigment destruction (Kevreśan et al., 1998; Klimentina et al., 2006). However, the differences between the groups were not statistically significant (Ashraf et al., 2003).

According to Hassan et al. (2005), Cadmium stress caused a decrease in chlorophyll content and plant height, as well. There are high correlations between relative water content (RWC) of lettuce plant and Cd concentrations ($P<0.01$) for the first and second experiments. While RWC of plants was decreased with increasing Cd concentrations ($P<0.01$), increasing SA showed an increase in RWC ($P<0.01$), as well.

A decrease in relative water content by increasing Cd concentrations was also reported by Zhang et al., (2014). Mohsenzadeh et al. (2011) were also pointed out the mitigating effect of Cd on seedling growth, shoot and root fresh weight, relative water content (RWC), chlorophyll amount on corn (*Zea mays*) plants.

This study showed that SA significantly reduced the inhibitory effects of cadmium on corn (*Zea mays*) seedlings. Our findings are matched with the result (Moradkhani et al., 2012) were also reported the same finding on sunflower (*Helianthus annuus*) plants. In general, increasing SA doses leads to increase macronutrients contents of the lettuce plant, while increasing Cd doses leads to a decrease in the contents of macronutrients in the lettuce plant.

Table 4.10. The variance analysis results on the effects of different salicylic acid and Cd applications on consumed weight, chlorophyll, relative humidity, and wastrel leaves

		Consumed weight		Chlorophyll		Wastrel leaves		RWC	
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F
				First Experiment					
SA	3	524.70	4.21**	51.87	3.33*	1.81	2.61 NS	52.97	38.77**
Cd	2	1826.2	14.67**	2.85	0.18 NS	5.36	7.72**	92.66	67.82**
SA*Cd	6	493.59	3.96**	65.86	4.23**	0.50	0.73 NS	6.49	4.75**
Error	24	124.49		15.58		0.69		1.36	
				Second Experiment					
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F
SA	3	484.13	8.16**	20.61	0.80NS	0.32	0.42 NS	65.63	46.70**
Cd	2	88.72	1.50 NS	88.26	3.44*	0.69	0.89 NS	97.37	69.29**
SA*Cd	6	143.30	2.42NS	68.19	2.66*	0.54	0.70 NS	6.86	4.89**
Error	24	59.32		25.6		0.77		1.40	

The F value indicated by ** is important at the 1% level (P <0.01)
The F value indicated by * is important at the 5% level (P <0.05)

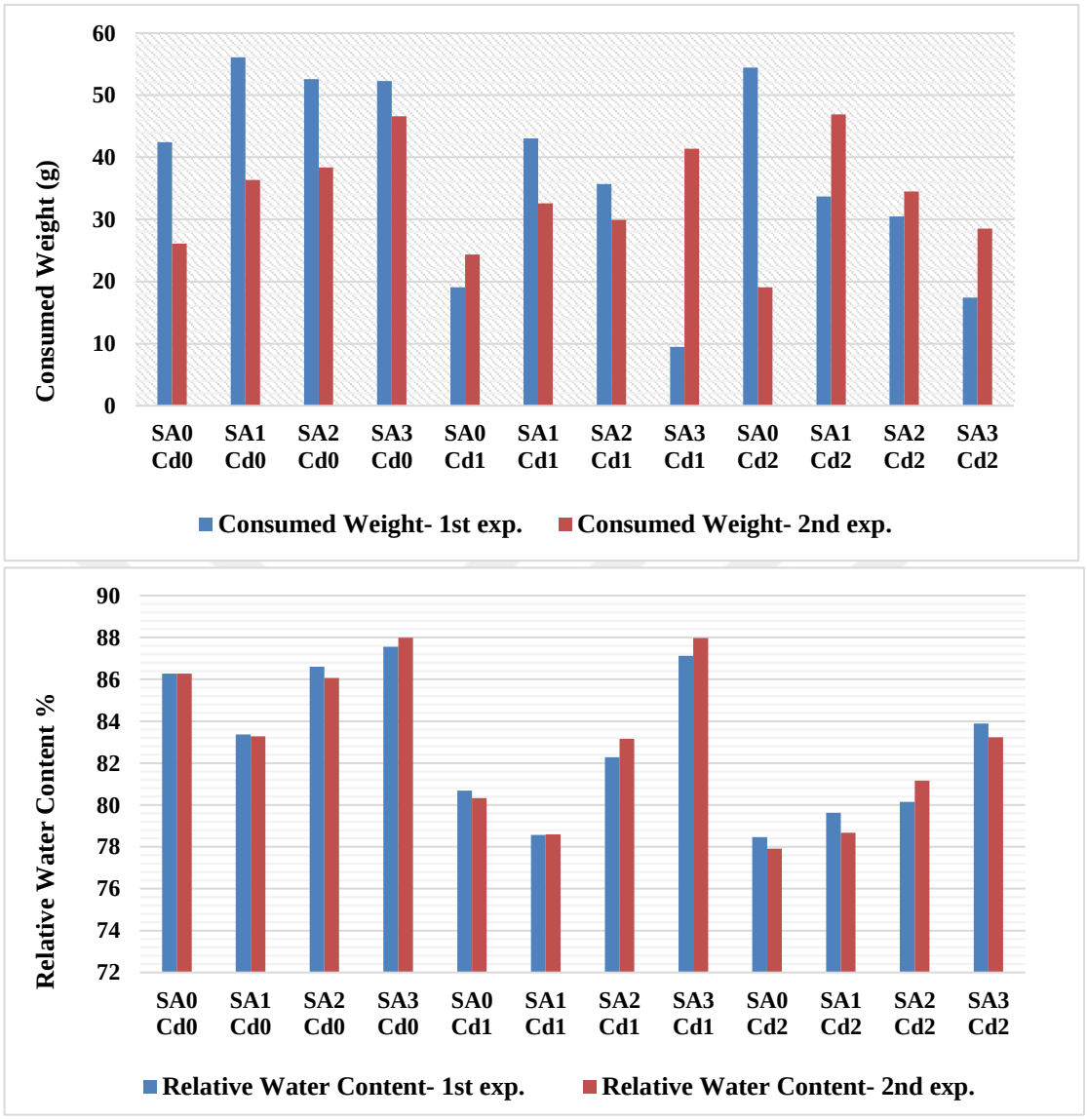

Figure 4.2. Effects of different Cd and SA doses on plant consumed weight and relative water content.

Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), and Magnesium (Mg) contents of plants Cd vs SA applications were given in (Table 4.11) and variance analysis results were given in (Table 4.12) for first and second experiments. In the first experiment, the highest N value was shown at SA3*Cd0 as 0.175 g. The lowest values were SA3*Cd1 and SA0*Cd1 as 0.073 and 0.078 g. The N content of the plants was increased gradually by SA increases in the first and second experiments. There is a positive correlation between SA levels and N concentrations ($P<0.01$). For the first experiments at Cd1, increasing SA concentrations, the N contents were increased as well.

But SA3 concentration was decreased to the lowest level as 0.073 g. For the second experiment, the highest values for N were shown at SA3*Cd0 and SA2*Cd0 as 0.149 and 0.139 g. The lowest value was SA0*Cd2 as 0.051 g. Cd1 levels N contents gradually increase with increasing SA levels ($P<0.01$). Although, there is a slight increase in N contents at Cd2 by increasing SA at lower correlations.

While the increase in P concentrations at the first experiment by SA levels, there were no differences for the second experiment ($p<0.01$). The highest value for P was SA3*Cd0 with 0.029, the lowest values were SA0*Cd1 and SA3*Cd2 with 0.014 and 0.015 g. In the second experiment, the highest values for P were in SA2*Cd0 and SA0*Cd0 with 0.025, the lowest values were SA2*Cd2; SA0*Cd2, and SA3*Cd2 as 0.012; 0.013 and 0.013 g. Either first or second experiments, at high Cd concentrations, P contents are lower or no correlations ($p<0.01$). P contents at any Cd2 vs SA are the lowest. SA3 was significantly alleviated partially P contents of plants at the Cd1 level as close to the control level as 0.023g.

The highest K^+ content value was calculated in SA3*Cd0 as 0.264 g, the lowest values were found in SA3*Cd2 as 0.109 g. for the first experiments. In the second experiment, the highest K^+ content value was calculated in SA3*Cd0 and SA2*Cd0 as 0.211 and 0.194 g, the lowest value was seen in SA0*Cd2 as 0.078 g. There was a gradual increase in K contents of plants increased doses SA with high correlations in the first and second experiments ($P<0.05$; $P<0.01$ respectively). Increasing Cd doses leads to decreases K contents in the plant. The highest Ca contents of the plant were recorded in SA1*Cd1 and SA3*Cd0 as 0.089 and 0.080 g, the lowest value was found in SA3*Cd2 as 0.036 g. In the second experiment, the highest Ca content of plant was recorded in SA3*Cd1 as 0.101 g., the lowest values were found in SA0*Cd2 and SA2*Cd2 as 0.032 and 0.036 g (Table 4.11). Ca contents of plants at increasing SA concentrations, were changing not correlatively. Ca contents are significantly decreasing with Cd concentrations at first experiments as 0.080;0.042 and 0.036 g. On the other hand, the highest value was obtained in SA1*Cd1. It was determined that, the lower levels of SA alleviated the negative effects of Cd. However, ameliorative effects of SA were limited in high Cd. In the second experiment, there were positive correlations between SA and Ca contents. The highest value for Mg was obtained at SA0*Cd1 as 0.026 g. and the lowest was found in SA3*Cd2 and SA1*Cd1 as 0.007 and 0.008 g in the first experiment.

In the second experiment, the highest values were obtained in SA3*Cd1 as 0.030g. and the lowest was in SA0*Cd1. Statistically, there were no significant differences in Mg contents of SA*Cd concentrations in the first and second experiments ($P<0.05$).

Table 4.11. The effects of different salicylic acid and Cd applications on N, P, K, Ca, and Mg with Duncan letters

	SA	Cd			SA means
		0	1	2	
First Experiment N (g plant^{-1})	0	0.088 b-d	0.078 cd	0.146 ab	0.104 B
	1	0.155 a	0.134 a-d	0.130 a-d	0.140 AB
	2	0.148 ab	0.126 a-d	0.138 a-c	0.138 A
	3	0.175 a	0.073 d	0.085 b-d	0.111 AB
	Cd means	0.141 A	0.103 B	0.125 AB	
	SA	Cd			SA means
		0	1	2	
Second Experiment N (g plant^{-1})	0	0.103 bc	0.088 c-e	0.051 f	0.080 C
	1	0.096 c	0.093 cd	0.097 c	0.096 B
	2	0.139 a	0.092 cd	0.072 e	0.101 B
	3	0.149 a	0.119 b	0.077 de	0.115 A
	Cd means	0.122 A	0.098 B	0.074 C	
	SA	Cd			SA means
		0	1	2	
First Experiment P (g plant^{-1})	0	0.016 ab	0.014 b	0.021 ab	0.017
	1	0.022 ab	0.026 ab	0.024 ab	0.024
	2	0.024 ab	0.019 ab	0.016 ab	0.020
	3	0.029 a	0.018 ab	0.015 ab	0.021
	Cd means	0.023	0.019	0.019	
	SA	Cd			SA means
		0	1	2	
Second Experiment P (g plant^{-1})	0	0.025 a	0.016 bc	0.013 d	0.018 AB
	1	0.019 b	0.015 cd	0.018 bc	0.017 B
	2	0.025 a	0.018bc	0.012 d	0.018 AB
	3	0.023 a	0.023 a	0.013 d	0.020 A
	Cd means	0.023 A	0.018 B	0.014 C	
	SA	Cd			SA average
		0	1	2	
First Experiment K (g plant^{-1})	0	0.131 b-d	0.235 a	0.109 d	0.158 B
	1	0.235 a	0.231 a	0.202 a-d	0.223 A
	2	0.217 a-c	0.190 a-d	0.222 ab	0.210 AB
	3	0.264 a	0.126 cd	0.112 d	0.167 B
	Cd average	0.212 A	0.196 AB	0.161 B	

Table 4.11. The effects of different salicylic acid and Cd applications on N, P, K, Ca, and Mg with Duncan letters (continued)

	SA	Cd			SA average
		0	1	2	
Second Experiment K (g plant^{-1})	0	0.154 bc	0.112 ef	0.078 g	0.115 C
	1	0.138 cd	0.128 d-f	0.138 cd	0.135 B
	2	0.194 a	0.135 c-e	0.106 f	0.145 B
	3	0.211 a	0.167 b	0.105 f	0.161 A
	Cd average	0.174 A	0.136 B	0.107 C	
	SA	Cd			SA average
		0	1	2	
First Experiment Ca (g plant^{-1})	0	0.057 ab	0.081 ab	0.043 ab	0.060 AB
	1	0.074 ab	0.089 a	0.076 ab	0.079 A
	2	0.054 ab	0.077 ab	0.075 ab	0.069 AB
	3	0.080 ab	0.042 b	0.036 b	0.053 B
	Cd average	0.066	0.072	0.058	
	SA	Cd			SA average
		0	1	2	
Second Experiment Ca (g plant^{-1})	0	0.056 cd	0.073 bc	0.032 d	0.054 B
	1	0.067 bc	0.051 cd	0.056 cd	0.058 B
	2	0.071 bc	0.052 cd	0.036 d	0.053 B
	3	0.085 ab	0.101 a	0.069 bc	0.085 A
	Cd means	0.070 A	0.069 A	0.048 B	
	SA	Cd			SA means
		0	1	2	
First Experiment Mg (g plant^{-1})	0	0.011	0.026	0.014	0.017
	1	0.023	0.008	0.013	0.015
	2	0.013	0.014	0.021	0.016
	3	0.021	0.011	0.007	0.013
	Cd means	0.017	0.015	0.014	
	SA	Cd			SA means
		0	1	2	
Second Experiment Mg (g plant^{-1})	0	0.015 b	0.014 b	0.007 b	0.012 B
	1	0.013 b	0.012 b	0.012 b	0.012 B
	2	0.015 b	0.015 b	0.015 b	0.015 AB
	3	0.014 b	0.030 a	0.014 b	0.020 A
	Cd means	0.014 AB	0.017 A	0.012 B	

a, b, c, d, e, f Superscripts with the same letters at each treatment are not significantly different, the mean values indicated by different letters are important for own lines and columns.

Table 4.12. The variance analysis results on the effects of different salicylic acid and Cd applications on N, P, K, Ca, and Mg

		N		P		K		Ca		Mg	
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
First Experiment											
SA	3	0.003	2.68 NS	0.00006	1.30NS	0.008	3.47*	0.0011	2.14 NS	0.00002	0.25NS
Cd	2	0.004	3.99*	0.00005	0.95NS	0.007	3.06 NS	0.0006	1.15 NS	0.00003	0.40NS
SA* Cd	6	0.003	2.87*	0.00007	1.32NS	0.009	3.71**	0.0009	1.69 NS	0.00017	1.81NS
Error	24	0.001		0.00005		0.002		0.0005		0.00009	
Second Experiment											
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
SA	3	0.0018	18.45**	0.000008	2.50NS	0.0034	19.31**	0.0021	11.46**	0.00011	4.55*
Cd	2	0.0067	68.39**	0.000270	75.74**	0.0139	78.63**	0.0018	9.93**	0.00008	3.27NS
SA*Cd	6	0.0009	9.72**	0.000034	9.77**	0.0017	9.69**	0.0004	2.39NS	0.00007	2.81NS
Error	24	0.00009		0.000003		0.0001		0.0001		0.00002	

The F value indicated by ** is important at the 1% level (P <0.01)
The F value indicated by * is important at the 5% level (P <0.05)

Plants' Iron (Fe), Cupper (Cu), Zinc (Zn), Manganese (Mn), and Sodium (Na) contents for Cd and SA applications were given in (Table 4.13) and variance analysis results were given in (Table 4.14) for first and second experiments. In the first experiment, the highest value for Fe was found at SA3*Cd0 with 0.230 g. The lowest values were obtained in SA3*Cd1 and SA3*Cd2 as 0.080 and 0.087 g. In the second experiment, the highest value for Fe was determined in SA3*Cd1 and SA3*Cd0 as 0.169 and 0.162 g. The lowest value was at SA0*Cd2 with 0.059 g. There was a high correlation between SA and Fe contents for the first and second experiments. The results show that SA influences the uptake of Fe in plants ($p<0.01$). However, Cd prevents the uptake of Fe at ($P<0.01$). At SA2*Cd1, the Fe content value was higher than in the control significantly. Therefore, at the lower Cd concentrations, SA was able to alleviate Cd effects. But at higher Cd concentrations, SA cannot cover the negative effects of Cd for Fe uptake ($P<0.01$).

The highest value for Cu was SA3*Cd0 as 0.040, the lowest values were SA3*Cd1; SA0*Cd2 and SA3*Cd2 as 0.017; 0.017 and 0.018 g. In the second experiment, the highest values for Cu were SA3*Cd0 and SA2*Cd0 as 0.049 and 0.046

g, the lowest values were SA0*Cd2; SA2*Cd2, and SA3*Cd2 as 0.016; 0.020 and 0.020 g. By increasing SA concentrations, Cu contents were also increased for the first and second experiments, as well ($p<0.01$). While increasing the Cd, the Cu content of plants was decreased ($p<0.01$). SA applications alleviated cupper up taking concentrations of Cd, the lowest Cu values were obtained for both first and second experiments ($p<0.05$; 0.01, respectively).

The highest Zn contents value was calculated in SA3*Cd0 and SA1*Cd0 as 0.128 and 0.120 g, the lowest value was found in SA2*Cd1 0.030 for the first experiments. Increasing Cd doses decreased plant Zn content. In the second experiment, the highest Zn contents were calculated in SA2*Cd0 and SA3*Cd0 with 0.136 and 0.132 g, the lowest value was seen in SA0*Cd2 as 0.050 g. In the second experiment, there are high correlations between SA and Zn contents. It was increased gradually and recorded the highest values ($P<0.01$). It was seen the alleviative effect of SA at Cd1 and Cd2 applications.

For the first experiments, the highest Mn contents of the plant were recorded in SA1*Cd0; SA3*Cd0 and SA0*Cd1 as 0.075; 0.072 and 0.072 g, the lowest values were found in SA3*Cd1; SA3*Cd2 and SA0*Cd2 as 0.031; 0.032 and 0.035 g. For the second experiment, the highest Mn contents of the plant were recorded in SA3*Cd0 and SA2*Cd0 as 0.130 and 0.118 g, the lowest values were found in SA0*Cd2 and SA3*Cd2 as 0.046 and 0.052 g. While the control group Mn content was 0.044 g., it increased up to 0.072 with the increase of SA concentrations, correlatively ($P<0.01$). Plant Mn value reached the lowest level at increasing Cd doses at high concentrations. SA1 and SA2 doses alleviative effects on Cd contents at ($P<0.05$).

At higher SA concentrations, the Mn contents of plants were the lowest values. In the second experiment, Mn contents of plants were about two times higher than the first experiments. SA2 application significantly increased plant Zn content compare to control, SA2, and SA3. For Cd applications, all values are the same or lower than the control group ($p<0.05$). it was also seen, SA1 and SA2 concentrations have ameliorative effects on Mn uptakes against the negative effects of Cd.

Table 4.13. The effects of different salicylic acid and Cd applications on Fe, Cu, Zn, Mn, and Cd with Duncan letters

	SA	Cd			SA means
		0	1	2	
First Experiment Fe (g plant^{-1})	0	0.091 cd	0.155 bc	0.091 cd	0.112 B
	1	0.162 b	0.178 ab	0.164 ab	0.168 A
	2	0.165 ab	0.132 b-d	0.164 ab	0.153 A
	3	0.230 a	0.080 d	0.087 d	0.132 AB
	Cd means	0.162 A	0.136 AB	0.126 B	
	SA	Cd			SA means
		0	1	2	
Second Experiment Fe (g plant^{-1})	0	0.109 cd	0.085 g	0.059 h	0.084 D
	1	0.104 d-f	0.091 fg	0.107 de	0.101 C
	2	0.144 b	0.123 b	0.094 e-g	0.120 B
	3	0.162 a	0.169 a	0.079 g	0.136 A
	Cd means	0.130 A	0.117 B	0.085 C	
	SA	Cd			SA means
		0	1	2	
First Experiment Cu (g plant^{-1})	0	0.022 b-d	0.033 a-c	0.017 d	0.024 B
	1	0.036 ab	0.034 ab	0.031 a-d	0.034 A
	2	0.035 ab	0.026 a-d	0.035 ab	0.032 AB
	3	0.040 a	0.017 d	0.018 cd	0.025 B
	Cd means	0.033 A	0.027 AB	0.025 B	
	SA	Cd			SA means
		0	1	2	
Second Experiment Cu (g plant^{-1})	0	0.035 b	0.028 c	0.016 d	0.026 C
	1	0.029 c	0.028 c	0.030 bc	0.029 B
	2	0.046 a	0.033 b	0.020 d	0.033 A
	3	0.049 a	0.035 b	0.020 d	0.035 A
	Cd means	0.040 A	0.031 B	0.022 C	
	SA	Cd			SA means
		0	1	2	
First Experiment Zn (g plant^{-1})	0	0.074 a-c	0.119 a	0.057 bc	0.083 AB
	1	0.120 a	0.112 a	0.102 ab	0.111 A
	2	0.073 a-c	0.030 c	0.108 ab	0.070 B
	3	0.128 a	0.054 bc	0.055 bc	0.079 B
	Cd means	0.099	0.079	0.080	
	SA	Cd			SA means
		0	1	2	
Second Experiment Zn (g plant^{-1})	0	0.097 bc	0.083 b-d	0.050 e	0.077 B
	1	0.104 b	0.098 bc	0.086 b-d	0.096 A
	2	0.136 a	0.090 b-d	0.068 de	0.098 A
	3	0.132 a	0.110 ab	0.072 c-e	0.105 A
	Cd means	0.117 A	0.095 B	0.069 C	

Table 4.13. The effects of different salicylic acid and Cd applications on Fe, Cu, Zn, Mn, and Cd with Duncan letters (contined)

	SA	Cd			SA means
		0	1	2	
First Experiment Mn (g plant $^{-1}$)	0	0.044 bc	0.072 ab	0.035 c	0.050 B
	1	0.075 a	0.068 ab	0.070 ab	0.071 A
	2	0.069 ab	0.043 bc	0.057 a-c	0.056 AB
	3	0.072 ab	0.031 c	0.032 c	0.045 B
	Cd means	0.065 A	0.054 AB	0.048 B	
	SA	Cd			SA means
		0	1	2	
Second Experiment Mn (g plant $^{-1}$)	0	0.092 b	0.066 cd	0.046 d	0.068 B
	1	0.091 b	0.084 bc	0.085 bc	0.087 A
	2	0.118 a	0.092 b	0.067 cd	0.092 A
	3	0.130 a	0.093 b	0.052 d	0.091 A
	Cd means	0.108 A	0.084 B	0.063 C	
	SA	Cd			SA means
		0	1	2	
First Experiment Cd (g plant $^{-1}$)	0	0.000 f	0.007 c	0.003 de	0.003 B
	1	0.001 ef	0.006 cd	0.014 a	0.007 A
	2	0.002 ef	0.006 cd	0.010 b	0.006 A
	3	0.002 ef	0.006 cd	0.004 de	0.004 B
	Cd means	0.001 C	0.006 B	0.008 A	
	SA	Cd			SA means
		0	1	2	
Second Experiment Cd (g plant $^{-1}$)	0	0.001 b	0.003 b	0.008 a	0.004 B
	1	0.001 b	0.002 b	0.008 a	0.004 B
	2	0.001 b	0.002 b	0.008 a	0.003 B
	3	0.002 b	0.006 a	0.009 a	0.006 A
	Cd means	0.001 C	0.003 B	0.008 A	

a, b, c, d, e, f Superscripts with the same letters at each treatment are not significantly different, the mean values indicated by different letters are important for own lines and columns.

