ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

MSc THESIS

NADIA ALI SIR ELKHTIM AHMED

EFFECT OF FOLIAR APPLICATIONS OF SALICYLIC ACID ON MINERAL NUTRITION AND SOME PHYSIOLOGICAL PROPERTIES OF BREAD WHEAT GENOTYPES UNDER SALT STRESS CONDITIONS

DEPARTMENT OF SOIL SCIENCE AND PLANT NUTRITION

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We certify that the thesis titled above was reviewed and approved for the award of the degree of the Master of Science by the board of jury on 20.12.2019.

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Prof. Dr. Selim EKER	Assoc. Prof. Dr Emin Bülent ERENOĞLU	Assoc. Prof. Dr Halil ERDEM
SUPERVISOR	MEMBER	MEMBER

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Registration Number:

Prof. Dr. Mustafa GÖK
Director
Institute of Natural and Applied Sciences

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ABSTRACT

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: Assoc. Prof. Dr. Halil ERDEM

The present study was conducted to determine the effect of foliar salicylic acid applications (0.0, 0.2, 0.5 and 1.0 mM) on plant dry matter productions, SPAD values, leaf relative water content (LRWC), membrane permeability and macro-micro nutrients in shoot at different salinity levels (control, 2.5, 5.0, and 10.0 dS m^{-1}) under greenhouse conditions. Salt treatments significantly decreased both the shoot and the root dry matter productions. Dry matter production increasing effects of salicylic acid were observed in shoots at 2.5 and 5.0 dSm^{-1} salinity levels and in roots at 2.5 dSm^{-1} salinity level. SA increased SPAD values at 0, 2.5, and 5.0 dS m^{-1} levels. LRWC significantly decreased with increasing salinity. On the other hand, SA treatments significantly increased LRWC. Shoot sodium (Na) concentrations significantly increased with increasing salinity. Sodium concentrations significantly decreased with enhancing SA under 2.5 and 5.0 dSm^{-1} levels. At 0, 2.5 and 5 dSm^{-1} salinity levels, both K concentrations and K contents significantly increased with SA. In the same salinity levels, K/Na ratios also significantly increased with SA treatments. Nitrogen, P, Mg, Fe, Zn, Mn ve Cu contents of the genotypes decreased dramatically with increasing salinity. At control treatments and 2.5 and 5.0 dS m^{-1} salt levels, increasing SA treatments enhanced both P concentrations and P contents of the genotypes. SA treatments increased Mn and Cu uptakes under both saline and non-saline conditions.

Present findings revealed that SA treatments (especially 1.0 mM) were quite effective in alleviation of negative impacts of 5 dS m^{-1} and lower salinity levels.

Keywords: Salicylic acid, salinity, wheat, macro-micronutrients

ÖZ

YÜKSEK LİSANS TEZİ

YAPRAKTAN SALİSİLİK ASİT UYGULAMASININ TUZ STRESİ ALTINDAKİ EKMEKLİK BUĞDAY GENOTİPLERİNİN MİNERAL BESLENME VE BAZI FİZYOLOJİK ÖZELLİKLERİ ÜZERİNE ETKİSİ