For the first experiments, the highest value of Cd was recorded in SA1*Cd2 as 0.014 g, whereas the lowest was found in SA0*Cd0 and SA1*Cd0 as 0.000 and 0.001 g. For the second experiment, the highest value of Cd was recorded in SA3*Cd2 as 0.009 g, whereas the lowest was found in SA0*Cd0; SA1*Cd0, and SA2*Cd0 as 0.001 g (Table 4.13). For the first and second experiments, Cd concentrations of the plant were increased by Cd applications ($P<0.01$). For Cd1 and Cd2 applications Cd in plants was increased ($P<0.01$).

Table 4.14. The variance analysis results on the effects of different salicylic acid and Cd applications on Na, Fe, Cu, Zn, and Mn

		Fe		Cu		Zn		Mn		Cd	
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
First Experiment											
SA	3	0.005	4.14*	0.0002	3.12*	0.002	3.39*	0.0011	4.39*	0.00002	9.79**
Cd	2	0.004	3.15 NS	0.0001	2.60 NS	0.001	1.79 NS	0.0008	3.25NS	0.00013	59.57**
SA* Cd	6	0.007	5.89**	0.0001	2.78*	0.003	4.72**	0.0007	3.01*	0.00002	11.92**
Error	24	0.001		0.00007		0.0008		0.0002		0.000002	
Second Experiment											
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
SA	3	0.004	64.38**	0.0001	16.01**	0.0013	5.66**	0.0011	8.28**	0.00001	4.13*
Cd	2	0.006	89.55**	0.0009	116.15**	0.0070	30.14**	0.0060	43.59**	0.00015	61.24**
SA* Cd	6	0.001	23.82**	0.0001	16.82**	0.0004	1.95 NS	0.0006	4.77**	0.000002	0.94 NS
Error	24	0.0007		0.00008		0.0002		0.0001		0.000002	

The F value indicated by ** is important at the 1% level (P <0.01)
The F value indicated by * is important at the 5% level (P <0.05)

Furthermore, the cadmium contents of plants have a high positive correlation with the concentration of these cations in soil (Zhang et al. 2014). On the other hand, in salicylic acid-treated plants, these elements were significantly increased. Kovacik et al. (2009) investigated the effect of salicylic acid on cadmium stress and found that salicylic acid reduced the Cd concentration in the plant (Metwally et al., 2003). On the other hand, Belkhadi et al. (2010), found that the increased Cd concentration in the plant prevents the transport of salicylic acid and leads to a decrease in the plant SA content. Exogenous applications of SA may alleviate the decreases of the K, Ca, Mg, and Fe concentrations in the plant under Cd stress. Increases of Cd in lettuce with Cd applications were also reported by (Jiang et al., 2004). Moreover, this study also reported that Cd is accumulated more in roots than shoots in the Indian Mustard plant. All these results with our findings showed that salicylic acid can be used to alleviate stress from plants under Cd conditions.

Cadmium causes many morphological and physiological changes in the plant by changing enzyme activities, nitrogen and carbohydrate metabolism, causing stomata closure, decrease in transpiration, disrupting the water balance and problems in the uptake and distribution of macro and micronutrients, and disruption of chlorophyll biosynthesis

and inhibition of photosynthesis (Prasad, 1995; Shah and Dubey, 1995; Hernandez et al., 1996; Mendelssohn et al., 2001; Ramos et al., 2002), etc. It causes the phytotoxic effect, chlorosis, regression in root and stem growth, leading the plant to death at large concentrations (Van Assche and Clijsters, 1990). The toxic effects of cadmium create oxidative stress with the production of free oxygen radicals and changes in the activities of various antioxidant enzymes, as well (Mendelssohn et al., 2001).

The most prominent features of Cd toxicity in plants are slow growth and chlorosis. Chlorosis occurs due to the interaction of toxic metals and a lack of Fe. Chlorosis resulting from excessive accumulation of Cd results from the direct or indirect interaction of this heavy metal with Fe in the leaves (Das et al., 1997).

In general, Cd stress causes leaf curl and chlorosis in plants. It prevents growth in roots and shoots. Cadmium is first taken with plant roots and its toxic effects are the first in this region (Shah and Dubey, 1995). Cd can also cause inhibition of nitrate reductase activity in shoots, leading to reduced nitrogen transport to the shoots (Hernandez et al., 1996).

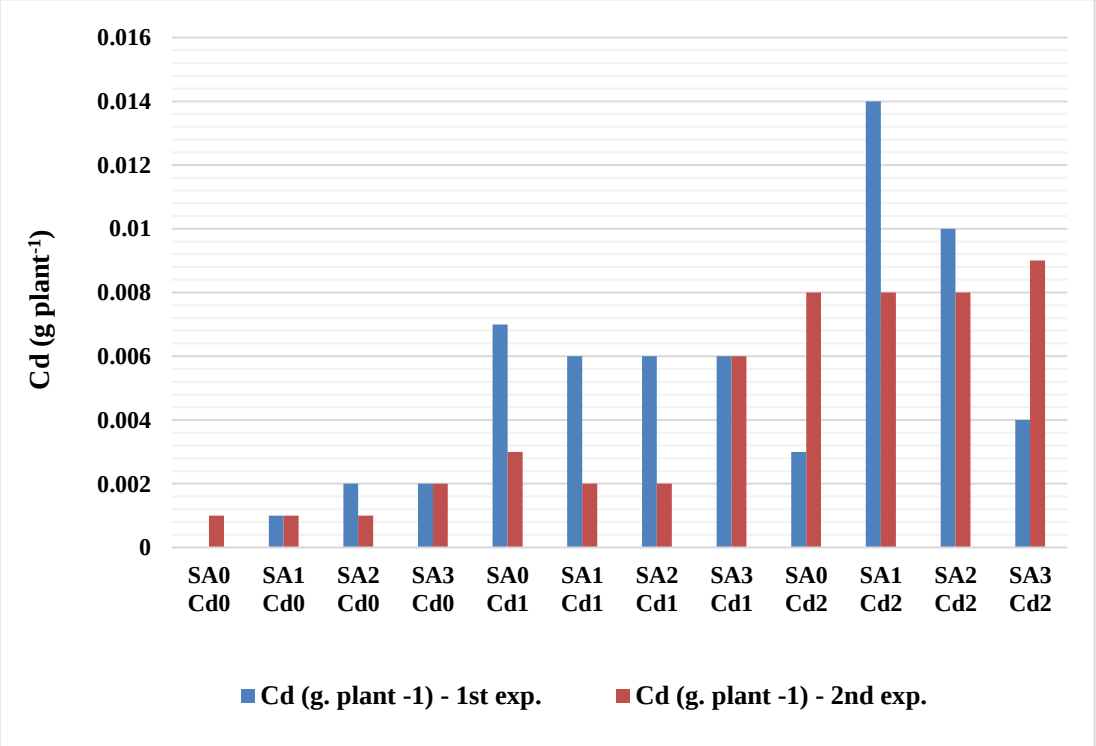

Figure 4.3. Effects of different Cd and SA doses on the content of Cd in lettuce plant.

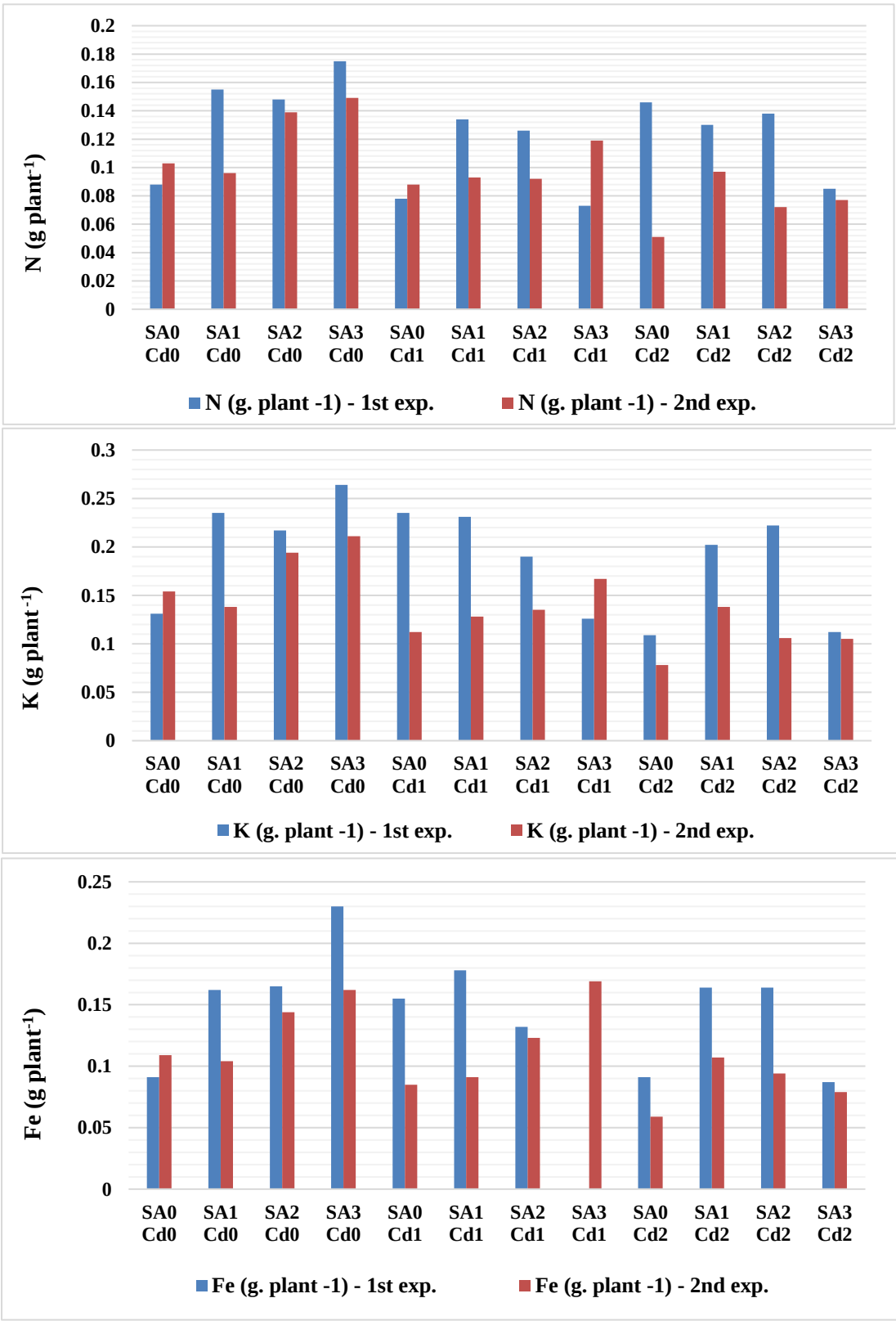

Figure 4.4. Effects of different Cd and SA doses on the content of N, K, and Fe in lettuce plant.

Azizian et al., 2011 was reported that, except of Fe, there are no significant effects of Cd on nutrient absorption, by the lettuce plant. High cadmium levels caused a decrease in the iron content of the lettuce plant. However, our findings showed that an increase in Cd concentrations leads to a decrease in macro and micronutrients' contents of plants. These results were corresponded with reported by (Zhang et al., 2014).

Because cadmium enters the plant through cation (Ca and Mg) channels or is transported with divalent cations such as Zn, Cu, Fe, and Mn concentrations are reduced in the root as it has an antagonistic relationship between them. Zhang et al., (2014) determined that Zn and K elements are effective in carrying Cd. Benavides et al., (2005) reported that cadmium used water and certain elements such as Ca, Mg, K, P while being transported. They also found that cadmium competes with the elements K, Ca, Mg, Fe, Mn, Cu, Zn, Ni (Benavides et al., 2005).

4.2.2. Interactions between NaCl and SA

Plants' anatomical measurements for SA and NaCl applications were given in (Table 4.15), for the first and second experiments. Variance analysis results were given in (Table 4.16). In the first experiment, the highest values for plant height were shown at SA0*S0 and SA1*S0 as 22.000;22.333 cm. The lowest values were SA0*S2 and SA0*S1 as 7.500;9.000 cm. The highest plant fresh weight value in SA1*S0 as 101.453 g, the lowest values were in SA0*S2 and SA0*S1 as 13.933;16.733 g. The highest values for plant dry weight, SA3*S0, and SA1*S0 as 6.193;5.637 cm, the lowest values were SA3*S2 and SA1*S2 as 1.730;1.827 g. The highest leaf number of plants was SA2*S0 as 30.667, the lowest values were SA0*S2 and SA0*S1 as 10.333;12.333. The highest values for plant diameter were shown at SA2*S2 and SA3*S1 as 12.500;12.000 cm. The lowest values were found in SA0*S2 and SA0*S1 as 4.800;5.407 cm (Table 4.15).

In the second experiment, the highest value for plant height was shown at SA0*S0 with 22.000 cm. The lowest value was SA0*S2 7.500 cm. The highest values for plant fresh weight, SA1*S0, and SA2*S1 as 59.133 and 56.133 g, the lowest values were SA0*S2 and SA0*S1 as 13.067;16.633 g. The highest values for plant dry weight, SA1*S0, and SA2*S1 as 4.473;4.160 g, the lowest value was SA0*S2 in 1.667 g. The highest leaf number of plants were SA3*S0 as 26.000, the lowest values were SA0*S2

and SA0*S1 as 10.333;12.667. The highest value for plant diameter was shown at SA3*S0 as 11.837 cm. The lowest values were SA0*S2 and SA0*S1 as 4.800;5.407 cm (Table 4.15).

The variance analyses on the effects of different salicylic acid and NaCl applications on plant growth criteria were given in (Table 4.16). Although there are no correlative changes between growth parameters such as plant height ($P<0.01$), fresh-dry weight ($P<0.05$), number of leaves ($P<0.01$), plant diameter was increased ($P<0.01$) in SA applications. There are high correlations between all growth parameters and NaCl concentrations. While NaCl concentration increased, as plant height ($P<0.01$), fresh-dry weight ($P<0.01$), leaf numbers ($P<0.01$), plant diameter ($P<0.01$) decreased.

There were significant differences between the mean values of plant height, dry weight, and leaf numbers as compared to control groups in NaCl applications. Using SA at different NaCl concentrations shows some mitigating effects on all growth parameters.

The increase was in plant height from 7.500 to 19.00 cm ($P<0.01$), fresh weight from 13.000 to 38.000 g ($P<0.01$), dry weight from 1.667 to 2.020 g. ($P<0.01$), no. of leaves from 10.333 to 19.000 ($P<0.05$) and plant diameters from 4.800 to 12.52, as the highest value ($P<0.01$). There were significant differences between control and NaCl applications. While the NaCl concentrations were increased, root parameters such as length, weight, and diameter are decreased as well ($P<0.01$). The lowest values were obtained from the highest NaCl concentrations. On the other hand, SA applications alleviated the negative effects of NaCl ($P<0.01$). For instance, root length increased from 6.433 to 16.567 cm at NaCl2 applications, when the SA was applied.

Root weight was increased from 0.617 to 6.823 and root diameter was increased from 4.133 to 9.720 mm, respectively. Furthermore, although there was no significant effect of SA on root length ($P<0.01$), Roots weight and root diameters were reached to the highest values, as doubled as control ($P<0.01$).

Table 4.15. The effects of different salicylic acid and NaCl applications on plant growth criteria with Duncan letters

	SA	NaCl			SA means
		0	1	2	
First Experiment Plant Height (cm)	0	22.000 ab	9.000 f	7.500 f	12.833 C
	1	22.333 a	18.500 c	14.667 d	18.500 B
	2	19.167 c	18.733 c	18.833 c	18.911 B
	3	21.667 ab	20.167 ab	19.467 c	20.433 A
	NaCl means	21.292 A	16.600 B	15.117 C	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Plant Height (cm)	0	22.000 a	12.667 g	7.500 h	14.056 B
	1	19.500 bc	17.333	15.333 f	17.389 A
	2	20.733 ab	18.133	15.600 ef	18.156 A
	3	20.867 ab	16.933	14.833 f	17.544 A
	NaCl means	20.775 A	16.267 B	13.317 C	
	SA	NaCl			SA means
		0	1	2	
First Experiment Plant Fresh Weight (g)	0	32.300 e	16.733 e	13.933 e	20.989 B
	1	101.453 a	54.640 d	30.893 e	62.329 A
	2	55.250 d	67.607 c	65.023 cd	62.627 A
	3	85.177 b	79.427 b	38.270 e	67.624 A
	NaCl means	68.545 A	54.602 B	37.030 C	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Plant Fresh Weight (g)	0	41.300 c-e	16.633 hi	13.067 i	23.667 B
	1	59.133 a	35.897 d-f	21.610 h-i	38.880 A
	2	33.003 e-g	56.133 ab	35.897 d-f	41.678 A
	3	50.200 a-c	46.290 b-c	28.407 f-h	41.632 A
	NaCl means	45.909 A	38.738 B	24.745 C	
	SA	NaCl			SA means
		0	1	2	
First Experiment Plant Dry Weight (g)	0	3.700 cd	3.233 de	2.167 fg	3.033 B
	1	5.637 a	4.367 bc	1.827 g	3.943 A
	2	4.803 b	3.590 c-e	2.817 ef	3.737 A
	3	6.193 a	3.887 cd	1.730 g	3.937 A
	NaCl means	5.083 A	3.769 B	2.135 C	

Table 4.15. The effects of different salicylic acid and NaCl applications on plant growth criteria with Duncan letters (continued)

	SA	NaCl			SA means
		0	1	2	
Second Experiment Plant Dry Weight (gm)	0	3.767 a-c	2.100 dc	1.667 d	2.511
	1	4.473 a	3.230 a-d	1.993 dc	3.232
	2	2.403 b-d	4.160 ab	2.270 dc	2.944
	3	3.710 a-c	3.250 a-d	2.020 dc	2.993
	NaCl means	3.588 A	3.185 A	1.988 B	
	SA	NaCl			SA means
		0	1	2	
First Experiment Leaf number. Plant^{-1}	0	21.333 e	12.333 g	10.333 g	14.667 D
	1	28.667 ab	25.000 cd	22.000 e	25.222 B
	2	30.667 a	26.333 bc	23.000 de	26.667 A
	3	28.000 b	23.000 de	19.000 f	23.333 C
	NaCl means	27.167 A	21.667 B	18.583 C	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Leaf number. Plant^{-1}	0	16.667 de	12.667 f	10.333 g	13.222 B
	1	23.333 b	20.333 c	17.333 de	20.333 A
	2	24.667 ab	20.000 c	17.667 c	20.778 A
	3	26.000 a	21.333 c	15.667 e	21.000 A
	NaCl means	22.667 A	18.583 B	15.250 C	
	SA	NaCl			SA means
		0	1	2	
First Experiment Plant Diameter (cm)	0	6.183 e	5.407 e	4.800 e	5.463 C
	1	12.730 a	10.580 b-d	10.340 cd	11.217 AB
	2	10.350 cd	11.850 a-c	12.520 a	11.573 A
	3	10.560 b-d	12.000 ab	9.443 d	10.668 B
	NaCl means	9.956	9.959	9.276	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Plant Diameter (cm)	0	6.183 e	5.407 ef	4.800 f	5.463 C
	1	10.730 b	8.857 c	8.380 cd	9.322 B
	2	10.380 b	8.883 c	7.813 d	9.026 B
	3	11.837 a	10.857 b	8.860 c	10.518 A
	NaCl means	9.783 A	8.501 B	7.463 C	

a, b, c, d, e, f Superscripts with the same letters at each treatment are not significantly different, the mean values indicated by different letters are important for own lines and columns.

Table 4.16. The variance analysis results in the effects of different salicylic acid and NaCl applications on plant growth criteria

		Plant Height		Plant Fresh Weight		Plant Dry Weight		Leaf Number		Plant diameter	
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
First Experiment											
SA	3	99.77	78.53**	4253.01	91.26**	1.66	7.59*	260.47	124.08**	74.07	109.45**
NaCl	2	124.68	98.13**	2992.75	64.22**	26.18	119.3**	226.86	123.74**	1.85	2.75NS
SA + NaCl	6	38.03	29.93**	1086.35	23.31**	1.63	7.47**	4.97	2.71*	4.47	6.61**
Error	24	1.27		46.602		0.219		1.83		0.67	
Second Experiment											
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
SA	3	30.80	39.51**	670.5	14.67**	0.81	0.94 NS	126.62	106.0**	42.65	155.0**
NaCl	2	169.3	217.7**	1390.3	30.43**	8.31	9.61**	165.58	138.6**	16.19	58.88**
SA* NaCl	6	17.88	22.94**	425.44	9.31**	1.87	2.16 NS	3.54	2.97*	0.58	2.14 NS
Error	24	0.779		45.69		0.86		1.19		0.27	

The F value indicated by ** is high significantly different at the 1% level (P <0.01)
The F value indicated by * is significantly different at the 5% level (P <0.05)

Many studies show similarities with the results of this experiment. In his study, El-Tayeb (2005) reported that an increase in NaCl concentrations decreases the germinations and growth parameters (Fresh and dry weight), both in roots and leaves of barley. SA applications increase RWC, fresh and dry weight as well.

Çanakçı and Munzuroğlu (2004) were also recorded the same changes in fresh-dry weights of roots and leaves in one week of bean seedling. Qing-Moo et al., (2007) found that SA applications made significant improvements in growth parameters such as plant height, stem diameter and total mass in NaCl stressed cucumber seedlings.

Akçalı (2014), in his thesis, investigated that the effects of exogenous SA application on certain proteome and biochemical parameters in canola seedlings exposed to salt stress, and it was stated that salt stress reduces root and stem growth.

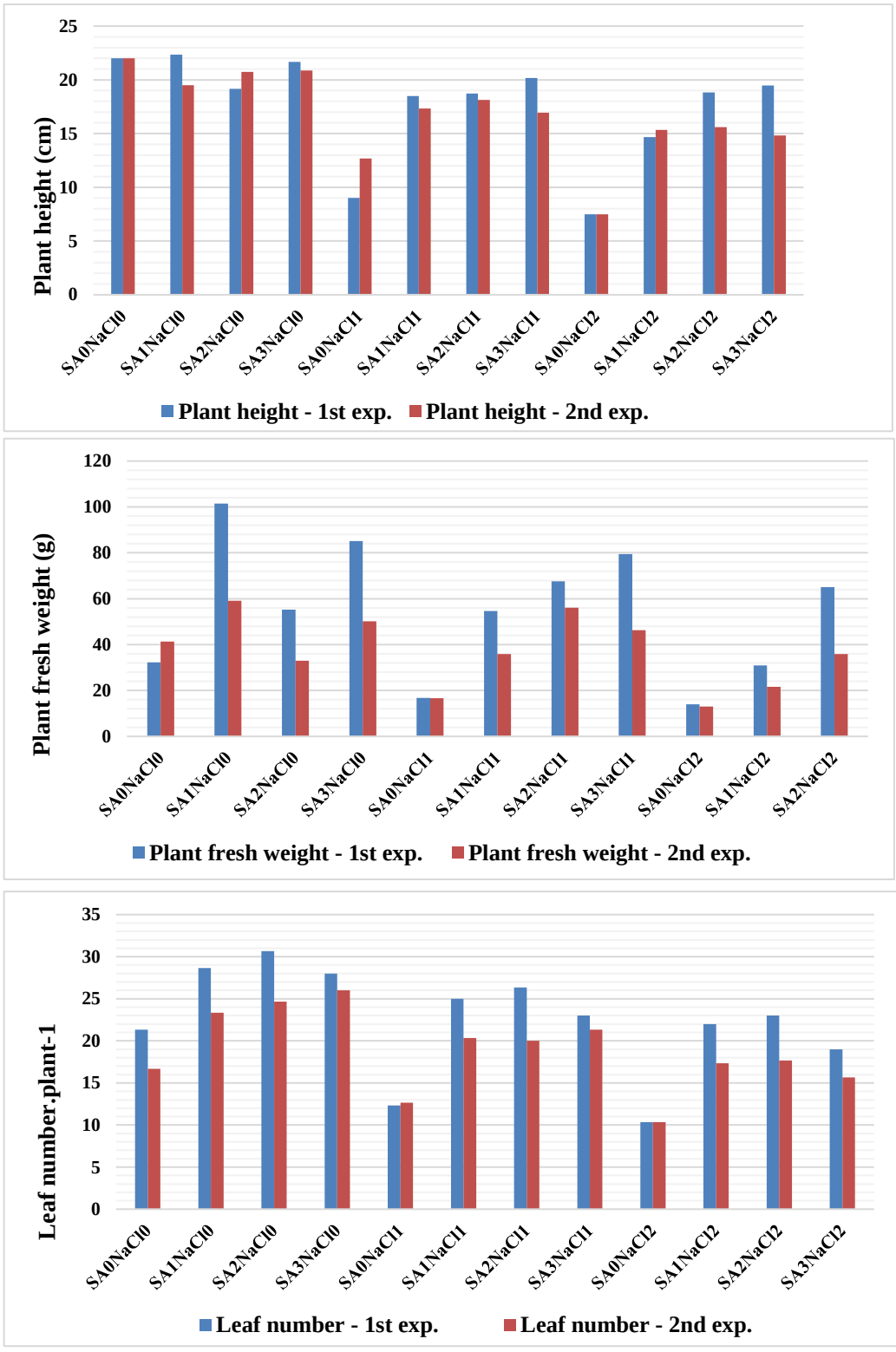

Figure 4.5. Effects of different NaCl and SA doses on plant height, plant fresh weight, and plant leaf number.

Table 4.17. The effects of different salicylic acid and NaCl applications on root growth criteria with Duncan letters

	SA	NaCl			SA means
		0	1	2	
First Experiment Root Length (cm)	0	16.333 d	14.333 d	6.433 e	12.367 B
	1	22.000 ab	23.000 a	15.667 d	20.222 A
	2	18.667 a-d	22.000 ab	17.000 b-d	19.222 A
	3	19.167 a-d	20.000 a-c	15.667 d	18.278 A
	NaCl means	19.042 A	19.833 A	13.692 B	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Root Length (cm)	0	20.667 ab	14.333 f	6.433 g	13.811 B
	1	22.167 a	18.333 d	16.767 e	19.089 A
	2	21.167 ab	20.267 bc	16.567 e	19.333 A
	3	21.000 ab	18.833 d	16.567 e	18.800 A
	NaCl means	21.250 A	17.942 B	14.083 C	
	SA	NaCl			SA means
		0	1	2	
First Experiment Root Weight (g)	0	2.200 f	0.900 f	0.617 f	1.239 C
	1	14.073 a	8.760 cd	4.890 e	9.241 A
	2	6.740 ed	8.797 cd	6.823 ed	7.453 B
	3	11.417 b	10.043	6.070 e	9.177 A
	NaCl means	8.608 A	7.125 B	4.600 C	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Root Weight (g)	0	2.200 fg	1.567 g	0.617 g	1.461 B
	1	9.553 ab	7.783 bc	4.717 de	7.351 A
	2	5.560 de	11.393 a	4.940 de	7.298 A
	3	9.643 ab	6.897 cd	4.270 ef	6.937 A
	NaCl means	6.739 A	6.910 A	3.636 B	
	SA	NaCl			SA means
		0	1	2	
First Experiment Root Diameter (mm)	0	5.927 d	5.677 d	4.133 d	5.246 B
	1	12.290 a	9.870 bc	10.740 ab	10.967 A
	2	10.563 a-c	11.393 ab	11.547 ab	11.168 A
	3	12.133 a	11.973 a	8.757 c	10.954 A
	NaCl means	10.228 A	9.728 A	8.794 B	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Root Diameter (mm)	0	5.927 b	5.677 b	4.133 b	5.246 B
	1	10.833 a	10.343 a	10.170 a	10.449 A
	2	9.757 a	11.750 a	11.043 a	10.850 A
	3	11.453 a	10.530 a	9.720 a	10.568 A
	NaCl means	9.493	9.575	8.767	

a, b, c, d, e, f Superscripts with the same letters at each treatment are not significantly different, the mean values indicated by different letters are important for own lines and columns.

The highest values for root length were obtained in SA1*S1, SA1*S0, and SA2*S1 as 23.000; 22.000, and 22.000 cm. The lowest was found in SA0*S2 as 6.433 cm. The highest root weight was found in SA1*S0 and as 14.073 g. whereas, the lowest values were measured in SA0*S2 and SA0*S1 as 0.617;0.900 g. The highest measurements for root diameters were recorded in SA1*S0 and SA3*S0 as 12.290;12.133 cm. The lowest value was found in SA0*S2 as 4.133 cm (Table 4.17).

In the second experiment, the highest root length value was obtained from SA1*S0 as 22.167 cm. The lowest was found in SA0*S2 as 6.433 cm. The highest root weight was found in SA2*S1 as 11.393 g. whereas, the lowest value was measured in SA0*S2 as 0.617 g. The highest measurements for root diameter was recorded with SA2*S1 and SA3*S0 as 11.750;11.453 cm. consequently. The lowest value was found in SA0*S2 as 4.133 cm (Table 4.17).

Table 4.18. The variance analysis results in the effects of different salicylic acid and NaCl applications on root growth criteria

		Root length		Root weight		Root diameter	
S. O. V.	DF	MS	F	MS	F	MS	F
			First Experiment				
SA	3	111.99	13.30**	128.87	73.95**	75.36	69.75**
NaCl	2	133.93	15.91**	49.26	28.27**	6.35	5.89**
SA + NaCl	6	10.34	1.23 NS	14.61	8.38**	4.23	3.92**
Error	24	8.41		1.74		1.08	
			Second Experiment				
S. O. V.	DF	MS	F	MS	F	MS	F
SA	3	62.74	60.74**	74.28	47.32**	65.29	50.65**
NaCl	2	154.38	149.45**	40.76	25.96**	2.37	1.84 NS
SA*NaCl	6	17.96	17.39**	12.93	8.24**	2.04	1.59 NS
Error	24	1.03		1.56		1.28	

The F value indicated by ** is important at the 1% level (P <0.01)
The F value indicated by * is important at the 5% level (P <0.05)

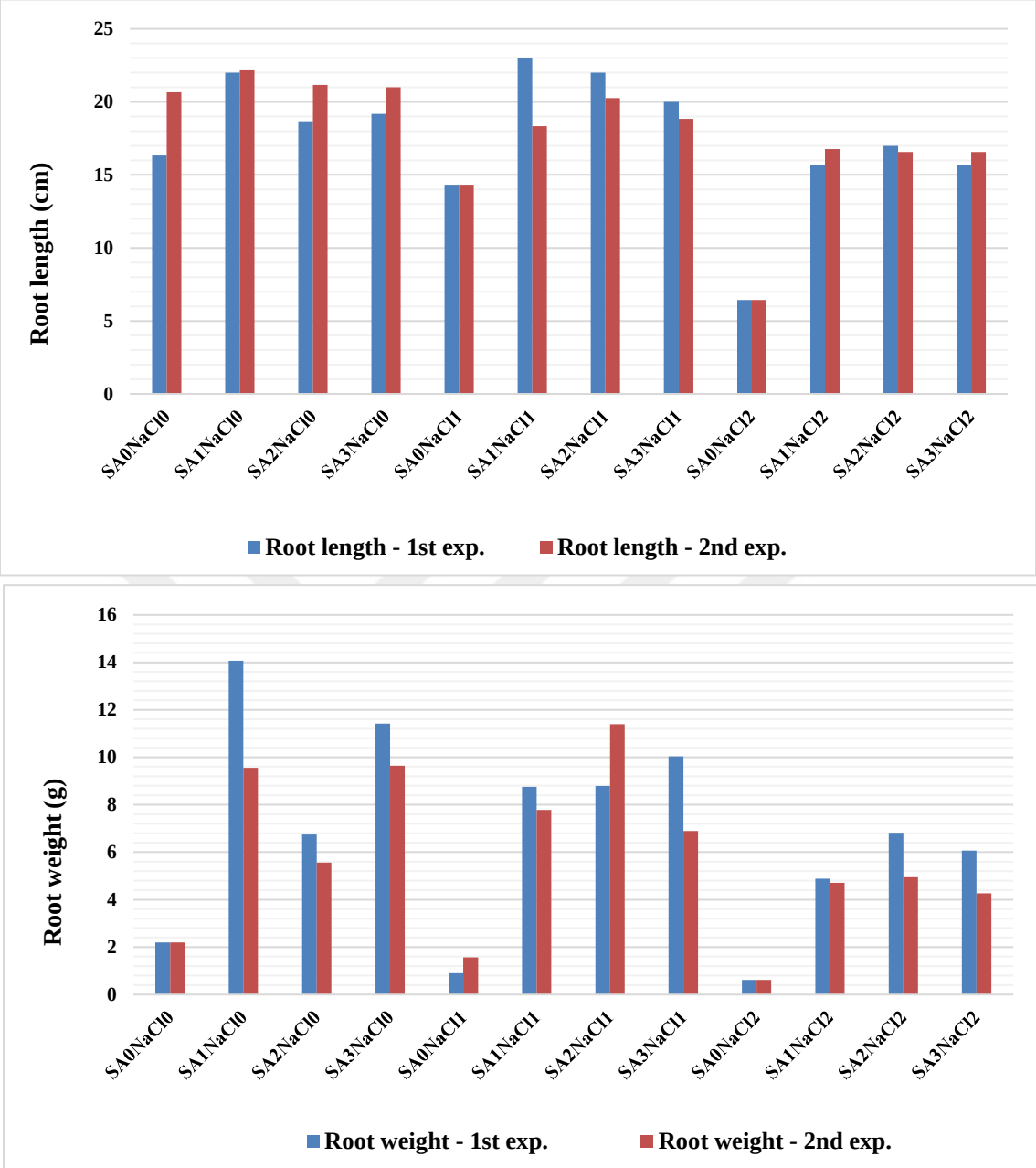

Figure 4. 6. Effects of different NaCl and SA doses on root length and root weight.

Plants' physiological parameter measurements for SA and NaCl applications were given in (Table 4.19) and variance analysis results were given in (Table 4.20) for the first and second experiments. In the first experiment, the highest consumed weight value was shown at SA1*S0 as 88.777 g, consequently. The lowest values were in SA0*S1 and SA0*S2 as 7.767;12.500 g. The highest values for chlorophyll content were SA3*S0 and SA1*S0 as 65.300;60.200 µg mg^{-1}, the lowest values were in SA0*S0 and SA0*S2 as 33.633;37.267 µg mg^{-1}. The highest value for leaf relative humidity was calculated in

SA3*S0 with 88.880, the lowest value was found in SA0*S2 as 65.987 g. The highest wastrel leaves the weight of plant was recorded in SA3*S0 as 2.000 g, the lowest values were found in SA3*S0 and SA2*S1 as 0.000 and 0.000 g.

In the second experiment, the highest plant consumed weight values were obtained in SA3*S0 and SA1*S0 as 58.350;57.720 g. The lowest values were in SA0*S1 and SA0*S2 as 4.433;7.167 g. The highest values for chlorophyll content were found in SA3*S0; SA2*S2 and SA1*S1 as 59.653;59.600 and 59.533 μg mg^{-1}, the lowest values were recorded in SA0*S2; SA0*S1 as 39.433;41.800 μg mg^{-1}. The highest values for leaf relative humidity were calculated in SA3*S2 and SA0*S0 as 87.477;87.107, the lowest value was obtained in SA0*S2 as 67.390. The highest wastrel leaves weights of the plant were recorded in SA0*S2 as 2.000 g and, the lowest values were found in SA2*S0 and SA3*S0 as 0.333 and 0.333 g.

Under NaCl stress, consumed weights were dramatically decreased from 35.067 to 7.167 g. ($P<0.01$) and wastrel leaves given the highest values as 2.000 g. ($P<0.01$). The presence of SA increased the consumed weight ($P<0.01$) while the wastrel leaves reduced ($P<0.01$). While there was no significant difference in chlorophyll contents of leaves in the first experiment ($P<0.05$), there was a gradual decrease in the second experiment chlorophyll contents from 44.333 to 39.433 μg mg^{-1} ($P<0.05$). On the other hand, SA increased the chlorophyll contents for both experiments ($P<0.01$). The highest values (65.300 μg mg^{-1}) were obtained from SA applications. The second highest values were obtained from SA*S applications as 59.600 μg mg^{-1}.

Chlorophyll content reductions because of the disruption in the overall metabolic process under salt stress have been reported by many researchers. El-Tayeb (2005) showed a decrease in chlorophyll and other photosynthetic pigment contents of barley under salt stress. Çiçek and Çakirlar (2002) reported in corn and Gadallah (1999) in broad bean plant reported that decreases in chlorophyll content of leaves under NaCl stress. Qing-Mao et al., (2007) also reported the same findings on the cucumber plant. The alleviative effects of SA have been published by Rafique et al. (2011) on pumpkin plants under salt stress. It was found that the increases in salinity caused a decrease in the chlorophyll content of the soybean plant and has been determined that the exogenous application of salicylic acid increases the exhaustion resistance against salt stress (Baran et al., 2014).

In the first experiment, the highest osmotic potential means were recorded in SA3*S2 and SA1*S2 as 5.694; 5.687 g, the lowest values were found in SA3*S0 and SA0*S0 as 1.602;1.868 g (Table 4.19). In the second experiment, the highest osmotic potential weights were recorded in SA3*S3 and SA1*S3 as 6.664; 6.107 -Mpa, the lowest value was found in SA3*S0 with 1.735 -Mpa (Table 4.19). Increasing NaCl in the soil decrease the leaf relative water contents via osmotic dynamics. NaCl prevents the uptake of water by roots and creates osmotic stress in plants, leading to a decrease in the water contents of leaves in general.

The lowest value of relative water content was obtained from the highest NaCl concentrations ($P<0.01$). The lowest osmotic potential also was found at higher NaCl ($P<0.01$). There was a slight increase in RWC with increasing SA concentrations ($P<0.01$). The highest RWC was obtained from the highest SA. Parallel to these findings, osmotic potentials were also the highest at the highest SA concentrations as 6.664 Mpa ($P<0.01$) and the lowest at the highest NaCl concentrations as 1.602 ($P<0.01$). It was also realized that, at higher SA*NaCl concentrations, the osmotic potentials were lower. It is difficult to understand low osmotic potentials despite higher RWC at higher SA*NaCl concentrations.

Baath et al., (2017), reported that an increase in irrigation water salinity caused a decrease in stomatal conductivity and water use efficiency on pepper plants. According to Çanakçı and Munzuroğlu (2004), the water content of bean seedlings, exposed to salts stress is lower than that of SA treated plants. El-Tayeb (2005) also found the same results in barley plants. Qing-Mao et al., (2007) reported that salicylic acid application may have important effects on cucumber seedlings NaCl tolerance through osmatic regulation, water balance, antioxidation, and membrane stability as well.

Table 4.19. The effects of different salicylic acid and NaCl applications on consumed weight, chlorophyll, relative humidity, wastrel leaves, and osmotic potential with Duncan letters

	SA	NaCl			SA means
		0	1	2	
First Experiment Consumed Weight (g)	0	35.067 e	7.767 f	12.500 f	18.444 B
	1	88.777 a	56.270 d	34.227 e	59.758 A
	2	55.250 d	66.097 b-d	65.023 cd	62.123 A
	3	78.843 ab	77.150 a-c	38.150 e	64.714 A
	NaCl means	64.484 A	51.821 B	37.475 C	
	SA		NaCl		SA means
		0	1	2	
Second Experiment Consumed Weight (g)	0	35.067 bc	4.433 d	7.167 d	15.556 B
	1	57.720 a	49.690 ab	29.120 c	45.510 A
	2	32.617 bc	59.660 a	34.537 bc	42.271 A
	3	58.350 a	41.913 a-c	28.277 c	42.847 A
	NaCl means	45.938 A	38.924 A	24.775 B	
	SA		NaCl		SA means
		0	1	2	
First Experiment Chlorophyll µg mg^{-1}	0	33.633 d	40.180 d	37.267 d	37.027 B
	1	60.200 ab	55.800 bc	56.467 bc	57.489 A
	2	56.800 bc	55.500 bc	55.800 bc	56.033 A
	3	65.300 a	59.667 ab	49.800 c	58.256 A
	NaCl means	53.983 A	52.787 AB	49.833 B	
	SA		NaCl		SA means
		0	1	2	
Second Experiment Chlorophyll µg mg^{-1}	0	44.333 cd	41.800 d	39.433 d	41.856 C
	1	59.100 a	59.533 a	57.200 ab	58.611 A
	2	54.233 ab	57.600 ab	59.600 a	57.144 A
	3	59.653 a	52.747 b	47.267 c	53.222 B
	NaCl means	54.330 A	52.920 AB	50.875 B	
	SA		NaCl		SA means
		0	1	2	
First Experiment Relative Water Content %	0	82.103 c	78.807 e	65.987 g	75.632 D
	1	81.947 c	82.017 c	78.503 e	80.822 B
	2	83.380 b	77.813 e	74.903 f	78.699 C
	3	88.880 a	80.667 d	78.413 e	82.653 A
	NaCl means	84.078 A	79.826 B	74.452 C	
	SA		NaCl		SA means
		0	1	2	
Second Experiment Relative Water Content %	0	87.107 a	79.700 bc	67.390 f	78.066 C
	1	79.250 cd	80.110 bc	75.653 e	78.338 BC
	2	81.833 b	79.493 b-d	77.120 de	79.482 B
	3	78.743 cd	79.713 bc	87.477 a	81.978 A
	NaCl means	81.733 A	79.754 B	76.910 C	

Table 4.19. The effects of different salicylic acid and NaCl applications on consumed weight, chlorophyll, relative humidity, wastrel leaves, and osmotic potential with Duncan letters (continued)

	SA	NaCl			SA means
		0	1	2	
First Experiment Wastrel Leaves (g)	1	1.000 bc	1.667 ab	1.000 bc	1.222 B
	2	1.333 ab	0.000 d	1.000 bc	0.778 BC
	3	0.000 d	1.333 ab	0.333 cd	0.556 C
	4	2.000 a	1.667 ab	1.667 ab	1.778 A
	NaCl means	1.083	1.167	1.000	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Wastrel Leaves (g)	0	0.667 bc	1.333 a-c	2.000 a	1.333
	1	0.667 bc	1.333 a-c	1.667 ab	1.222
	2	0.333 c	0.667 bc	1.667 ab	0.889
	3	0.333 c	0.667 bc	1.333 a-c	0.778
	NaCl means	0.500 C	1.000 B	1.667 A	
	SA	NaCl			SA means
		1	2	3	
First Experiment Osmotic Potential (Mpa)	1	1.868 cd	3.127 bc	4.460 ab	3.152 B
	2	3.165 bc	4.376 ab	5.687 a	4.409 A
	3	2.233 cd	2.754 cd	4.159 b	3.049 B
	4	1.602 d	2.060 cd	5.694 a	3.118 B
	NaCl means	2.217 C	3.079 B	5.000 A	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Osmotic Potential (Mpa)	0	2.065 fg	3.127 de	5.287 b	3.493 B
	1	3.338 c-e	4.144 c	6.107 ab	4.530 A
	2	2.812 d-f	3.712 cd	5.138 b	3.887 B
	3	1.735 g	2.355 e-g	6.664 a	3.585 B
	NaCl means	2.488 C	3.334 B	5.799 A	

a, b, c, d, e, f Superscripts with the same letters at each treatment are not significantly different, the mean values indicated by different letters are important for own lines and columns.