NADIA ALI SIR ELKHTIM AHMED

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Bu çalışma, sera koşullarında değişik tuz seviyeleri altında (kontrol, 2.5, 5.0 ve 10 dS m^{-1}) yetiştirilen ekmeklik buğday genotiplerine yapraktan salisilik asit (0.0, 0.25, 0.5 ve 1.0 mM) uygulamalarının bitki kuru madde üretimi, SPAD değerleri, yaprak relatif su içerikleri, membran permeabilitesi ve yeşil aksam makro-mikro besin elementleri üzerine etkilerinin belirlenmesi amacıyla gerçekleştirilmiştir. Tuz uygulaması genotiplerin hem yeşil aksam hem de kök kuru madde verimlerini önemli ölçüde azaltmıştır. Salisilik asitin kuru madde üretimini artırıcı etkisi yeşil aksamda tuzun 2.5 ve 5.0 dS m^{-1} düzeylerinde ortaya çıkarken, köklerde tuzun 2.5 dS m^{-1} seviyesinde ortaya çıkmıştır. SA uygulaması tuzun 0, 2.5 ve 5.0 dS m^{-1} seviyelerinde SPAD değerlerini arttırmıştır. Artan oranlarda tuz uygulamasıyla beraber yaprakların relatif su içerikleri önemli ölçüde düşmüştür. Diğer yandan, SA uygulamaları relatif su içeriğini önemli ölçüde artırmıştır. Artan tuz düzeyleri yeşil aksam sodyum (Na) konsantrasyonunu önemli ölçüde yükseltmiştir. Tuzun 2.5 ve 5.0 dS m^{-1} seviyelerinde artan SA uygulaması Na konsantrasyonunu önemli ölçüde azaltmıştır. Kontrol koşullarında ve tuzun 2.5 ve 5 dS m^{-1} seviyelerinde hem K konsantrasyonu hem de içeriği SA uygulamasıyla önemli ölçüde yükselmiştir. Aynı tuz seviyelerinde, K/Na oranları da SA uygulamasıyla birlikte önemli ölçüde yükselmiştir. Artan tuz uygulamasıyla beraber çeşitlerin ortalama N, P, Mg, Fe, Zn, Mn ve Cu içerikleri önemli ölçüde azalmıştır. Tuzun 0, 2.5 ve 5.0 dS m^{-1} seviyelerinde SA uygulaması hem P konsantrasyonu hem de P içeriğini önemli ölçüde arttırmıştır. Hem kontrol hem de tuz stresi altında SA uygulamaları Mn ve Cu alımlarını arttırmıştır.

Elde edilen sonuçlara göre, SA uygulamalarının (özellikle 1.0 mM) 5 dS m^{-1} ve altındaki tuzluluğun olumsuz etkilerinin azaltılmasında etkili olduğu bulunmuştur.

Anahtar Kelimeler: Salisilik asit, tuzluluk, buğday, makro-mikro besin elementleri

GENİŞLETİLMİŞ ÖZET

Toprak tuzluluğu bitkisel üretimi sınırlayan önemli abiyotik bir stres faktörüdür. Dünyadaki karasal alanların %6'dan fazlasının ve sulanan alanların yaklaşık %20'sinin tuzluluktan etkilendiği tahmin edilmektedir. Tuz stresine tolerans; bitki transkriptomu, proteomu ve metabolizma kompozisyonundaki değişikliklere eşlik eden gen ifadesindeki önemli değişiklikleri kapsamaktadır. Fizyolojik, moleküler genetik ve fonksiyonel genomik çalışmalarla tuz toleransı hakkında önemli bilgiler sağlanmıştır. Genel olarak tuz stresi bitki büyüme düzenleyicilerinin sentezini azaltmakta veya degradasyona neden olabilmektedir.

Salisilik asit (SA), bitkilerde birçok metabolik ve fizyolojik cevabı oluşturan ve dolayısıyla bitki büyüme ve gelişmesini etkileyen içsel bir bitki büyüme düzenleyicisidir. SA, yerel patojen saldırısına karşı bitki savunma cevaplarında (hipersensitif cevap) ve sistemik kazanılmış dirençte önemli rol oynamaktadır. SA, stres koşullarında büyüme, gelişme ve savunma cevaplarında önemli rol oynayan bir sinyal molekülüdür. Bitkilerde hastalık direnci sağlamasının yanında, SA, birçok stres durumuna karşı bitki cevaplarını düzenleyebilmektedir. Salisilik asit bitki büyüme ve gelişmesi, fotosentez, stomatal regülasyon, solunum, çiçeklenme, senesens ve iyon alımında önemli rol oynamaktadır. Bitkilerde SA-aracılı büyüme ve gelişmenin moleküler durumları ile ilgili araştırmalar, SA'in etki mekanizmalarının yanında, fizyolojik rollerinin de daha iyi anlaşılmasını sağlamaktadır. Tohum çimlenmesinde SA'in rolü ile ilişkili çalışmalar çelişkili olup, SA'in ya çimlenmeyi inhibe ettiği ya da tohum canlılığını arttırdığı ileri sürülmüştür.