Table 4.20. The variance analysis results on the effects of different salicylic acid and NaCl applications on consumed weight, chlorophyll, relative humidity, wastrel leaves, and osmotic potential

		Consumed weight		Chlorophyll		RWC		Wastrel leaves		Osmotic potential	
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
First Experiment											
SA	3	4344.32	78.80**	928.69	65.92**	81.85	190.97**	2.62	10.48**	3.83	6.91**
NaCl	2	2191.31	39.69**	54.75	3.89*	279.2	651.49**	0.08	0.33 NS	24.35	43.85**
SA* NaCl	6	801.12	14.51**	60.14	4.27**	32.35	75.48**	1.12	4.48**	1.17	2.11NS
Error	24	55.20		14.08		0.42		0.25		0.55	
Second Experiment											
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
SA	3	1780.28	16.19**	517.70	63.33**	28.63	16.00**	0.62	2.06NS	1.97	6.40**
NaCl	2	1394.56	12.68**	36.21	4.43*	70.54	39.43**	4.11	13.45**	35.51	115.0**
SA* NaCl	6	494.57	4.50**	41.35	5.06**	109.7	61.33**	0.07	0.24NS	1.46	4.76**
Error	24	109.94		8.17		1.78		0.30		0.30	

The F value indicated by ** is important at the 1% level (P <0.01)
The F value indicated by * is important at the 5% level (P <0.05)

While N content was gradually increased with SA increase (P<0.01), increasing NaCl concentrations decreased the N contents from 0.127 to 0.076 g (P<0.01). the lowest N values obtained from the highest NaCl levels as well. Although there was some increase in N contents of plants at lower NaCl concentrations (SA*S1), there were no significant changes at the highest levels of NaCl by using SA (P<0.01). In many studies, it was determined that salt application reduces leaf N content. Pırlak and Eşitken (2004) found in their study with Fern and Camarosa strawberry varieties that the amount of leaf N decreased due to the increase in salt concentration. In contrast, Saied et al. (2005) determined that salt application increases N content in their study with Karona and Elsenta strawberry varieties. Besides, another study in tomato (Inal et al., 1997) found that salt application reduced the amount of N. The decrease in the amount of N in the addition of NaCl to the growing medium is related to the opposite relationship between N and Cl. The addition of salt to the growing medium negatively affects the N uptake of the plant (Wehrmann and Hahndel, 1984).

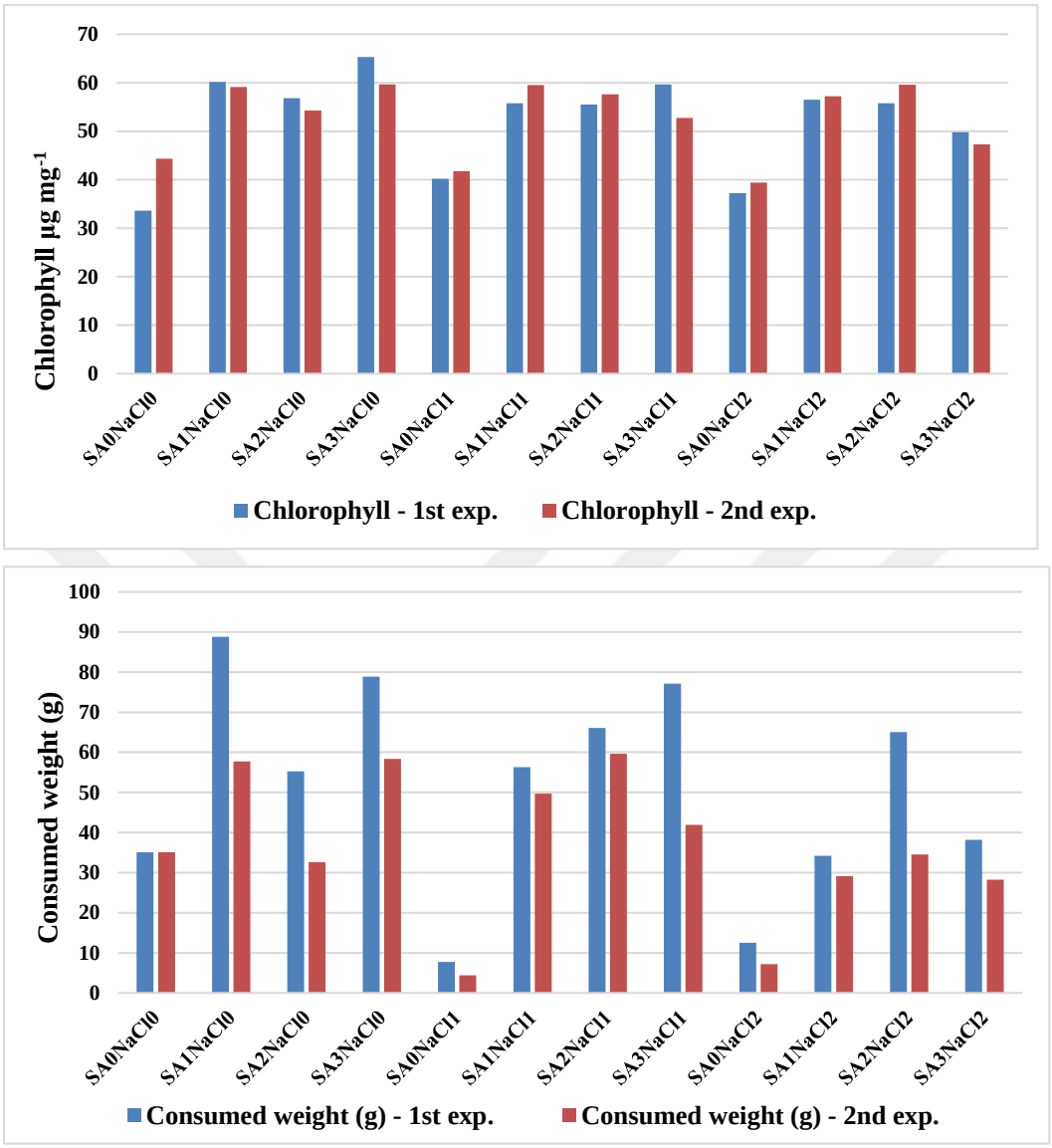

Figure 4.7. Effects of different NaCl and SA doses on consumed weight and chlorophyll.

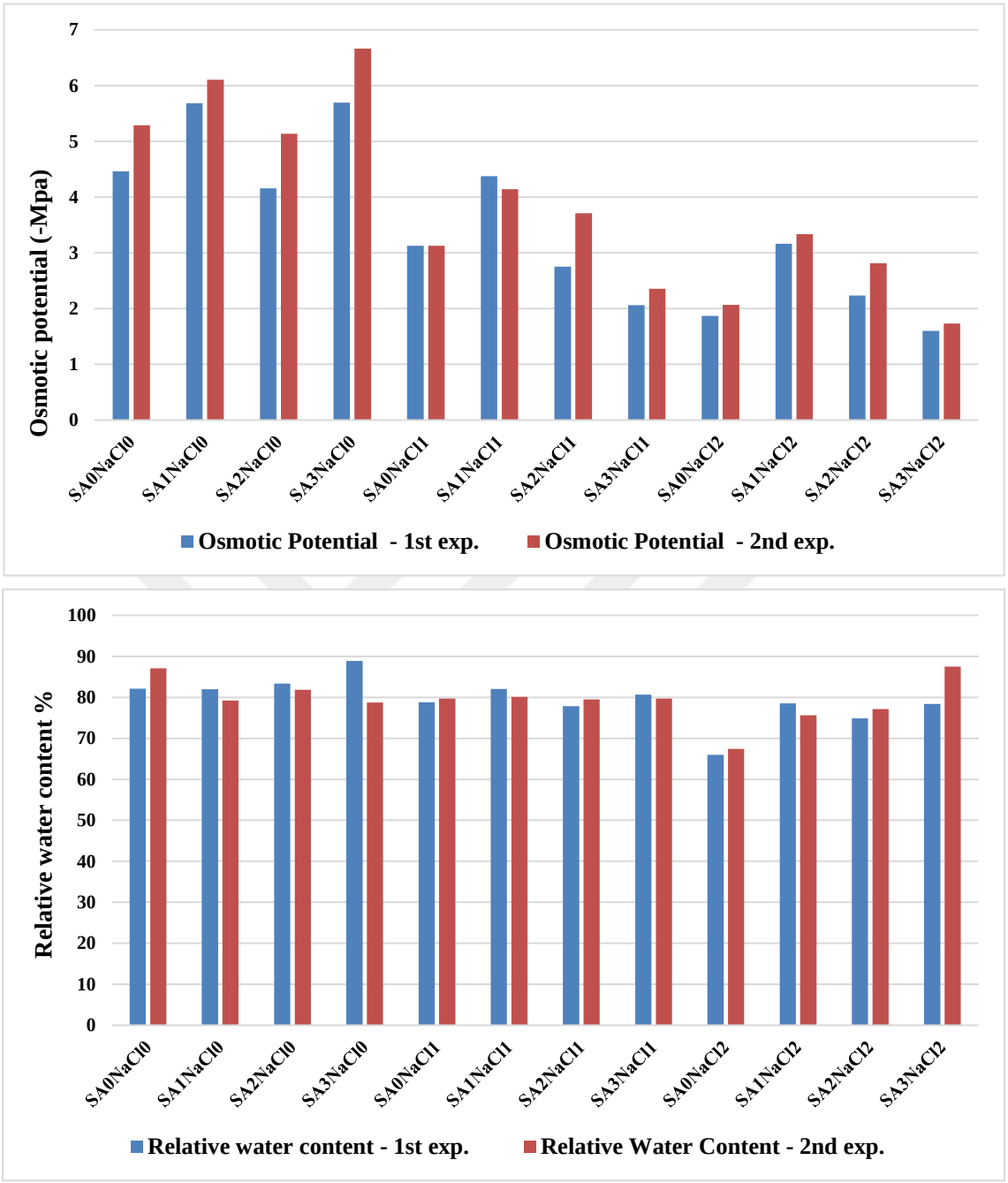

Figure 4.8. Effects of different NaCl and SA doses on osmotic potential and relative water content.

It was recorded that; SA1 increased the P contents of plants from 0.008 to 0.014 g. At higher SA applications there was no significant difference in P contents ($P<0.01$). For the first experiment, while there was no difference between control and lower NaCl1 applications, at the highest NaCl concentrations P content was decreased to 0.005. In the second experiment, P contents were decreased from 0.009 to 0.005 g at each NaCl

applications. At NaCl1dose, SA slightly increased the P contents, even higher than the control. But at higher NaCl concentrations there were no significant differences in P values ($P<0.01$). In previous studies, it has been determined that salt application significantly affects the amount of P. In studies with different varieties of strawberries (Pırlak and Eşitken, 2004; Turhan and Eriş, 2004) and wheat (Alparslan et al., 1998), the salt application leads to decrease the amount of P. In contrast, Saied et al. (2005) found that salt application increases the P content in their study on strawberries. In addition, in another study in beans and tomatoes (Cooper and Dumbroff 1973), it was determined that the amount of P increased in the salt plant.

Potassium contents lead to a decrease at high NaCl concentrations, but this decrease was not significant ($P<0.01$). The lowest values were obtained at the highest NaCl concentrations as 0.087 g. It also was seen that there were no strong correlations between SA concentrations and K contents ($P<0.01$). In general, there was a decrease in K contents by increasing NaCl concentrations at each level. At lower NaCl concentrations, there was a significant increase in K contents from 0.117 to 2.039 g. at the presence of SA. In some plant species and strawberry varieties, it was determined that the amount of K increased while other nutrients decreased with the application of salt. Pırlak and Eşitken (2004) found that the amount of K decreases with the application of salt in strawberries.

The amount of calcium was decreased at higher NaCl concentrations but not significant ($P<0.01$). Ca content was significantly increased by higher SA concentrations ($P<0.05$). The highest values were obtained at SA1*S1as 0.109 g. Although, at the highest concentrations of NaCl, there was a decrease in Ca, even at higher SA applications for the first experiment ($P<0.01$), for the second experiment Ca concentrations were slightly increased. But not reach the control anyway.

El-Tayeb (2005) reported that increased NaCl level decreases K, Ca, P in both root and leaves of barley seedlings. There were no significant differences found in SA applications. Yaşar et al. (2006) stated that under salt stress, two tolerant and two sensitive eggplant varieties were used, and there were decreases in K^+ and Ca^{+2} ions in the sensitive plant variety. Kemmler and Kraus (1971) reported that if additional K^+ ions are given to plants under saline conditions, there is a decrease in Ca^{+2} uptake by replacing Na^{+2} in the root hair.

Table 4.21. The effects of different salicylic acid and NaCl applications on N, P, K, Ca, and Mg with Duncan letters

	SA	NaCl			SA means
		0	1	2	
First Experiment N (g plant^{-1})	0	0.127 de	0.110 e	0.076 fg	0.105 B
	1	0.195 b	0.151 cd	0.062 g	0.136 A
	2	0.162 c	0.105 ef	0.073 g	0.113 B
	3	0.233 a	0.134 c-e	0.062 g	0.143 A
	NaCl means	0.179 A	0.125 B	0.068 C	
	SA	NaCl			SA means
		0	1	2	
Second Experiment N (g plant^{-1})	0	0.135 a-c	0.069 cd	0.066 d	0.090
	1	0.151 a	0.128 a-d	0.075 b-d	0.118
	2	0.084 b-d	0.136 a-c	0.075 b-d	0.098
	3	0.138 ab	0.108 a-d	0.072 b-d	0.106
	NaCl means	0.127 A	0.110 A	0.072 B	
	SA	NaCl			SA means
		0	1	2	
First Experiment P (g plant^{-1})	0	0.008 bc	0.008 bc	0.005 cd	0.007 B
	1	0.014 a	0.011 ab	0.005 cd	0.010 A
	2	0.013 a	0.008 bc	0.007 b-d	0.009 A
	3	0.013 a	0.012 a	0.004 d	0.010 A
	NaCl means	0.012 A	0.010 B	0.006 C	
	SA	NaCl			SA means
		0	1	2	
Second Experiment P (g plant^{-1})	0	0.009 ab	0.005 a-c	0.005 a-c	0.006 AB
	1	0.010 a	0.008 ab	0.004 dc	0.007 AB
	2	0.005 a-c	0.007 a-d	0.003 d	0.005 B
	3	0.009 ab	0.009 ab	0.006 a-d	0.008 A
	NaCl means	0.008 A	0.007 A	0.004 B	
	SA	NaCl			SA means
		0	1	2	
First Experiment K (g plant^{-1})	0	0.180 c-e	0.164 c-e	0.128 e	0.157 C
	1	0.424 a	0.268 bc	0.141 de	0.278 A
	2	0.290 b	0.197 b-e	0.150 de	0.212 B
	3	0.416 a	0.243 b-d	0.098 e	0.252 AB
	NaCl means	0.327 A	0.218 B	0.129 C	
	SA	NaCl			SA means
		0	1	2	
Second Experiment K (g plant^{-1})	0	0.191 a-d	0.117 c-e	0.089 e	0.132
	1	0.249 a	0.178 a-e	0.087 e	0.172
	2	0.112 de	0.239 ab	0.149 b-e	0.167
	3	0.215 a-c	0.208 a-d	0.119 c-e	0.181
	NaCl means	0.192 A	0.186 A	0.111 B	

Table 4.21. The effects of different salicylic acid and NaCl applications on N, P, K, Ca, and Mg with Duncan letters (continued)

	SA	NaCl			SA means
		0	1	2	
First Experiment Ca (g plant^{-1})	0	0.070 cd	0.069 cd	0.046 cd	0.062 B
	1	0.199 a	0.102 bc	0.039 cd	0.113 A
	2	0.151 ab	0.085 b-d	0.047 cd	0.094 AB
	3	0.114 bc	0.076 cd	0.022 d	0.071 B
	NaCl means	0.133 A	0.083 B	0.038 C	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Ca (g plant^{-1})	0	0.066 a-d	0.044 d	0.035 d	0.049 B
	1	0.097 ab	0.109 a	0.041 d	0.082 A
	2	0.058 b-d	0.068 a-d	0.048 cd	0.058 AB
	3	0.094 a-c	0.083 a-d	0.048 cd	0.075 A
	NaCl means	0.079 A	0.076 A	0.043 B	
	SA	NaCl			SA means
		0	1	2	
First Experiment Mg (g plant^{-1})	0	0.015 d	0.023 d	0.011 d	0.016 C
	1	0.090 a	0.048 bc	0.017 d	0.051 A
	2	0.057 b	0.037 c	0.017 d	0.037 B
	3	0.049 bc	0.036 c	0.012 d	0.032 B
	NaCl means	0.052 A	0.036 B	0.014 C	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Mg (g plant^{-1})	0	0.030 a-c	0.019 bc	0.013 c	0.021
	1	0.039 a	0.035 ab	0.014 c	0.029
	2	0.023 a-c	0.024 a-c	0.015 c	0.021
	3	0.033 ab	0.030 a-c	0.014 c	0.026
	NaCl means	0.031 A	0.027 A	0.014 B	

a, b, c, d, e, f Superscripts with the same letters at each treatment are not significantly different, the mean values indicated by different letters are important for own lines and columns

Tohma (2007) found that the strawberry plant had a decrease in leaf Ca amount due to the increase in salt concentrations and had a significant positive effect on leaf Ca amount as a result of SA applications.

The decrease in Ca concentration at high salt doses (4 and 6 dS m^{-1}) was found as a positive effect of salicylic acid, as stated in (Tohma, 2007).

Magnesium was reached the highest level at SA1 applications at both first and second experiments. After that concentration, Mg was significantly decreased ($P<0.01$).

The lowest values were found at the highest NaCl concentrations as 0.011 g and differences were not significant.

At lower NaCl concentration (S1), the Mg content was slightly increased by SA increase from 0.023 to 0.048 at SA1 applications. Then, in SA2 and SA3 there were decreases there were still higher than control (P<0.01). Özdüven (2016), found that the Mg contents did not have a statistically significant effect on the summer pumpkin cultivation where different SA doses were applied.

Table 4.22. The variance analysis results on the effects of different salicylic acid and NaCl applications on N, P, K, Ca, and Mg

		N		P		K		Ca		Mg	
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
First Experiment											
SA	3	0.002	9.19**	0.00001	5.19**	0.02	7.78**	0.004	3.08*	0.001	39.19**
NaCl	2	0.03	116.43**	0.0001	41.11**	0.11	37.13**	0.02	17.37*	0.004	91.05**
SA + NaCl	6	0.002	7.29**	0.00001	3.59*	0.01	3.70**	0.002	1.63NS	0.0006	13.33**
Error	24	0.003		0.00003		0.003		0.001		0.0004	
Second Experiment											
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
SA	3	0.002	1.07NS	0.000	2.24NS	0.003	1.47NS	0.002	3.39*	0.0001	1.98NS
NaCl	2	0.009	8.04**	0.000	7.76**	0.02	8.96**	0.004	7.76**	0.0001	12.38**
SA + NaCl	6	0.002	1.71NS	0.000	1.05NS	0.008	3.11*	0.0006	1.07NS	0.000	0.73NS
Error	24	0.001		0.00006		0.002		0.006		0.0008	

The F value indicated by ** is important at the 1% level (P <0.01)
The F value indicated by * is important at the 5% level (P <0.05)

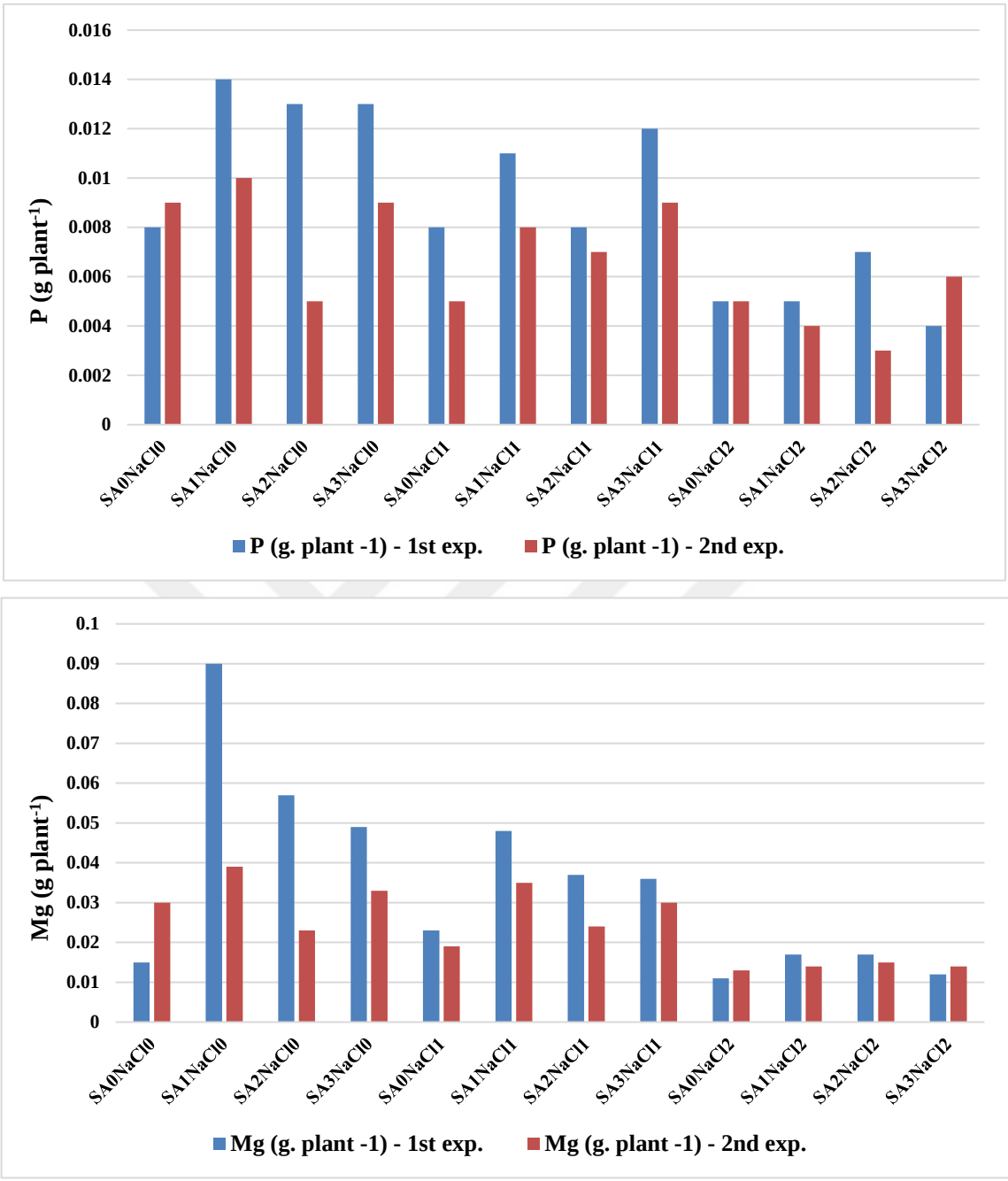

Figure 4.9. Effects of different NaCl and SA doses on the content of P and Mg in lettuce plant.

Plants' Iron (Fe), Cupper (Cu), Zinc (Zn), Manganese (Mn), and Sodium (Na) contents for SA and NaCl applications were given in (Table 4.23) and variance analysis results were given in (Table 4.24) for first and second experiments. In the first experiment, the highest Fe value was shown at SA3*S1 as 0.105 g. The lowest value was SA3*S2 as 0.030 g. The highest value for Cu was SA3*S0 as 0.065, the lowest values were SA3*S2

as 0.013 g. The highest value for Zn was calculated in SA1*S0 with 0.066 g, the lowest value was found in SA3*S2 as 0.018 g. The highest Mn contents of the plant were recorded in SA3*S0 as 0.090 g, the lowest value was found in SA3*S2 as 0.019 g. The highest value of Na was recorded in SA1*S1 as 0.137 g, whereas the lowest was found in SA0*S0 as 0.027 g (Table 4.23).

In the second experiment, the highest Fe value was obtained at SA3*S0 and SA3*S1 as 0.100 and 0.099 g. The lowest value was at SA0*S2 with 0.039 g. The highest values for Cu were SA1*S0 and SA2*S1 as 0.032 and 0.038 g, the lowest values were SA0*S2; SA2*Cd2 as 0.014 g. The highest value for Zn was calculated in SA1*S0 with 0.066 g, the lowest value was seen in SA0*S2 as 0.018 g. The highest Mn contents of the plant were recorded in SA1*S0 and SA2*S1 as 0.045 and 0.046 g, the lowest value was found in SA0*S2 as 0.020 g. The highest value of Na was recorded in SA3*S0 as 0.145 g, whereas the lowest was found in SA0*S0 as 0.026 g (Table 4.23).

Fe content was significantly decreased with an increase of NaCl ($P<0.01$). There were no significant changes at different SA applications ($P<0.01$). Although, there is no correlation of Fe contents between SA and NaCl at the highest concentrations, At the SA2 level the Fe content is close to the control group as 0.095. At lower NaCl concentrations SA applications increase the Fe content at both first and second experiments. In a study conducted in wheat and rice (Alpaslan et al., 1998), it was found that Fe content decreases in some varieties with the salt application, while it increases in other varieties. (Amal et al., 2014) determined that as a result of the increased salt application, there is a decrease in the accumulation of Fe^{+2} ion in lettuce plants. Furthermore, (Tohma, 2007) found that SA application effects on Fe content were not statistically significant. The results we obtained in our study are similar to these studies.

Cupper contents were increased with SA applications, significantly. It was seen an increase in Co contents at lower NaCl concentrations. The values of S1 applications are the same or higher than the control group. There are also reported some decrease in Cu content with higher NaCl applications. Although, at lower NaCl concentrations, there were some positive effects of SA on Cu contents, at higher concentrations there were no effects of SA ($P<0.01$). Al-Karaki (2000) determined that it decreases Cu intake with an increasing salt concentration in the soil. Kant (2008) found that as the salt dose applied to plants increases, Cu concentrations decrease. Tohma (2007) found that strawberry

plants adversely affect the amount of Cu due to the increase in salt concentrations and significantly positively affect the amount of Cu as a result of SA applications.

There were significant decreases in the Zinc contents of plants with an increase in NaCl ($P<0.01$) for the first and second experiments. Zn contents of the plant non significantly changed by SA applications ($P<0.01$). At the highest SA concentration, the Zn was the highest as 0.086 g. In this study, there were no significant effects of SA on plant Zn content were found. Al-Karaki (2000) determined that increasing salt concentration in soil decreased Zn uptake of the plant. Amal et al. (2014) determined that as a result of the increased salt application, there is a decrease in the accumulation of Zn^{+2} ions in the plant. Zurnaci (2019) also found a decrease in Zn^{+2} contents of lettuce plants with increasing NaCl. But there were no significant differences at SA and SA*Salt applications. The findings of our study showed similarities with Zurnaci (2019) results as well.

Manganese contents of plants significantly decreased with increasing NaCl concentrations from 0.058 to 0.028 g ($P<0.01$) for the first and second experiments. SA and SA*Salt applications showed no significant differences ($P<0.01$) in the Mn contents of lettuce plants. Özdüven (2016) at summer pumpkin and Zurnaci (2019) at lettuce reported that NaCl, SA, and SA*Salt combinations did not have a statistically significant effect on plants. Our findings also have similarities with their states.

Sodium contents of plants significantly increased with NaCl increase from 0.027 to 0.106 g ($P<0.01$). Na contents were significantly increased with SA increase as well ($P<0.01$). Na values were increased from 0.026 to 0.145 g the highest value. SA applications on different NaCl concentrations showed a slight decrease in Na contents of plants, but not significant ($P<0.01$). (Zurnaci, 2019) also reported an increase in Na with increasing NaCl applications. Moreover, (Zurnaci, 2019) pointed out that, there were no statistically important differences in SA and SA*Salt applications. (Niu et al., 1995) and Tuteja (2007) found that the uptake of Na^+ ion into the plant cell, the disruption of the membrane potential, and the help of Cl^- entrance without energy, with the help of anion channels. (Parida and Das, 2005) determined that a high amount of NaCl application to plants caused an increase in Na^+ and Cl^- accumulation in the cell and also decreased plant water potential and negatively affected plant development. These findings showed similar results in our study.

Table 4.23. The effects of different salicylic acid and NaCl applications on Fe, Cu, Zn, Mn, and Na with Duncan letters

	SA	NaCl			SA means
		0	1	2	
First Experiment Fe (g plant^{-1})	0	0.098 ab	0.069 cd	0.055 de	0.074
	1	0.083 a-c	0.096 ab	0.045 ef	0.075
	2	0.086 a-c	0.074 b-d	0.095 ab	0.085
	3	0.092 a-c	0.105 a	0.030 f	0.076
	NaCl means	0.090 A	0.086 A	0.056 B	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Fe (g plant^{-1})	0	0.094 a	0.046 c	0.039 c	0.060 B
	1	0.077 a-c	0.076 a-c	0.043 c	0.065 AB
	2	0.055 bc	0.090 ab	0.050 c	0.065 AB
	3	0.100 a	0.099 a	0.046 c	0.082 A
	NaCl means	0.082 A	0.078 A	0.044 B	
	SA	NaCl			SA means
		0	1	2	
First Experiment Cu (g plant^{-1})	0	0.024 e-g	0.025 e-g	0.017 g-i	0.022 D
	1	0.030 de	0.040 c	0.014 hi	0.028 C
	2	0.050 b	0.027 d-f	0.021 g-f	0.033 B
	3	0.065 a	0.033 cd	0.013 i	0.037 A
	NaCl means	0.042 A	0.031 B	0.016 C	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Cu (g plant^{-1})	0	0.024	0.015 c	0.014 c	0.018
	1	0.032 ab	0.020 bc	0.016 c	0.023
	2	0.018 bc	0.038 a	0.014 c	0.023
	3	0.028 a-c	0.022 bc	0.015 c	0.022
	NaCl means	0.025 A	0.024 A	0.015 B	
	SA	NaCl			SA means
		0	1	2	
First Experiment Zn (g plant^{-1})	0	0.073 ab	0.067 b	0.029 c	0.056
	1	0.067 b	0.073 ab	0.021 c	0.054
	2	0.065 b	0.047 c	0.035 cd	0.049
	3	0.086 a	0.048 c	0.018 c	0.050
	NaCl means	0.073 A	0.059 B	0.026 C	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Zn (g plant^{-1})	0	0.066 a	0.028 cd	0.018 c	0.037
	1	0.053 ab	0.033 b-d	0.027 cd	0.038
	2	0.029 cd	0.055 ab	0.026 cd	0.037
	3	0.045 a-c	0.044 a-c	0.026 cd	0.039
	NaCl means	0.048 A	0.040 A	0.024 B	

Table 4.23. The effects of different salicylic acid and NaCl applications on Fe, Cu, Zn, Mn, and Na with Duncan letters (continued)

	SA	NaCl			SA means
		0	1	2	
First Experiment Mn (g plant $^{-1}$)	0	0.058 bc	0.049 c	0.028 de	0.045 B
	1	0.053 bc	0.052 bc	0.022 e	0.042 B
	2	0.063 b	0.047 c	0.034 d	0.048 AB
	3	0.090 a	0.050 c	0.019 e	0.053 A
	NaCl means	0.066 A	0.050 B	0.026 C	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Mn (g plant $^{-1}$)	0	0.044 ab	0.030 a-c	0.020 c	0.031
	1	0.045 ab	0.044 ab	0.024 bc	0.037
	2	0.031 a-c	0.046 a	0.030 a-c	0.036
	3	0.039 a-c	0.039 a-c	0.029 a-c	0.036
	NaCl means	0.040 A	0.040 A	0.026 B	
	SA	NaCl			SA means
		0	1	2	
First Experiment Na (g plant $^{-1}$)	0	0.027 f	0.042 ef	0.106 bc	0.058 B
	1	0.078 cd	0.083 cd	0.137 a	0.099 A
	2	0.069 de	0.098 b-d	0.117 ab	0.095 A
	3	0.079 cd	0.090 b-d	0.101 bc	0.090 A
	NaCl means	0.063 C	0.078 B	0.12 A	
	SA	NaCl			SA means
		0	1	2	
Second Experiment Na (g plant $^{-1}$)	0	0.026 d	0.029 cd	0.081 b-d	0.045 C
	1	0.058 b-d	0.097 ab	0.145 a	0.100 A
	2	0.062 b-d	0.085 bc	0.113 ab	0.087 AB
	3	0.063 b-d	0.066 b-d	0.070 b-d	0.066 BC
	NaCl means	0.052 C	0.064 B	0.102 A	

a, b, c, d, e, f Superscripts with the same letters at each treatment are not significantly different, the mean values indicated by different letters are important for own lines and columns.

NaCl stress as a primary effective stress factor, followed by reduced water intake, i.e. water stress and mineral substance imbalances and nutritional deterioration as secondary stress factors (Levitt, 1980). Salinity causes the biosynthesis of ABA, a stress hormone, and the accumulation of reactive oxygen species (ROS) (Jia et al., 2002, Xiong and Zhu, 2003). ABA and ROS regulate ionic and osmotic homeostasis as well as the control and repair mechanism of stress destruction. Cell volume decreases with the loss of turgor under NaCl stress. This is done by withdrawing the plasma membrane from the cell wall (Kreps et al., 2002; Seki et al., 2002). In plants under NaCl stress, there is a significant

decrease in the ability of the roots to absorb water, thereby decreasing activities such as root development and stem growth. The stems of the plants under stress decrease and their length are small compared to the control. Likewise, during the transition to the leaf area and the generative phase, flowering and fruit yield are also negatively affected. It has been reported by other researchers in many plants that there are significant reductions in dry matter and wet weights in the shoots and roots of plants under stress (Irshad et al., 2002; Daşgan et al., 2002). Salinity causes nutritional deficiency, ion toxicity, the metabolic imbalance caused by osmotic stress causes oxidative stress inplants (Zhu, 2002). Ion cytotoxicity is due to the loss of functions of proteins due to the displacement of K^+ and Na^+ in biochemical reactions and conformational changes, as well as the inhibition of non-covalent interaction between amino acids.

To mitigate the negative effects of NaCl, exogenous applications of growth regulatory hormones were tried by many scientists. Salicylic acid (SA), a kind of GRH, acts as a signal molecule in the induction of defense mechanisms in plants (Raskin, 1992; Shah, 2003).

Table 4.24. The variance analysis results on the effects of different salicylic acid and NaCl applications on Na, Fe, Cu, Zn, and Mn

		Na		Fe		Cu		Zn		Mn	
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
First Experiment											
SA	3	0.003	11.27**	0.0002	1.39NS	0.0003	19.75**	0.00	0.90NS	0.00	3.83*
NaCl	2	0.002	8.19**	0.003	23.23**	0.002	112.45**	0.006	71.26**	0.00	103.7**
SA* NaCl	6	0.002	9.99**	0.001	9.09**	0.0004	23.26**	0.00	4.44**	0.00	7.84**
Error	24	0.002		0.0001		0.0001		0.00009		0.0004	
Second Experiment											
S. O. V.	DF	MS	F	MS	F	MS	F	MS	F	MS	F
SA	3	0.005	5.73**	0.0008	2.07NS	0.00	0.81NS	0.00	0.04NS	0.00	0.48NS
NaCl	2	0.000	0.75NS	0.005	12.7**	0.00	6.09**	0.001	11.81**	0.00	6.60**
SA* NaCl	6	0.003	3.71**	0.001	2.63*	0.00	2.71*	0.00	3.96**	0.00	1.22NS
Error	24	0.008		0.0003		0.0006		0.0001		0.0001	

The F value indicated by ** is important at the 1% level (P <0.01)
The F value indicated by * is important at the 5% level (P <0.05)

It has been reported to be responsible for the regulation of certain processes in plants subjected to stress, such as heat, chilling, osmotic, and salt stress (Janda et al., 1999; Borsani et al., 2001; Singh and Usha, 2003), thus improving the growth and development (Senaratna et al., 2000; Horvath et al., 2007; Hayat et al., 2008; Khan et al., 2015).

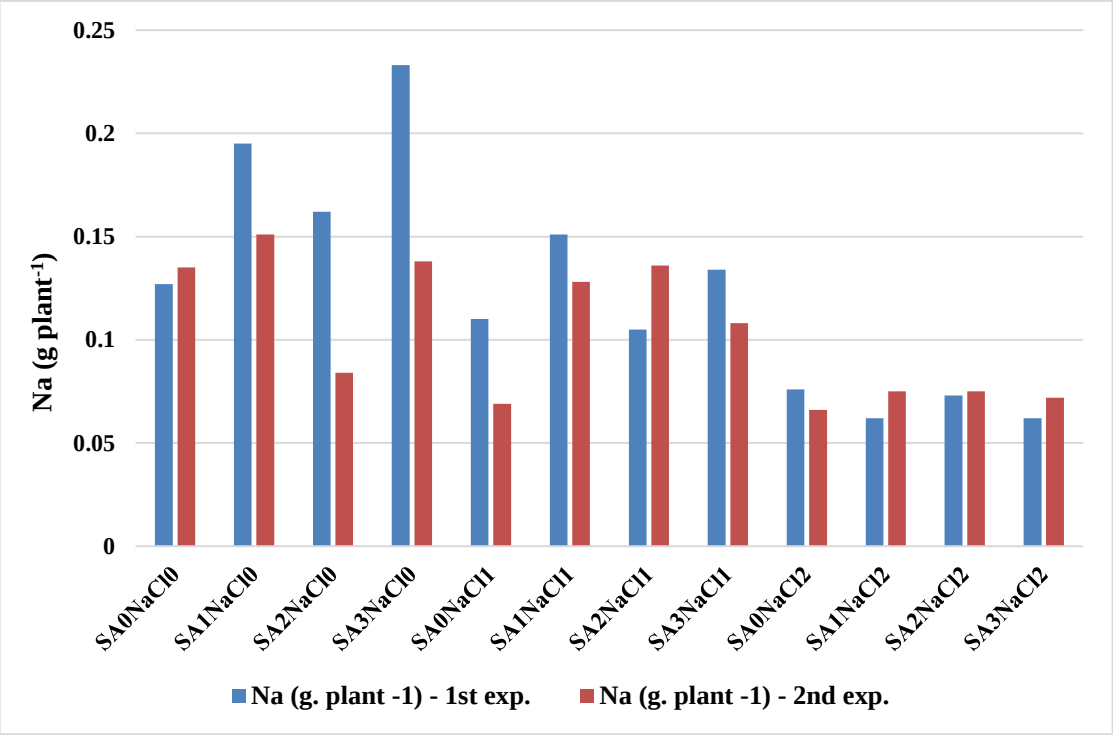

Figure 4.10. Effects of different NaCl and SA doses on the content of Na in lettuce plant.

5. CONCLUSIONS

Lettuce (*Lactuca sativa*) a member of the Asteraceae family, is an annual plant cultivated for its edible leaves. The different varieties of lettuce are simply cultivated and widely consumed all over the world. Pollutions of soils with different contaminants originated from industrial and domestic wastes effects on the quality and quantity of lettuce as other plants. Cd and NaCl are important agents, that decrease plant growth, and quality i.e. productivity. To understand the effects of the mechanisms, and alleviate the negative effects of those agents, scientists published many studies and reports.

This study was carried out in a controlled growing room depending on the lettuce plant's request. We investigate the ameliorative effects of salicylic acid on the growth of lettuce under Cd and NaCl stresses. The effects of different Cd and NaCl concentrations on growth parameters such as plant height, fresh and dry weight, leaf number, plant diameter and root measurements, plant physiological parameters such as consumed weight, chlorophyll content, relative water content, wastrel leaves, and osmotic potential were observed. Furthermore, macronutrients such as Nitrogen (N), Phosphorus (P), Potassium (K) and Magnesium (Mg) and micronutrients such as Iron (Fe), Copper (Cu), Zinc (Zn), Manganese (Mn), and Sodium (Na) contents of plants were measured, as well.

As some conclusions, most of the growing and plant nutrient parameters were negatively affected by increasing Cd and NaCl concentrations as also reported by many studies.

Cadmium leads to negative changes in many morphological and physiological phenomena on lettuce plants causing stomata closure, a decrease in transpiration, disrupting the water balance, and problems in the uptake and distribution of macro and micronutrients, and disruption of chlorophyll biosynthesis and inhibition of photosynthesis. Excessive Cd concentrations may cause phytotoxic effect s as well.

According to the research results, it was found that increased salt concentration negatively affected the development of the lettuce plant and the uptake of some plant macro and micronutrients. With the increasing salt concentration, the amount of Na in the plant increased and as a result, the reduction in leaves and roots fresh/dry weights, K, and Zn concentrations in the plants were determined. Although there was no significant

change in Ca, Cu, and P concentrations in plants with increasing salt concentration, only certain doses have been decreased. Increasing salt doses caused fluctuation in Fe concentration in the plant, and it was found that it did not affect Mg and Mn concentrations.

SA, a phenolic compound, is a kind of plant growth regulator (PGR) i.e. a plant hormone and has various physiological and biochemical roles in plants. SA is thought to play a major role in regulating plant responses to many environmental stresses including heavy metal as Cd and salt as NaCl induced stresses in plants.

In a conclusion, polluted agricultural soils by heavy metals and degraded by salt may cause many hazardous effects on especially cultivated plants such as lettuce. Eliminating or reducing these harmful effects can be remediated by clearing the soils from these pollutants or increasing the plants' tolerances to pollutants. The remediation of agricultural soils has time and economic costs. On the other hand, exogenous applications of some plant regulators such as hormones may be cost-effective solutions, that alleviate the negative effects on productivity. Our results and many studies are supporting these states.

When the results are examined, it was seen that the presence of NaCl reduces direct water intake and causes water stress. This causes mineral imbalances and nutritional disorders in the plant. Exogenous SA applications generally reduce the negative effects of NaCl and Cd. In addition, it has been concluded that SA2 (2 mM) is the optimum dose for eliminate the harm of Cd and/or NaCl in plant, especially in SA and NaCl applications (plant height, plant dry, leaf number, root diameter, chlorophyll, K, and Cd, in SA and NaCl applications plant height, plant fresh weight, plant dry weight, leaf number, root length, root diameter, consumed weight, Mg, and Na.

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EXTENDED TURKISH SUMMARY
(GENİŞLETİLMİŞ TÜRKÇE ÖZET)

BAZI ABİYOTIK STRES KOŞULLARINDA SALİSİLİK ASİT UYGULAMALARININ MARULDA (*LACTUCA SATIVA*) BİTKİ GELİŞİM KRİTERLERİ VE BESİN ELEMENTİ ALIMINA ETKİSİ

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Ocak 2021, 133 Sayfa

ÖZ

Bu çalışmada bazı abiyotik stres koşullarında salisilik asit uygulamalarının marulda (*Lactuca sativa*) bitki gelişim kriterleri ve besin elementi alımına etkisi belirlenmesi amaçlanmıştır. Kontrollü koşullarıda 72 saksıda yetiştirilen marul (*Lactuca sativa*) fideleri deneme bitkisi olarak kullanılmıştır. Denemeler, 3 kg toprak kapasiteli 144 plastik saksıda, tam şansa bağlı deneme desenine göre iki ayrı dönemde ve 3 tekrarlamalı olarak Van YüzüncüYıl Üniversitesi, Ziraat Fakültesi, Toprak Bilimi ve Bitki Besleme Bölümüne ait bitki büyütme odasında, sıcaklık nem ve ışık kontrollü steril koşullarda yürütülmüştür. Salisilik asit (0, 1, 2, 4 mM), kadmiyum (0, 40 ve 80 mg kg^{-1}), ve tuz (0, 30 ve 60 mM) yetiştirme ortamlarına kadmiyum nitrat ($CdNO_3$) ve sodyum klorür (NaCl) formlarında uygulanmıştır. Denemeler fide dikimini takiben 8 hafta sonunda sonlandırılmıştır. Hasat edilen bitki örneklerinde bitki büyüme parametrelerile makro ve mikro bitki besin elementleri belirlenmiştir. Sonuç olarak bu araştırmada artan Cd ve NaCl dozlarının bazı parametreler üzerinde az veya çok olumsuz etkileri gözlenmiştir. Ayrıca genel olarak 2 mM'nin Cd ve NaCl uygulamalarında optimum doz olduğu sonucuna varılmıştır.Özellikle SA ve Cd uygulamalarında bitki boyu, bitki kuru ağırlığı, yaprak sayısı, kök çapı, klorofil, K, ve Cd parametrelerinde, SA ve NaCl uygulamalarında bitki boyu, bitki yaş ağırlığı, bitki kuru ağırlığı, yaprak sayısı, kök uzunluğu, kök çapı, tüketilen ağırlık, Mg, ve Na parametrelerinde SA2 dozu etkili bulunmuştur.

Anahtar kelimeler: Kadmiyum, Tuz, Salisilik asit, Marul, Bitki büyüme parametreleri, Besin elementleri.

1. GİRİŞ

Stres, genellikle bitki üzerinde dezavantajlı bir etki yaratan herhangi bir olumsuz dış faktör olarak tanımlanır. Bitkiler hem doğal hem de tarımsal alanlarda birçok farklı çevresel strese maruz kalmaktadır. Bitki türlerinin dağılımında doğal habitatlar üzerindeki baskı büyük rol oynarken, tarımsal topraklarda üretimde potansiyel verimde düşüşe neden olur. Genel olarak, stresin neden olduğu hasarlar, genel büyüme ile ilgili olan bitkinin hayatta kalmasını, ürün verimini, büyümeyi (biyokütle birikimi) veya birincil asimilasyon süreçlerini (CO_2 ve mineral alımı) etkiler. Stres faktörleri biyotik ve abiyotik olarak sınıflandırılır. Bitkilerde stres oluşturan iklim ve toprakgibi çevresel veya abiyotik faktörlerin yanı sıra, biyotik faktörler (yabani otlar, patojenler ve böcek) de stres oluşturabilir.(Taiz ve Zeiger, 2002).

Son yıllarda ağır metaller çevre kirliliğine ve giderek daha büyük zararlanmalara neden olan en önemli faktörler arasında yer almaktadır. 19. yüzyılın sonlarında ve 20. yüzyılın başlarında, madencilik ve endüstriyel faaliyetler arttıkça, metaller ile çevre kirliliği yaygınlaşmıştır. Bakır, kadmiyum, kurşun ve civa dünya çapında mevcut mineral üretimi açısından önemlidir (Pinto, 2004). Topraktaki ağır metaller, endüstri kaynaklı atmosferik çamur, madencilik faaliyetleri, evsel depolama alanları (antropojenik kaynaklar) ve fosfatlı gübre ve atık su çamuru gibi çeşitli kaynaklardan oluşabilir (Williams ve David, 1976). Sonuç olarak, artan sayıda farklı antropojenik kaynaklardan türetilen bu kirleticiler, çeşitli ekosistemleri ciddi şekilde etkilemiştir (Macfarlane ve Burchett, 2001).

Kadmiyumun tarım topraklarına girişi ve yayılması endüstriyel faaliyetler, fosforlu gübreler, lağım atıkları ve atmosferik depositler yoluyla olmaktadır (Haktanır, 1987). Toprakta 3 mg/kg, bitki kuru maddesinde ise 1 mg/kg'dan fazla kadmiyum toksik etkilidir (Özbek ve ark., 1995). Bitki ve topraklara ulaşan kadmiyumun büyük kısmı kadmiyum içeren toz zerreciklerinin havadan çökelmesi yolu ile olmaktadır. Trafiğin yoğun olduğu alanlardaki yol kenarlarındaki topraklarda toz çökelmesi ile yılda m2'ye 0.2-1.0 mg kadmiyum ilavesinin olduğu ölçülmüştür (Haktanır, 1987).

Metal iyonlarının çoğu bitki hücrelerine, özel veya genel metal iyon taşıyıcıları veya kanallar yoluyla serbest enerji yoluyla girer. Bazı ağır metaller, bitkiler için besin görevi gören diğer ağır metaller tarafından kullanılan zarlarda lokalize olan taşıyıcılardan

kolaylıkla geçebilir (Clakrson ve Lüttge, 1989). Metal iyonları köke girdiğinde ya depolanır ya da sürgünlere gönderilir.

Toprak tuzluluğu dünya tarımında abiyotik stresin en önemli kaynaklarından biridir ve toprağın artan tuzluluğu ile sulama suyundaki tuzun artması dünyanın birçok yarı kurak ve kurak bölgesinde tarımsal verimliliği engellemektedir. UNEP, dünyadaki tarım alanlarının% 20'sinin ve ekili alanların% 50'sinin tuz stresi altında olduğunu belirtmektedir (Flower ve Yeo, 1995). Toprak tuzluluğu; toprağın temel yapısı, kalitesiz su kullanımı, fazla su, drenaj eksikliği ve aşırı gübre kullanımından kaynaklanabilir. Sulama suyunun her yıl azalması ile birlikte kalitenin düşmesi ekilebilir alanların tuzluluğunu arttırmaktadır.

Killi topraklarda, sodyumun negatif yüklü kile bağlanarak kil kümelerinin oluşması, toprağın ürün yetiştiriciliğini etkisiz hale getirerek toprağın sodisitesine (yüksek sodyum konsantrasyonu) neden olur. Tuzluluk sorunu bazen toprak kaynaklı olmayıp sulama suyundan kaynaklanabilir. Özellikle kurak ve yarı kurak ekolojilerde yapılan tarımsal üretimde sadece yağışlarla karşılanamayan su ihtiyacı sulama ile karşılanmaktadır. Tüm yüzey ve yeraltı sularında sulama suyu olarak kullanılabilecek az veya daha fazla çözünmüş tuz bulunmaktadır.

Salisilik asit (SA), genellikle bir hidroksil grubu ya da onun fonksiyonel türevini taşıyan, aromatik bir halkaya sahip bitki fenoliklerinin bir grubudur. İlk olarak laboratuvarda Raffaele Piria adlı bir bilim adamı tarafından 1828 yılında izole edilen asetilsalisilik asit aspirin olarak bilinen en iyi bilinen ve kullanılan anti-stres bileşiklerinden biridir (Popova ve diğerleri, 1997). Salisilik asit, kimyasal formülü $C_7H_6O_3$ ile renksiz kristalli bir organik asittir.

Güçlü bir sinyal molekülü olan salisilik asit, bitkilerdeki spesifik biyotik ve abiyotik faktörlere yanıt verir. Salisilik asidin bitkiyi kadmiyum toksisitesinden koruduğu da bilinmektedir (Janda ve diğerleri, 1999; Metwally ve diğerleri, 2003). Harici olarak uygulanan salisilik asit, , bitkilerde çeşitli savunma genlerini aktive eder. Enfeksiyona, ultraviyole ışığa ve ozona maruz kalmaya yanıt olarak belirli sistemik direncin bir sonucu olarak bitkilerde salisilik asit, seviyesi artar ve sinyal verme sürecinin bir parçası olduğuna inanılmaktadır (Rasmussen ve diğerleri, 1991).

Bu çalışmada, salisilik asit uygulamalarının tuz ve kadmiyum stresleri altundaki marul (*Lactuca sativa*) bitkisinde bitki gelişimi, verim parametreleri ve besin elementi içeriğine etki leri araştırılmıştır.

2. MATERYAL VE YÖNTEM

Araştırma, Van Yüzüncü Yıl Üniversitesi Ziraat Fakültesi Toprak Bilimi ve Bitki Besleme Bölümü bitki yetiştirme odasında gerçekleştirilmiştir. Araştırmada deneme bitkisi olarak *y*edikule marul (*Lactuca sativa*) çeşidi kullanılmıştır. Fideler, büyüme ve gelişme sırasında % 45-55 nem, 16 saat aydınlık ve 8 saat karanlık fotoperiyod, 25 ± 1 ° C sıcaklık ve 10.000 Lux / gün ışığı yoğunluğuna ayarlanmış kontrollü koşullarda yetiştirme odasında yetiştirilmiştir. Bitki yetiştirme odasında sıcaklık, nem, ışık ve sterilizasyon kontrolleri yapılmıştır.

Araştırma, faktöriyel denreme desenine göre, 72 adet plastik saksıda üç tekrarlamalı olarak yürütülmüştür. Salisilik asidin Cd ve NaCl stresleri üzerindeki etkilerini daha iyi belirleyebilmek için aynı deneme iki kez kurulmuş, her iki denme için de toplam 144 marul (*Lactuca sativa*) fidesi 3 kg kapasiteli 144 saksıya ekilmiş ve deneme toprağı olarak tınlı toprak kullanılmıştır. İlk deneme 16 Kasım 2017'de normal büyüme koşullarında sekiz hafta olarak ayarlanmış ve saksılar düzenli olarak sulanmıştır. İkinci denemeye 22 Mart 2018 tarihinde aynı yetiştirme ortamında, aynı bitki çeşidi kullanılarak başlanmış ve sekiz hafta sonra sonlandırılmıştır. Her iki deneme de marul bitkileri hasat edilerek birinci ve ikinci deneme için aynı ölçümler ve analizler yapılmıştır.

$CdNO_3$ olarak üç farklı kadmiyum dozu (0-40-80 mg kg^{-1}) (Cd0: 0 g, Cd1: 0.1862 g ve Cd2: 0.3724 g) ve üç farklı dozda tuz (0-30-60 mM) (NaCl0 : 0 g, NaCl1: 5.256 g ve NaCl2: 10.512 g) NaCl olarak sırasıyla kullanılmıştır. Ayrıca salisilik asit (0-1-2-4 mM) (SA0: 0 g, SA1: 0.414 g, SA2: 0.828 g ve SA3: 1.656 g) olarak dört doz uygulanmıştır (Demirkiran vd., 2007). Uygulamalarda kullanılacak olan salisilik asit çözeltisi, katı salisilik asidin damıtılmış suda çözülmesi ve 6 saat çalkalanması ile hazırlanmıştır. Ekimden bir hafta önce toprağa kadmiyum ve tuz, ekimden bir hafta sonra da salisilik asit çözelti olarak uygulanmıştır.

1.1. Gübreleme ve Sulama

Temel gübreleme olarak uygulanan her saksı sırasıyla $(NH_4)_2SO_4$, TSP ve K_2SO_4 (300 mg kg^{-1} azot, 150 mg kg^{-1} fosfor (P_2O_5) ve 200 mg kg^{-1} potasyum (K_2O) uygulanmıştır. Sulama için saf su kullanılmıştır.

1.2. Bitki örneklerinde morfolojik ölçümler

1.1.1. Bitki boyu (cm / bitki)

Kök boğazından hasat edilen bitkilerin kök boğazı ile tepe noktası arasındaki mesafe cetvel yardımıyla ölçülmüştür.

1.1.2. Bitki yaş ve kuru ağırlıkları (g / bitki)

Deney sonunda hasat edilen bitkiler hassas terazilerde tartılarak yaş ağırlıkları belirlenmiştir. Aynı numuneler 65 °C'lik fırında 48 saat boyunca sabit ağırlığa kadar kurutulduktan sonra kuru ağırlıkları alınmıştır.

1.1.3. Yaprak sayısı (adet / bitki)

Her saksıdan alınan bitkinin yaprakları sayılarak ortalamaları alınmıştır.

1.1.4. Kök yaş ve kuru ağırlıkları (g / bitki)

Deney sonunda bitki kökleri hassas terazilerde tartılarak yaş ağırlıkları belirlenmiştir. Aynı numuneler 65 °C'lik fırında 48 saat boyunca sabit ağırlığa kadar kurutulmuş ve ardından kuru ağırlıkları alınmıştır.

1.1.5. Kök uzunluğu ve çapı (cm)

Kök tepesinden bitkinin kök ucuna kadar olan kısım cm cinsinden cetvelle ölçülmüştür. Kumpas yardımı ile kökün çapı cm olarak belirlenmiştir.

1.1.6. Tüketilebilir ağırlık (g / bitki)

Kök boğazından kesilerek hasat edilen bitkilerde, en dıştaki sararmış, bozulmuş, çürümüş ve çok katılaşan yenilemeyecek durumdaki yapraklar koparıldıktan sonra bitkinin tekrar tartılması ile bulunmuştur.

1.1.7. Iskarta yaprak saysı (adet)

Her saksıdan alınan bitkilerin çok ekonomik pazarlanmayacak yaprakları sayılarak ortalamaları alınmıştır.

1.1.8. Klorofil

Bitki örneklerinde klorofil içeriği SPAD metre yardımı ile ölçülmüştür.

1.1.9. Osmotik potansiyel

Herbir saksıdan alınan yaprak örneklerinin osmotic potansiyelinin ekstraktsiyonunda Jones ve Turner'in (1978) kullandığı metoddan yararlanılmıştır. Potansiyel, Vapour pressure osmometer (Vapro Osmometer) yardımı ile YYÜ Fen Fakültesi Biyoloji Bölümü laboratuvarında ölçülmüştür.

1.1.10. Nisbi nem içeriği

Herbir saksıdan alınan yaprak örnekleri hemen tartılarak yaş ağırlıkları belirlenmiş (YA) ve örnekler 4 saat saf suda bekletilerek turgor haline getirilip (TA) tekrar tartılmıştır. Son olarak örnekler 60 ^{o}C de hava sirkülasyonlu kurutma dolabında

24 saat kurutulup kuru ağırlıkları (KA) belşirlenmiştir (Dhanda and Stehil 1998). Aşağıdaki formülle yaprakların nisbi nem içeriği hesaplanmıştır.

NNİ=(YA-KA) / (TA-KA) x 100

1.2. Toprak ve bitki analizleri

Deneme toprağında, toplam tuz, Richards (1954); kireç, Allison ve Moodie (1965); organik madde, modifiye edilmiş Walkey Black (Jackson, 1962); azot; Kjeldahl (Kacar, 1994); fosfor, sodyumbikarbonat (Olsen ve ark.,1954) yöntemine göre; değişebilir potasyum, kalsiyum, magnezyum, Thomas (1982) yöntemine göre ; demir, bakır, mangan ve çinko atomik absorpsiyon spektrofotometresi ile (Lindsay ve Norvell, (1978) belirlenmiştir. Toprağın kadmiyum içeriği çift asit ekstraktsiyon yöntemi kullanılarak, 3:1 oranında nitrik asit perklorik asit karışımında atomik absorbsiyon spektrofotometresi (Thermo ICE 3000 series) ile belirlenmiştir (Kacar,1994).

Bitki örneklerinde azot, Kjeldahl yöntemi ile, fosfor, vanado molibdo fosforik sarı renk yötemine göre; potasyum, kalsiyum, magnezyum, demir, çinko, bakır ve mangan atomik absorbsiyon spektrofotometresi ile belirlenmiştir (Kacar, 1994).

Toprakta ve bitkide kadmiyum çift asit ekstraktsiyon yöntemi kullanılarak , 3:1 oranında nitrik asit perklorik asit karışımında atomik absorbsiyon spektrofotometresi (Thermo ICE 3000 series) ile belirlenmiştir (Kacar ve İnal, 2008).

1.3. İstatistiksel analiz

Elde edilen verilerin istatistiksel analizi için SPSS yazılım paket programı kullanılarak varyans analizi yapılmış ve sonuçlar Duncan çoklu karşılaştırma testine göre gruplandırılmıştır (SPSS, 2018).

2. BULGULAR VE TARTIŞMA

Bu araştırmada artan dozlarda Cd ve NaCl uygulamalarının tüm parametreler üzerinde az veya çok olumsuz etkileri gözlenmiş, bunu takip eden SA uygulamasıyla da bu olumsuz etkilerin kontrol gruplarına göre farklı oranlarda azaltıldığı kaydedilmiştir.

Cd ve SA uygulamalarında bitki büyüme parametreleri (bitki boyu, bitki çapı, ve bitki yaş ağırlığı,) ölçülmüştür. Bu parametreler için yüksek ve en düşük değerleri sırasıyla 1. deneme için 22.833 – 14.400 cm ; 2 . deneme için 26.00 - 15.667 cm; 1. deneme için 9.010 – 4.807 cm ; 2 . deneme için 5.967 - 3.74 cm ; 1. deneme için 69.100 - 12.867 g – 2. deneme için 46.36 – 19.73 g olarak belirlenmiştir. En yüksek ve en düşük tüketilebilir kısım ağırlık 1. deneme için 56.100 - 9.467g ; 2 . deneme için 46.900 - 19.083 g ve yaprak nisbi nem içeriği 1. deneme için % 87,553 - 78.460 % ; 2 . deneme için % 87.993; 77.910 olarak kaydedilmiştir. Cd uygulamaları genel olarak bitkilerdeki makro ve mikro besin elementi miktarını düşürürken SA uygulamalarının da artırdığı kaydedilmiştir. Ayrıca en yüksek ve en düşük N, K, Fe, ve Cd içerikleri sırasıyla 1. deneme için 0.175 - 0.073; 2. deneme için 0.149 – 0.051 g plant^{-1}; 1. deneme için 0.264 - 0.109; 2. deneme için 0.211; 0.078 g plant^{-1}; 1. deneme için 0.230- 0.080; 2. deneme için 0.169-0.059 g plant^{-1} ve 1. deneme için 0.014 - 0.001; 2. deneme için 0.009 - 0.001 g plant^{-1} olarak belirlenmiştir.

Elde edilen sonuçlar Cd toksisitesinin bitkilerde en çok yavaş büyüme ve kloroza neden olduğunu göstermiştir. Cd tosisitesine bağlı olarak enzim aktivitelerinin, nitrojen ve karbonhidrat metabolizmasının değişmesi, su dengesinin bozulması besin maddesi alımı ve dağılımını da olumsuz etkilemektedir. Ancak salisilik asit uygulamalarının sınırlı da olsa kadmiyumun neden olduğu zararlı etkileri azalttığı elde edilen bulgular ile desteklenmiştir.

NaCl ve SA uygulamalarında bitki boyu ve bitki yaş ağırlığı incelendiğinde en yüksek ve en düşük değerler sırasıyla 1. deneme için 22.333 - 7.500 cm ; 2. deneme için 22.00 - 7.500 cm, ve 1. deneme için 101.453; 13.933 g; 2. deneme için 56.133 - 13.067 g olarak ölçülmüştür. En yüksek ve en düşük değerler tüketilebilir kısım ağırlık ise 1. deneme için 88.777 - 7.767 g ; 2. deneme için 59.660; 7.167 g en yüksek ve en düşük klorofil içeriği 1. deneme için 65.300 - 33.633 μg mg^{-1}, 2. deneme için 59.653 - 39.433 μg mg^{-1}, en yüksek ve en düşük yaprak nisbi nem içeriği 1. deneme için % 88.880 - 65.987 ; 2. deneme için % 87.477; 67.390 ve ozmotik potansiyel 1. deneme için 5.694 - 1.602 (-Mpa) –2. deneme için 6.664 -1.735 (-Mpa) olarak bulunmuştur.

NaCl ve SA uygulamalarında bitkilerdeki makro ve mikro besin elementi alımına bakıldığında P, Mg, ve Na için en yüksek ve en düşük değerler sırasıyla 1. deneme için 0.014 - 0.004 ; g plant $^{-1}$; 2.deneme için 0.010 - 0.003 g plant $^{-1}$; 1. deneme için 0.090 -

0.011 g plant $^{-1}$; 2. deneme için.0.039 - 0.013 g plant $^{-1}$ ve 1. deneme için 0.137- 0.027 g plant $^{-1}$; 2. deneme için 0.145- 0.026 g plant $^{-1}$ olarak belirlenmiştir.

Araştırma sonuçlarına göre, NaCl varlığının doğrudan su alımını azalttığı ve su stresine yol açtığı belirlenmiştir. Bu da bitkide besin elementi dengesizliklerine ve beslenme bozukluklarına neden olmaktadır. Endojen salisilik asit uygulamalarının ise genel olarak NaCl'ün olumsuz etkilerini azalttığı belirlenmiştir.

3. SONUÇ

Ayrıca genel olarak SA2 (2 mM)'nin Cd ve NaCl uygulamalarında optimum doz olduğu sonucuna varılmıştır. 2 mM uygulamalarının bitki boyu, bitki kuru ağırlığı , yaprak sayısı ve kök çapı parametrelerinde Cd zararlanmalarını önemli düzeyde azalttığı belirlenmiştir. NaCl'ün olumsuz etkilerinin iyileştirilmesinde ise 2 mM uygulamaları bitki boyu, bitki taze ağırlığı, bitki kuru ağırlığı, yaprak sayısı, kök uzunluğu, kök çapı, tüketilen ağırlık, Mg alımı ve Na alımında önemli düzeyde etkili bulunmuştur.

Ağır metallerle kirlenen ve tuzla bozulan tarım toprakları, kültür bitkileri üzerinde pek çok tehlikeli etkiye neden olabilmektedir. Bu zararlı etkilerin ortadan kaldırılması veya azaltılması, toprakların bu zararlı etmenlerden arındırılması veya bitkilerin kirletici maddelere karşı toleranslarının artırılması yolu ile düzeltilebilir. Tarımsal toprakların ıslahı için uzun zamana ve ekonomik açıdan yüksek maliyetlere gereksinim duyulmaktadır. Bu araştırmada olduğu gibi, salisilik asit gibi bazı bitki düzenleyicilerinin endojen uygulamaları, stres faktörlerinin verimlilik üzerindeki olumsuz etkilerini azaltan maliyet etkin çözümler olarak önerilmektedir.

Appendix 1. SA and Cd first experiment

Pots	No.	Plant height	Root height	Plant weight	Root weight	Consumed weight	Plant dry weight	Chlorophyll	Number of leaves	Wastrel leaves	Plant diameter cm	Root diameter cm	RWC
SA0 CD0	1	25.5	13	52.7	1.5	36.2	2.8	37.66	16	0	6.63	6.79	85.92
SA0 CD0	2	22	14	41.5	1.9	32.8	3.5	40.7	17	1	6.68	5.77	85.51
SA0 CD0	3	21	14	72	2.3	58.3	2	38.18	17	1	6.97	6.87	87.39
SA0 CD1	4	18	9	78.5	1.5	17	4.8	42.88	16	1	6.63	5.73	81.32
SA0 CD1	5	17	11	76	1.5	28.9	4.5	45.08	18	2	6.46	5.15	80.27
SA0 CD1	6	16	9.5	52.8	0.8	11.3	3.6	39.82	14	1	5.18	6.17	80.48
SA0 CD2	7	19.5	14	18.3	2.7	60.3	2	44.8	20	3	8.34	8.32	78.73
SA0 CD2	8	21	10	31	2.1	54	2.6	39.62	22	3	7.82	8.87	78.7
SA0 CD2	9	18	13	13.5	2.3	49	2	42.22	15	3	7.39	6.5	77.95
SA1 CD0	10	22	13	64	1.7	48	4	33.2	16	1	7.43	7.32	83.79
SA1 CD0	11	23	14	60.2	1.6	52.8	4.4	46.18	16	0	7.17	6.3	83.21
SA1 CD0	12	23.5	15	71.2	2.6	67.5	5.7	46.58	17	1	8.48	8.62	83.11
SA1 CD1	13	20.5	10	41.5	1.7	38.1	3.4	41.38	18	1	7.42	7.86	79.38
SA1 CD1	14	19	9	52.1	2.1	38.6	4.3	48.82	14	1	7.12	8.44	80.36
SA1 CD1	15	20	17	45.5	5	52.4	5.3	52	16	1	8.32	8.27	75.98
SA1 CD2	16	15.7	10	38.3	2.6	29.6	4.2	42.84	15	2	6.32	9.9	78.94
SA1 CD2	17	14.5	13	41.6	3.5	39.6	4	51	14	2	6.37	7.45	78.84
SA1 CD2	18	13	16	38.8	2.1	31.8	4.1	50.36	15	1	6.30	11.15	81.12
SA2 CD0	19	21	13	44.1	2.3	39.8	4.2	43.76	20	0	8.08	10.45	85.56
SA2 CD0	20	18	13.5	59	1.7	58	3.7	41.86	18	0	9.62	9.94	87.53
SA2 CD0	21	20	14	70	1.6	60	4.7	48.48	16	0	9.33	11.95	86.72
SA2 CD1	22	16	10	24	0.6	23.3	2.5	43.74	16	0	8.60	8.4	83.74
SA2 CD1	23	17	9	40.2	2.1	60.3	5.7	50.1	18	3	7.33	7.41	80.41
SA2 CD1	24	18.5	9.5	24.2	1.3	23.5	2.4	41.62	17	0	7.13	7.95	82.68
SA2 CD2	25	18.5	8	23.6	1.1	22.4	2.7	47.6	16	0	4.77	5.44	80.12
SA2 CD2	26	20	10	30.8	4.8	42.1	6.6	53.8	19	3	8.65	6.25	81.61
SA2 CD2	27	17	9	27.4	1.8	27	3	48.64	18	1	6.92	7.11	78.72
SA3 CD0	28	20	9.5	47.3	9	39.1	4.7	53.14	16	1	7.80	9.8	88.84
SA3 CD0	29	23	10	77.3	15.5	68.1	6.1	55.72	17	0	9.43	9.62	86.46
SA3 CD0	30	23.5	8.6	56.8	12.25	49.6	5	49.18	14	0	8.68	9.7	87.36
SA3 CD1	31	17.5	7.3	9.1	8.3	8.3	1.9	41.94	16	0	3.73	6.25	87.38
SA3 CD1	32	16	9.5	12.7	11.5	11.5	2	41.68	16	1	5.48	5.42	86.57
SA3 CD1	33	16.5	8.5	28.9	8.6	8.6	2.7	42.72	16	1	5.21	6.3	87.43
SA3 CD2	34	14	8.2	9.7	3.9	9	1.8	39.38	16	0	6.22	7.3	84.35
SA3 CD2	35	15	7.5	16.1	4.8	15.5	2.2	38.6	14	2	6.82	7.1	83.84
SA3 CD2	36	14.5	5	12.8	3	27.7	2.9	44.18	16	1	7.55	8.96	83.47

Appendix 2. SA and Cd first experiment

Pots	No.	pH	EC (µs)	MC %	N g/Plant	P g/Plant	K g/Plant	Ca g/Plant	Mg g/Plant	Cd mg/Plant	Fe mg/Plant	Cu mg/Plant	Zn mg/Plant	Mn mg/Plant
SA0 CD0	1	7.4	728	5.43	0.0868	0.02072	0.1328572	0.0481152	0.0127596	0.0004256	0.090524	0.023044	0.073164	0.045136
SA0 CD0	2	7.3	732	5.3	0.112	0.0154	0.140448	0.0777315	0.016415	0.000364	0.116935	0.02681	0.0973	0.056875
SA0 CD0	3	7.3	705	4.92	0.064	0.0116	0.1191168	0.04474	0.004242	0.00019	0.06566	0.015	0.05236	0.03028
SA0 CD1	4	7.37	656	5.13	0.0704	0.02208	0.2928586	0.1063392	0.0295296	0.0073248	0.180192	0.037392	0.13321632	0.079824
SA0 CD1	5	7.32	635	5.23	0.09308	0.0126	0.2296224	0.0561915	0.027693	0.006507	0.1548	0.034155	0.12375	0.07632
SA0 CD1	6	7.3	675	5.17	0.0706	0.00864	0.1836378	0.0791532	0.019476	0.006048	0.12852	0.02754	0.099144	0.058788
SA0 CD2	7	7.7	662	4.98	#REF!	0.0194	0.099723	0.044664	0.010466	0.002488	0.0828	0.01534	0.0516	0.03264
SA0 CD2	8	7.76	654	5.12	#REF!	0.02548	0.1282411	0.0362622	0.016666	0.0046878	0.11024	0.019682	0.067938	0.04108
SA0 CD2	9	7.6	632	4.97	#REF!	0.0174	0.0994678	0.048332	0.014058	0.002944	0.07968	0.01584	0.05094	0.03102
SA1 CD0	10	7.5	654	5.68	0.132	0.0148	0.1589496	0.047916	0.015404	0.00108	0.137	0.02856	0.10496	0.06468
SA1 CD0	11	7.4	643	5.63	0.1408	0.01848	0.2620891	0.091388	0.0301532	0.0006952	0.147092	0.03586	0.110792	0.068904
SA1 CD0	12	7.58	631	5.15	0.19152	0.03135	0.2847315	0.0830262	0.0247722	0.000798	0.200754	0.044631	0.14307	0.091713
SA1 CD1	13	7.63	563	5.47	0.1088	0.01428	0.1797648	0.0835686	0.0094792	0.0047464	0.151776	0.02788	0.083878	0.048348
SA1 CD1	14	7.75	534	6.3	0.129	0.03268	0.2554088	0.0882962	0.0081829	0.006536	0.171312	0.032164	0.114896	0.071982
SA1 CD1	15	7.55	507	5.42	0.1643	0.03074	0.2590317	0.0936457	0.0077009	0.0056763	0.210516	0.041181	0.137005	0.084906
SA1 CD2	16	7.3	532	5.52	0.126	0.02226	0.1669592	0.0712908	0.0097566	0.0122976	0.170856	0.031122	0.09534	0.069972
SA1 CD2	17	7.42	509	6.2	0.12	0.0244	0.2385104	0.085804	0.020756	0.011812	0.14084	0.03076	0.10356	0.07116
SA1 CD2	18	7.2	502	5.73	0.14432	0.0246	0.2008221	0.0702658	0.009266	0.0164861	0.179293	0.031652	0.1066	0.068429
SA2 CD0	19	7.41	419	5.64	0.13356	0.02814	0.2066476	0.0655284	0.0245868	0.0027048	0.156366	0.033348	0.104328	0.067662
SA2 CD0	20	7.23	413	5.71	0.13468	0.02072	0.1836103	0.0416879	0.0064787	0.0010878	0.153587	0.029489	0.092389	0.059163
SA2 CD0	21	7.22	421	5.45	0.17672	0.02256	0.2601309	0.0553895	0.0075858	0.0014993	0.184757	0.040843	0.021667	0.07896
SA2 CD1	22	7.43	481	5.31	0.0815	0.01225	0.1697475	0.04706	0.0135525	0.0043325	0.109375	0.019925	0.0117	0.04065
SA2 CD1	23	7.52	452	5.42	0.2109	0.03591	0.282956	0.1365834	0.0061959	0.0080427	0.185022	0.042123	0.021603	0.079344
SA2 CD1	24	7.5	484	5.65	0.08592	0.00792	0.1179362	0.0468	0.0235032	0.0045888	0.100584	0.017256	0.057432	0.009984
SA2 CD2	25	7.7	578	5.6	0.1026	0.0108	0.1647308	0.045819	0.0125577	0.0088587	0.110457	0.021789	0.064422	0.038853
SA2 CD2	26	7.6	563	5.8	0.198	0.02574	0.3282345	0.1253604	0.0366762	0.0128832	0.266112	0.057948	0.186846	0.088638
SA2 CD2	27	7.4	581	5.9	0.114	0.0123	0.173793	0.054465	0.012696	0.006774	0.11481	0.02574	0.07158	0.04254
SA3 CD0	28	7.42	529	5.81	0.1504	0.02303	0.2332925	0.0785323	0.0048081	0.0019505	0.224613	0.036002	0.115338	0.064531
SA3 CD0	29	7.7	531	5.63	0.20862	0.03294	0.3033317	0.0893223	0.0485011	0.0016897	0.250893	0.045018	0.148047	0.082106
SA3 CD0	30	7.4	538	5.8	0.165	0.0315	0.255019	0.07226	0.01043	0.00117	0.2139	0.0378	0.1211	0.06855
SA3 CD1	31	7.6	696	5.76	0.0722	0.01558	0.0947576	0.0379867	0.0038285	0.0046075	0.067659	0.013338	0.045353	0.027132
SA3 CD1	32	7.5	546	5.44	0.064	0.0174	0.1200212	0.034884	0.014414	0.005948	0.07454	0.01798	0.0499	0.02778
SA3 CD1	33	7.72	605	5.12	0.0837	0.01998	0.1617276	0.0541242	0.0140994	0.0072981	0.099225	0.018927	0.065961	0.03807
SA3 CD2	34	7.21	512	5.72	0.07056	0.009	0.0896657	0.0275382	0.0077256	0.0025488	0.072216	0.013464	0.042966	0.024066
SA3 CD2	35	7.71	504	5.47	0.0836	0.01716	0.1301344	0.0427394	0.0026752	0.0040172	0.077946	0.01595	0.052426	0.031218
SA3 CD2	36	7.5	518	6.1	0.10208	0.01885	0.1152388	0.0389267	0.0107474	0.004205	0.109388	0.025433	0.069136	0.040542

Appendix 3. SA and Cd second experiment

Pots	No.	Plant height	Root height	Plant weight	Root weight	Consumed weight	Plant dry weight	Chlorophyll	Number of leaves	Wastrel leaves	Plant diameter cm	Root diameter cm	RWC
SA0 CD0	1	20	14	21.7	0.5	21.1	2.9	49.8	11	0	4.2	4.48	85.26
SA0 CD0	2	19	22	19.6	1.5	19.6	3.1	42.2	9	1	3.98	5.93	86.63
SA0 CD0	3	21	15	50	1.6	37.6	2.9	36.6	9	2	4.3	5.1	86.92
SA0 CD1	4	18.2	20.1	19.1	1.4	18.9	2.4	36.2	13	1	4.01	5.85	79.96
SA0 CD1	5	18.5	10.1	25.9	0.7	25.7	2.3	46.6	12	1	4.62	5.76	79.91
SA0 CD1	6	18.5	15.1	28.7	1.4	28.5	2.1	46.2	14	1	5.32	7.3	81.11
SA0 CD2	7	17	7.3	15.1	0.8	14.8	1.6	54.4	10	0	4.19	5.25	79.15
SA0 CD2	8	15.5	20	30.9	2.2	30.05	1.7	54	13	1	4.6	7.05	76.97
SA0 CD2	9	14.5	8.3	13.2	0.5	12.4	1.4	53	13	1	4.54	6.42	77.61
SA1 CD0	10	24.6	11.2	35.5	1.6	35	2.8	44.6	13	1	5.34	7.54	81.93
SA1 CD0	11	21.1	7.5	33	1.7	32.8	2.8	38.4	14	1	6.12	8.09	84.1
SA1 CD0	12	18.7	15.2	41.5	1.5	41.3	2.9	48	13	1	6.44	7.8	83.82
SA1 CD1	13	17.2	18.1	22.2	1.3	22.2	2.5	48.2	14	3	4.84	6.87	80.21
SA1 CD1	14	20	10.2	21.4	1.1	21.4	2.7	49.4	11	0	4.47	7.28	78.83
SA1 CD1	15	21	11.5	54.5	1.8	54.1	2.6	40.2	12	1	5.88	8.83	76.74
SA1 CD2	16	21.3	18	61	5.2	51.7	2.9	52.1	13	0	5.12	6.4	79.32
SA1 CD2	17	22.1	10.7	39.5	1.4	39	2.9	47	12	0	5.29	8.58	77.73
SA1 CD2	18	19	13.5	50.1	1.8	50	2.8	43	14	0	5.33	7.7	78.98
SA2 CD0	19	22	12.6	35.8	1.6	35.6	3.8	49.4	13	2	6.36	8.6	84.92
SA2 CD0	20	20	13.7	38	2	37.1	4.2	43.2	13	1	5.77	7.73	85.55
SA2 CD0	21	18.6	23.6	42.5	2.4	42.4	3.7	41	13	1	5.57	7.57	87.74
SA2 CD1	22	23.6	14.6	30	1.9	29.6	2.8	46.2	13	2	4.84	7.37	84.46
SA2 CD1	23	19.2	12.9	36	1.6	32	2.8	47.3	12	0	5.34	7.12	81.72
SA2 CD1	24	22.1	13.7	31.5	2.2	28.1	2.9	51.2	12	0	5.88	7.85	83.3
SA2 CD2	25	28.2	13.6	41.43	4.2	33.8	2.2	35.4	13	3	4.6	8.66	81.82
SA2 CD2	26	22.4	12.5	41.8	2.3	34.5	1.9	43.3	12	0	5.02	6.13	79.91
SA2 CD2	27	18.3	11.7	42.47	2.4	35.2	2.3	47.1	13	1	4.89	8.71	81.74
SA3 CD0	28	24	15.1	45.7	1.3	43.4	4.4	48.2	13	0	5.83	8.72	89.18
SA3 CD0	29	26	16.7	52	1.9	52	4.6	47.9	14	1	5.08	6.26	85.97
SA3 CD0	30	28	18.4	41.4	1.8	44.4	3.7	50.1	13	1	5.03	6.74	88.83
SA3 CD1	31	30.5	10.3	39.7	1.8	37.5	3.6	35.4	13	0	4.62	7.35	88.32
SA3 CD1	32	22.1	11.5	41.3	1,8	41.3	3.3	38.8	14	1	3.26	4.32	86.95
SA3 CD1	33	25.2	9.3	42.4	2.8	45.3	3.1	50.5	13	2	3.34	6.93	88.63
SA3 CD2	34	21.5	9.3	28.1	1.4	23.1	2	54.8	10	0	4.83	6.64	83.37
SA3 CD2	35	21.3	8.9	33.4	1.5	33.4	2.2	60.8	13	0	4.24	5.92	83.39
SA3 CD2	36	20.3	9.4	29.1	1.4	29.1	2.1	49.2	11	1	4.64	5.94	82.94

Appendix 4. SA and Cd second experiment

Pots	No.	pH	EC (µs)	Moisture Content %	N g/Plant	P g/Plant	K g/Plant	Ca g/Plant	Mg g/Plant	Cd mg/Plant	Fe mg/Plant	Cu mg/Plant	Zn mg/Plant	Mn mg/Plant
SA0 CD0	1	7.3	595	5.78	0.1073	0.027057	0.146508	0.054694	0.013282	0.0008439	0.1093851	0.0328019	0.10005	0.0801386
SA0 CD0	2	7.5	594	5.78	0.1054	0.02325	0.160735	0.059892	0.01643	0.0020212	0.1130818	0.0357554	0.0972625	0.0967665
SA0 CD0	3	7.33	622	5.92	0.0957	0.02581	0.155208	0.054491	0.01537	0.001218	0.1055484	0.0352205	0.0930523	0.0978373
SA0 CD1	4	7.32	582	5.84	0.0984	0.01776	0.129408	0.069	0.012144	0.0007512	0.090552	0.029892	0.0993	0.0713424
SA0 CD1	5	7.5	568	5.46	0.092	0.01633	0.111711	0.079649	0.014145	0.0037858	0.0795708	0.0260659	0.0738875	0.0678178
SA0 CD1	6	7.5	573	5.91	0.0735	0.01533	0.093849	0.070602	0.014826	0.0041181	0.0838194	0.0280602	0.0758625	0.0596022
SA0 CD2	7	7.4	580	5.86	0.0496	0.01376	0.080064	0.026848	0.008672	0.0071888	0.0657408	0.0147312	0.0472	0.0521504
SA0 CD2	8	7.36	577	5.63	0.0544	0.01377	0.082416	0.053873	0.008466	0.0106301	0.0620619	0.0174845	0.0563125	0.0465817
SA0 CD2	9	7.51	577	5.53	0.0476	0.0112	0.071554	0.014154	0.004326	0.0072352	0.0495572	0.017129	0.04585	0.0405538
SA1 CD0	10	7.43	587	5.57	0.0896	0.02352	0.131376	0.05642	0.010192	0.000448	0.0986944	0.0314776	0.0994	0.0968744
SA1 CD0	11	7.42	554	5.94	0.0924	0.01988	0.137256	0.057792	0.009044	0.001274	0.10262	0.0290052	0.0931	0.0854392
SA1 CD0	12	7.6	546	5.49	0.1073	0.01479	0.146508	0.085898	0.019082	0.0008526	0.1096316	0.0269207	0.12035	0.0918807
SA1 CD1	13	7.52	563	5.53	0.0875	0.013	0.1211	0.04445	0.00925	0.0006275	0.0849875	0.0304675	0.0828125	0.0659675
SA1 CD1	14	7.54	541	5.63	0.0972	0.0162	0.135432	0.055134	0.012042	0.0030888	0.0964521	0.0250587	0.1103625	0.1010718
SA1 CD1	15	7.46	493	5.64	0.0936	0.01664	0.128804	0.053196	0.013312	0.002951	0.0909636	0.0292604	0.1001	0.0837512
SA1 CD2	16	7.41	540	5.73	0.0928	0.01595	0.137257	0.059653	0.016008	0.0097585	0.1112933	0.0324191	0.0841	0.07105
SA1 CD2	17	7.43	495	5.58	0.0986	0.01856	0.138156	0.055477	0.010962	0.0071775	0.1085963	0.0296728	0.0851875	0.0856573
SA1 CD2	18	7.4	498	5.43	0.1008	0.0182	0.137172	0.051912	0.01008	0.0068376	0.1023736	0.0287308	0.08785	0.0990444
SA2 CD0	19	7.5	420	5.93	0.133	0.02508	0.190456	0.07448	0.015808	0.0006346	0.1368114	0.0468122	0.110675	0.1049978
SA2 CD0	20	7.31	410	5.68	0.147	0.02772	0.214284	0.07938	0.016968	0.0008232	0.1509858	0.0428232	0.182175	0.141225
SA2 CD0	21	7.3	425	5.71	0.1369	0.02331	0.178636	0.058497	0.013653	0.0002516	0.1430161	0.048951	0.1160875	0.1066895
SA2 CD1	22	7.45	485	6.1	0.0896	0.01736	0.131348	0.03948	0.009548	0.002996	0.1222732	0.0314972	0.0924	0.0917308
SA2 CD1	23	7.5	439	5.58	0.0924	0.01764	0.130984	0.0644	0.014588	0.00092652	0.1221948	0.0342328	0.0854	0.0835968
SA2 CD1	24	7.48	495	5.36	0.0928	0.01885	0.143086	0.053563	0.019633	0.00107735	0.124758	0.0326018	0.092104	0.1013724
SA2 CD2	25	7.44	782	6.2	0.0814	0.0121	0.107932	0.035706	0.01298	0.0077044	0.0966108	0.022506	0.072325	0.067727
SA2 CD2	26	7.52	571	5.91	0.0646	0.01121	0.091181	0.048089	0.010583	0.0066101	0.0828514	0.0174895	0.0596125	0.0509485
SA2 CD2	27	7.47	572	5.82	0.0713	0.01242	0.118312	0.024541	0.021229	0.0085583	0.101361	0.021137	0.0710125	0.0826413
SA3 CD0	28	7.39	532	5.62	0.1496	0.02288	0.183216	0.077792	0.001892	0.001078	0.1653784	0.0537548	0.12705	0.1193852
SA3 CD0	29	7.61	514	6.11	0.17066	0.02392	0.244076	0.087492	0.0253	0.0031648	0.181654	0.0520352	0.153364	0.1461236
SA3 CD0	30	7.63	567	5.58	0.12691	0.02294	0.205683	0.09102	0.01628	0.0011951	0.1392421	0.0416657	0.1151625	0.1236281
SA3 CD1	31	7.57	567	5.58	0.13536	0.02484	0.176832	0.088416	0.029484	0.0063684	0.176058	0.0369288	0.1188	0.0947232
SA3 CD1	32	7.48	486	5.71	0.1122	0.02343	0.160182	0.079365	0.03069	0.00569118	0.1669701	0.0374682	0.1142625	0.0912912
SA3 CD1	33	7.65	515	5.63	0.10912	0.02108	0.164517	0.135377	0.02945	0.0070742	0.1629763	0.0320044	0.098425	0.0922312
SA3 CD2	34	7.37	513	5.82	0.072	0.0126	0.0994	0.07928	0.01018	0.013542	0.074856	0.018456	0.06675	0.049468
SA3 CD2	35	7.64	518	5.74	0.0825	0.01364	0.109648	0.065208	0.02222	0.0072402	0.0825176	0.0225478	0.074525	0.0522302
SA3 CD2	36	7.58	512	6.23	0.07581	0.01302	0.106428	0.063441	0.011046	0.0066045	0.0782103	0.0193263	0.0753375	0.0538944

Appendix 5. SA and Salt first experiment

Pots	No.	Plant height	Root height	Plant weight	Root weight	Consumed weight	Plant dry weight	Chlorophyll	Number of leaves	Wastrel leaves	Plant diameter cm	Root diameter cm	Osmotic potential	RWC
SA0 S0	1	23	15	28.6	1.8	29.6	3.6	33.4	21	1	4.88	5.24	5.4529	82.57
SA0 S0	2	23	23	34.1	2.8	28.9	3.8	33.2	22	1	6.56	5.36	3.8283	81.43
SA0 S0	3	20	11	34.2	2	46.7	3.7	34.3	21	1	7.11	7.18	4.1002	82.31
SA0 S1	4	10	15	18.2	1.5	4	3.1	42.96	12	1	5.16	4.64	3.4984	78.62
SA0 S1	5	8	13	16.4	0.9	4	3.3	37.58	11	2	4.96	4.54	3.7556	79.94
SA0 S1	6	9	15	15.6	0.3	15.3	3.3	40	14	2	6.10	7.85	2.1282	77.86
SA0 S2	7	7.5	6.3	13.6	0.5	11.8	2.1	35.8	10	1	4.50	3.8	2.1181	66.82
SA0 S2	8	7.4	6	13.5	0.45	12.5	2.2	36.1	9	1	5.10	4.5	1.808	65.12
SA0 S2	9	7.6	7	14.7	0.9	13.2	2.2	39.9	12	1	4.80	4.1	1.677	66.02
SA1 S0	10	21.5	18	98.44	10.84	85.83	4.81	61.1	29	2	14.03	13.86	4.2004	82.01
SA1 S0	11	24.5	27	109.58	14.22	90.48	6.4	59.2	30	1	11.95	11.54	6.2285	82.32
SA1 S0	12	21	21	96.34	17.16	90.02	5.7	60.3	27	1	12.21	11.47	6.6316	81.51
SA1 S1	13	17.5	23	56.27	8.76	56.27	4.4	55.8	25	0	10.58	9.87	4.7894	81.63
SA1 S1	14	19.6	22	53.32	8.76	56.27	4.5	55.8	25	0	10.58	9.87	3.9485	82.47
SA1 S1	15	18.4	24	54.33	8.76	56.27	4.2	55.8	25	0	10.58	9.87	4.3914	81.95
SA1 S2	16	14	14	34.9	5.05	34.9	2.24	59.7	21	1	10.88	10.58	3.3105	78.71
SA1 S2	17	16	17	33	6.12	33	1.73	62.5	22	1	9.42	10.45	3.2485	77.96
SA1 S2	18	14	16	24.78	3.5	34.78	1.51	47.2	23	1	10.72	11.19	2.9357	78.84
SA2 S0	19	18	18	49.77	5.12	49.77	4.26	56.1	29	0	10.78	10.7	5.078	82.43
SA2 S0	20	20	19	61.85	6.36	61.85	5.57	57.1	32	0	10.36	10.44	3.1925	84.23
SA2 S0	21	19.5	19	54.13	8.74	54.13	4.58	57.2	31	0	9.91	10.55	4.2075	83.48
SA2 S1	22	18.2	18	68.1	8.24	65.84	3.75	53.2	29	2	11.39	12.06	2.2638	77.48
SA2 S1	23	18.5	28	60.57	7.85	58.3	3.18	57.4	25	1	10.81	9.74	2.7445	78.12
SA2 S1	24	19.5	20	74.15	10.3	74.15	3.84	55.9	25	1	13.35	12.38	3.2535	77.84
SA2 S2	25	19.5	17	65.93	7.96	65.93	2.81	54.8	22	0	12.08	11.45	2.7342	74.45
SA2 S2	26	18	16	63.44	5.95	63.44	2.88	54.9	24	0	12.84	11.51	1.2943	75.57
SA2 S2	27	19	18	65.7	6.56	65.7	2.76	57.7	23	1	12.64	11.68	2.669	74.69
SA3 S0	28	23	21	83	11.34	78.1	6.73	66.2	27	3	10.08	11.44	5.065	89.86
SA3 S0	29	21	19	84.69	10.5	74.12	5.83	61.6	27	1	10.74	11.45	5.4399	88.36
SA3 S0	30	21	17.5	87.84	12.41	84.31	6.02	68.1	30	2	10.86	13.51	6.576	88.42
SA3 S1	31	21	20	85.47	10.1	84.68	3.04	57.9	22	2	11.7	10.5	1.0625	80.16
SA3 S1	32	20	21	83.3	10.9	79.5	4.42	55.7	23	1	11.78	13.24	2.6452	81.32
SA3 S1	33	19.5	19	69.51	9.13	67.27	4.2	65.4	24	2	12.52	12.18	2.4712	80.52
SA3 S2	34	18.7	14	27.29	5.64	27.29	1.47	47.9	19	1	8.01	8.06	1.6791	78.54
SA3 S2	35	19	15	29.34	5.61	28.98	1.24	57.2	20	2	9.57	8.55	1.4969	78.52
SA3 S2	36	20.7	18	58.18	6.96	58.18	2.48	44.3	18	2	10.75	9.66	1.6303	78.18

Appendix 6. SA and Salt first experimen

Pots	No.	pH	EC (µs)	Moisture Content	N g/Plant	P g/Plant	K g/Plant	Ca g/Plant	Mg g/Plant	Na g/Plant	Fe mg/Plant	Cu mg/Plant	Zn mg/Plant	Mn mg/Plant
SA0 S0	1	7.64	610	5.38	0.13104	0.00797256	0.195588	0.0513936	0.0115812	0.023508	0.096696	0.022716	0.065448	0.057132
SA0 S0	2	7.6	655	4.97	0.11894	0.00848198	0.163894	0.0751184	0.021413	0.031692	0.101726	0.020482	0.081396	0.061218
SA0 S0	3	7.54	665	5.45	0.13246	0.00857401	0.180782	0.0831131	0.0105968	0.026011	0.094498	0.02923	0.07289	0.057091
SA0 S1	4	7.75	1212	5.12	0.11067	0.00731011	0.153667	0.0758477	0.0230516	0.038223	0.063271	0.02573	0.049507	0.053072
SA0 S1	5	7.61	1222	5.18	0.1155	0.00741708	0.166782	0.0698082	0.0212982	0.046035	0.072138	0.02541	0.07095	0.045474
SA0 S1	6	7.6	1200	5.21	0.10395	0.00839322	0.171996	0.0615582	0.0234729	0.042801	0.072963	0.023034	0.080289	0.047652
SA0 S2	7	7.45	1945	5.31	0.07644	0.00493206	0.129444	0.0468972	0.0094374	0.098931	0.049434	0.017052	0.028707	0.031941
SA0 S2	8	7.65	1955	5.22	0.0748	0.00466884	0.117106	0.046893	0.0122254	0.10923	0.060852	0.017468	0.028534	0.02805
SA0 S2	9	7.4	1935	5.19	0.077	0.00583704	0.136862	0.0438834	0.0106106	0.109164	0.0561	0.017292	0.02893	0.025146
SA1 S0	10	7.53	560	5.34	0.15873	0.012988299	0.3042806	0.080177986	0.07567092	0.055793355	0.09343425	0.0300625	0.0620009	0.04129866
SA1 S0	11	7.52	590	5.35	0.21504	0.015768	0.5447936	0.316704128	0.090250752	0.08393152	0.0844288	0.029568	0.082752	0.0594688
SA1 S0	12	7.6	580	5.24	0.2109	0.012021129	0.4218798	0.198636108	0.103963269	0.1095939	0.0718941	0.031293	0.054777	0.0594054
SA1 S1	13	7.9	1109	5.17	0.1452	0.010580328	0.3579708	0.118065244	0.050005472	0.138710132	0.093698	0.041756	0.06864	0.051788
SA1 S1	14	8.3	1005	5.41	0.1512	0.010732095	0.236943	0.109539	0.0512235	0.146385	0.10188	0.04014	0.07452	0.0484515
SA1 S1	15	7.6	1215	5.26	0.1554	0.01045212	0.2088744	0.0780066	0.0414204	0.124992	0.091812	0.03675	0.076482	0.0556626
SA1 S2	16	7.63	1853	5.5	0.07392	0.006104896	0.1971648	0.050181622	0.025272733	0.091633427	0.05083904	0.0205856	0.0242592	0.02582272
SA1 S2	17	7.53	1767	5.12	0.060896	0.005864908	0.0993539	0.036442052	0.015458588	0.07474837	0.04467379	0.0124387	0.0228014	0.0224554
SA1 S2	18	7.5	2141	5.35	0.050736	0.004523839	0.1273081	0.028930452	0.009321336	0.068169705	0.03995158	0.0087731	0.0170781	0.01642427
SA2 S0	19	7.5	540	5.25	0.147396	0.012174867	0.2724483	0.16850856	0.059271084	0.05224464	0.07380876	0.044943	0.055806	0.05627886
SA2 S0	20	7.52	568	5.27	0.18381	0.012954595	0.34821969	0.128252759	0.052224097	0.07983481	0.09545309	0.0547531	0.0816005	0.07311182
SA2 S0	21	7.4	523	5.18	0.15572	0.014624032	0.24831386	0.155718626	0.059181111	0.07618372	0.08737724	0.0502884	0.0587614	0.06046516
SA2 S1	22	7.9	949	5.52	0.126	0.008499938	0.1670025	0.078979013	0.038013075	0.116528138	0.06460875	0.032475	0.0455625	0.045915
SA2 S1	23	7.8	1056	5.32	0.08904	0.003886024	0.171879	0.080574776	0.034039579	0.113257544	0.05966634	0.0267438	0.0353298	0.04965252
SA2 S1	24	7.3	1036	5.15	0.09984	0.010898842	0.25204224	0.095085734	0.038925389	0.121153613	0.0984	0.021696	0.0614784	0.046368
SA2 S2	25	7.8	1316	5.47	0.07587	0.007200063	0.13996048	0.032578578	0.016465476	0.11004522	0.09026001	0.016017	0.0327646	0.03264658
SA2 S2	26	7.6	1414	5.24	0.07488	0.006527952	0.15128352	0.05872968	0.012242074	0.09752832	0.0913968	0.02376	0.036	0.03495744
SA2 S2	27	7.8	1214	5.36	0.067896	0.008268739	0.15940932	0.048709667	0.021075636	0.08498879	0.10465368	0.0228252	0.0376188	0.03477048
SA3 S0	28	7.6	675	5.17	0.253048	0.011142457	0.38203518	0.08655379	0.054474504	0.13082447	0.11842781	0.0705304	0.0819041	0.09747732
SA3 S0	29	7.5	720	5.42	0.212212	0.014018935	0.38290274	0.170158986	0.056220089	0.085509776	0.08830118	0.0633721	0.0803957	0.07879828
SA3 S0	30	7.62	540	5.38	0.232372	0.01411985	0.48376118	0.08654051	0.03504242	0.08754886	0.06969354	0.0609224	0.0943334	0.0925575
SA3 S1	31	7.6	1450	5.29	0.09728	0.008208821	0.1649352	0.068410579	0.031729909	0.061814752	0.0816088	0.025992	0.0352336	0.037772
SA3 S1	32	7.62	1220	5.35	0.152932	0.014287385	0.2893995	0.054494578	0.042771854	0.104111332	0.11916762	0.0385866	0.0586092	0.06265792
SA3 S1	33	7.4	1740	5.23	0.15036	0.01448685	0.2747724	0.106390578	0.033167862	0.102869382	0.1143156	0.034314	0.051324	0.049875
SA3 S2	34	7.56	2124	5.18	0.050862	0.003766581	0.0940359	0.01798104	0.00828051	0.06712755	0.02335389	0.0109074	0.0148764	0.0153468
SA3 S2	35	7.42	2015	5.28	0.04836	0.0030194	0.06337764	0.013919	0.0091326	0.0631966	0.021343252	0.0096224	0.0129208	0.0132122
SA3 S2	36	7.41	2025	5.37	0.085808	0.005786088	0.13612224	0.03559544	0.01930184	0.10751048	0.044326032	0.0173104	0.0247504	0.0280984

Appendix 7. SA and Salt second experiment

Pots	No.	Plant height	Root height	Plant weight	Root weight	Consumed weight	Plant dry weight	Chlorophyll	Number of leaves	Wastrel leaves	Plant diameter cm	Root diameter cm	Osmotic potential	RWC
SA0 S0	1	23	21	40.6	1.8	29.6	3.8	46.6	16	1	4.88	5.24	4.12	87.11
SA0 S0	2	23	22	34.1	2.8	28.9	3.4	44.3	17	0	6.56	5.36	5.732	86.64
SA0 S0	3	20	19	49.2	2	46.7	4.1	42.1	17	1	7.11	7.18	6.008	87.57
SA0 S1	4	12	15	15.7	1.5	4	1.9	40.2	13	1	5.16	4.64	3.363	82.58
SA0 S1	5	13	13	18.6	0.9	4	2.5	45.2	13	1	4.96	4.54	2.786	78.65
SA0 S1	6	13	15	15.6	2.3	5.3	1.9	40	12	2	6.10	7.85	3.233	77.87
SA0 S2	7	7.5	6.3	11.7	0.5	14.4	1.6	38.7	10	2	4.50	3.8	2.001	67.76
SA0 S2	8	7.4	6	13.8	0.45	3	1.8	37.5	11	2	5.10	4.5	1.973	65.94
SA0 S2	9	7.6	7	13.7	0.9	4.1	1.6	42.1	10	2	4.80	4.1	2.221	68.47
SA1 S0	10	20	22	78.3	9.6	74.5	6.7	54.1	22	1	10.79	12.21	5.098	80.23
SA1 S0	11	19.5	21.5	42.6	8.9	42.6	3.2	62.7	25	0	10.86	12.06	6.472	78.94
SA1 S0	12	19	23	56.5	10.16	56.06	3.52	60.5	23	1	10.54	8.23	6.751	78.58
SA1 S1	13	17	18	32.4	5	32.4	1.83	54.3	19	2	9.09	8.87	4.127	79.93
SA1 S1	14	18	19	40.01	8.95	39.72	2.82	63.1	21	1	8.97	11.13	4.0218	80.24
SA1 S1	15	17	18	35.28	9.4	76.95	5.04	61.2	21	1	8.51	11.03	4.283	80.16
SA1 S2	16	15	16.6	20.48	2.85	20.48	1.04	54.3	17	2	8.46	9.72	3.197	75.5
SA1 S2	17	14.5	17.2	22.68	4.5	22.21	1.63	60.1	17	2	9.31	9.97	3.723	74.36
SA1 S2	18	16.5	16.5	21.67	6.8	44.67	3.31	57.2	18	1	7.37	10.82	3.095	77.1
SA2 S0	19	21.3	21	31.1	5.8	31.1	2.41	54.8	23	0	10.58	10.18	5.098	83.35
SA2 S0	20	20.5	19.5	34.71	6.04	34.71	2.53	52.8	26	1	10.58	10.26	5.223	80.94
SA2 S0	21	20.4	23	33.2	4.84	32.04	2.27	55.1	25	0	9.98	8.83	5.094	81.21
SA2 S1	22	18.2	19	51.54	8.92	50.7	3.41	55.5	18	0	9.23	11.33	3.094	80.72
SA2 S1	23	18.5	21	55.29	12.02	66.71	4.75	61.4	21	1	8.74	11.62	3.967	78.62
SA2 S1	24	17.7	20.8	61.57	13.24	61.57	4.32	55.9	21	1	8.68	12.3	4.074	79.14
SA2 S2	25	14.2	17.8	24.12	3.57	24.14	1.35	56.5	17	2	7.98	10.86	2.914	79.76
SA2 S2	26	16	15.5	41.66	5.5	38.45	2.58	61.3	19	2	7.46	11.65	2.743	76.63
SA2 S2	27	16.6	16.4	41.91	5.75	41.02	2.88	61	17	1	8	10.62	2.7782	74.97
SA3 S0	28	22.1	22	48.88	9.91	55.93	3.11	62.1	26	0	11.67	11.96	6.125	79.73
SA3 S0	29	20.7	20	50.6	9.89	58.64	3.3	58.9	27	0	11.72	10.06	7.843	78.13
SA3 S0	30	19.8	21	51.12	9.13	60.48	4.72	57.96	25	1	12.12	12.34	6.025	78.37
SA3 S1	31	17.3	18.2	45.93	6.5	40.83	2.83	51.34	21	1	10.7	10.41	2.113	79.84
SA3 S1	32	16	19.3	48.78	6.28	41.16	3.06	52.2	22	1	11.04	10.08	2.974	80.32
SA3 S1	33	17.5	19	44.16	7.91	43.75	3.86	54.7	21	0	10.83	11.1	1.978	78.98
SA3 S2	34	15.5	16	26.27	4.3	26.27	2.2	46.3	17	1	8.89	8.81	1.784	87.34
SA3 S2	35	14.7	16.4	27.57	4.05	27.18	1.67	48.6	15	2	9.01	10.2	1.683	88.2
SA3 S2	36	14.3	17.3	31.38	4.46	31.38	2.19	46.9	15	1	8.68	10.15	1.739	86.89

Appendix 8. SA and Salt second experiment

Pots	No.	pH	EC (µs)	Moisture Content	N g/Plant	P g/Plant	K g/Plant	Ca g/Plant	Mg g/Plant	Na g/Plant	Fe mg/Plant	Cu mg/Plant	Zn mg/Plant	Mn mg/Plant
SA0 S0	1	7.75	543	5.74	0.12996	0.00806	0.19418	0.0621832	0.0291612	0.026106	0.096216	0.0247	0.062586	0.048754
SA0 S0	2	7.6	578	5.25	0.1394	0.00837	0.16898	0.0635596	0.026469	0.024888	0.083878	0.020774	0.064124	0.035904
SA0 S0	3	7.8	651	5.23	0.13612	0.01001	0.20992	0.0732547	0.0350386	0.027593	0.101557	0.025912	0.072406	0.048544
SA0 S1	4	7.7	1124	5.61	0.0741	0.00379	0.10963	0.0401584	0.0175237	0.025118	0.041477	0.01406	0.021508	0.023693
SA0 S1	5	7.6	1154	5.28	0.0725	0.00592	0.14075	0.05903	0.0214525	0.035925	0.056825	0.01875	0.032925	0.03865
SA0 S1	6	7.7	1243	5.22	0.05985	0.00501	0.10184	0.0341696	0.0176909	0.025878	0.039444	0.01349	0.029393	0.027626
SA0 S2	7	7.42	2654	5.54	0.0656	0.00406	0.08176	0.0356064	0.0109472	0.074768	0.036064	0.01456	0.014736	0.019712
SA0 S2	8	7.5	2121	5.26	0.0738	0.0057	0.09864	0.0351792	0.013761	0.094158	0.04563	0.014652	0.019368	0.021168
SA0 S2	9	7.51	2454	5.24	0.0592	0.00437	0.08672	0.0339536	0.014008	0.074912	0.035744	0.01416	0.0184	0.018448
SA1 S0	10	7.95	602	5.35	0.2278	0.01611	0.37118	0.1638151	0.0634829	0.115511	0.1161043	0.044689	0.083817	0.0647823
SA1 S0	11	8.3	585	5.32	0.104	0.00751	0.18144	0.0540325	0.0259725	0.053607	0.0576768	0.028416	0.036864	0.0324992
SA1 S0	12	7.97	575	5.23	0.122496	0.0068	0.195712	0.0729273	0.0273375	0.085448	0.0562566	0.022352	0.0396352	0.03652
SA1 S1	13	8.1	1226	5.71	0.059658	0.00548	0.092049	0.0617958	0.0188763	0.061858	0.0438834	0.0123159	0.019032	0.02676192
SA1 S1	14	7.87	1267	5.21	0.116184	0.00661	0.14946	0.1117451	0.0400525	0.0990158	0.0729337	0.0161586	0.0271566	0.0377175
SA1 S1	15	7.7	1165	5.42	0.207144	0.01291	0.293832	0.1535033	0.0466272	0.1787184	0.1111622	0.0311472	0.0542808	0.06605928
SA1 S2	16	8.1	2204	5.48	0.034528	0.00205	0.047944	0.0207455	0.0073285	0.0293635	0.0269017	0.0073112	0.0127816	0.01176136
SA1 S2	17	8.1	2067	5.28	0.063081	0.00283	0.086064	0.045191	0.013673	0.0596067	0.0368331	0.0126814	0.0197393	0.01761215
SA1 S2	18	7.64	2194	5.33	0.127104	0.00594	0.127104	0.0558836	0.0209291	0.0982696	0.065581	0.0288301	0.0476309	0.04140148
SA2 S0	19	7.8	554	5.36	0.085314	0.00551	0.108932	0.0546942	0.0200261	0.0666835	0.0459683	0.0140021	0.0272812	0.02858019
SA2 S0	20	8	558	5.32	0.09361	0.00588	0.11891	0.0691658	0.0264585	0.0881472	0.060004	0.0195063	0.032131	0.0326623
SA2 S0	21	7.9	576	5.27	0.073775	0.00456	0.107825	0.0507535	0.0234363	0.05551	0.0599666	0.0203619	0.0273535	0.03164153
SA2 S1	22	8	1105	5.38	0.118668	0.00672	0.202213	0.0573454	0.0231675	0.0521153	0.0718521	0.0262911	0.0454894	0.04071199
SA2 S1	23	7.6	1254	5.27	0.1482	0.00515	0.263625	0.0796437	0.0210728	0.0620343	0.0990613	0.04237	0.0541975	0.0503595
SA2 S1	24	8.2	1321	5.19	0.139968	0.00937	0.25056	0.0668152	0.0283592	0.0745003	0.0990014	0.0460944	0.0648432	0.04838832
SA2 S2	25	7.7	1456	5.43	0.04725	0.00032	0.082485	0.0358623	0.0095013	0.0503557	0.0282852	0.0089775	0.015093	0.014607
SA2 S2	26	7.65	1734	5.29	0.08772	0.0007	0.174924	0.045936	0.0134762	0.0533759	0.0548173	0.0139836	0.02838	0.03429594
SA2 S2	27	7.83	1657	5.31	0.08928	0.00658	0.189504	0.0617322	0.0211738	0.0933298	0.0658944	0.018144	0.0355968	0.04132512
SA3 S0	28	7.81	587	5.47	0.117869	0.00815	0.192509	0.0790369	0.0266081	0.1184411	0.0848843	0.0154256	0.0388128	0.03352269
SA3 S0	29	7.75	590	5.21	0.12837	0.00826	0.18183	0.0839408	0.0284961	0.11504	0.080454	0.030195	0.037389	0.0359436
SA3 S0	30	7.9	568	5.32	0.167088	0.01014	0.269984	0.118258	0.0449129	0.2025786	0.1359313	0.0379016	0.059236	0.048026
SA3 S1	31	7.6	1768	5.35	0.09056	0.00692	0.187912	0.0672415	0.0205471	0.0837301	0.0853415	0.0164706	0.0402709	0.03181203
SA3 S1	32	7.8	1638	5.42	0.118422	0.00754	0.190638	0.0986268	0.0359079	0.1366715	0.1055731	0.0164016	0.0409122	0.03943422
SA3 S1	33	7.4	1724	5.23	0.11387	0.01164	0.245882	0.0817111	0.0333834	0.0707591	0.1056675	0.034354	0.0509906	0.04515042
SA3 S2	34	7.4	2375	5.34	0.07876	0.0059	0.12276	0.0671992	0.0168212	0.0745294	0.049203	0.02057	0.02574	0.030811
SA3 S2	35	7.65	2292	5.47	0.062458	0.00484	0.102371	0.0350447	0.0113081	0.0440104	0.0373262	0.0122244	0.0242985	0.02364553
SA3 S2	36	7.7	2376	5.29	0.075555	0.00846	0.131619	0.0404529	0.0136418	0.054463	0.0504116	0.0114603	0.0292365	0.03345444

CURRICULUM VITAE

He was born in 1987 in Duhok. He studied Primary school in BEGOVA and RIZGARY schools, Secondary school KHABOUR and High school ZAKHO. In 2005 began to study at Duhok University College of Agriculture in the Soil and Water Science Department and graduated with the title of Agricultural Engineer in 2009. Work as a demonstrator at Duhok University. In 2010 he began to study master's degree at Newcastle University, Environmental Science Department, and graduated with the title of Environmental Consultant in 2010. In 2013, he worked as an assistant teacher at Duhok University, College of Agriculture, that scientific name changed from assistant teacher to teacher in 2016. At the end of 2016, he started studying Ph.D. at Van YüzüncüYil University Turkey, Soil Science, and Plant Nutrition Department.

Education

- 2016-2020 Van YüzüncüYil University, Turkey, Soil Science and Plant Nutrition (Ph.D.)
- 2010-2013 Newcastle University, United Kingdom, Environmental Science (M.Sc.).
- 2005-2009 Duhok University College of Agriculture, Soil and Water Science (Bachelor).
- 2000-2005 Zakho High School.
- 1998-2000 Khabour Secondary School.
- 1992-1998 Begova and Rizgary Primary School.

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