Bu çalışma, sera koşullarında 4 farklı tuz seviyesi altında (kontrol, 2.5, 5.0 ve 10 dS m^{-1}) yetiştirilen ekmeklik buğday genotiplerine (Altınöz, Candaş, Gökkan, Yakamoz) yapraktan 4 değişik dozda salisilik asit uygulamasının (0.0, 0.25, 0.5 ve 1.0 mM) bitki kuru madde üretimi, SPAD değeri, relatif su içeriği, membran permeabilitesi ve sodyum (Na), azot (N), fosfor (P), potasyum (K), kalsiyum (Ca), magnezyum (Mg), demir (Fe), çinko (Zn), mangan (Mn) ve bakır (Cu) elementleri üzerine etkilerini araştırmak amacıyla yürütülmüştür.

Tuz stresi bitkilerin büyümes ve gelişmesini olumsuz şekilde etkilemektedir. Tuz stresi altındaki bitkiler sıklıkla su eksikliği ve zararlı iyon toksisitesiyle mücadele ederler. Bu çalışmada, artan oranlarda tuz uygulaması genotiplerin yeşil aksam ve kök kuru madde üretimlerinin istatistiksel olarak önemli ölçüde azalmasına neden olmuştur. Aynı dozlarda, ortalama kök kuru madde üretimindeki gerilemelerin yeşil aksama göre daha fazla olduğu görülmüştür. Artan tuz dozuna bağlı olarak tüm genotiplerin hem yeşil aksam hem de kök kuru madde üretimlerindeki azalma eğilimlerinin birbirlerine yakın olduğu görülmüştür. Salisilik asit uygulamaları genotiplerin hem yeşil aksam hem de kök kuru madde üretimlerini önemli ölçüde değitirmiştir. Çeşitlerin ortalaması açısından hem yeşil aksam hem de kök kuru madde üretimlerinin birbirlerinden önemli ölçüde farklı olduğu görülmüştür. Çeşitler arasında aynı anda hem yeşil aksam hem de kök büyümesi en fazla olan çeşit Candaş olmuştur. Bu tez çalışmasında, tuzlulukla beraber kök büyümesinde meydana gelen azalmaların yeşil aksama göre daha fazla olduğu görülmektedir. Tuz x SA interaksiyonu açısından bakıldığında; tuzun uygulanmadığı durumda SA uygulamaları hem yeşil aksamın hem de köklerin kuru madde üretimlerini artırmıştır. Tuz x çeşit interaksiyonu açısından bakıldığında; kontrol koşullarında Altınöz çeşidinin en düşük yeşil aksam kuru madde üretimine sahip olduğu görülmüştür. Salisilik asit x çeşit interaksiyonu açısından bakıldığında ise, salisilik asit dozlarının ortalamasına bağlı olarak tüm çeşitlerin yeşil aksam ve kök kuru madde üretimi yükselmiştir.

Salisilik asit uygulamasına bağlı olarak çeşitlerin ortalama SPAD değerlerinin önemli ölçüde yükseldiği bulunmuştur. Kontrol koşullarına göre tuzun 2.5 ve 5.0 dS m^{-1} düzeyleri SPAD değerlerinin yükselmesine neden olmuştur. Bu durum, tuz stresiyle beraber yeşil aksamda büyümede meydana gelen gerilemeye bağlı olarak klorofilin konsantre durumu gelmesiyle ilişkili bir durum olabilir. Tüm çeşitler içinde Altınöz çeşidinin SPAD değerinin düşüklüğü ön plana çıkmıştır. SA'in 1.0 mM uygulamasıyla kontrole göre en yüksek artış Yakamoz çeşidinde ortaya çıkmıştır.

Artan oranlarda tuz uygulamasıyla beraber yaprakların relatif su içerikleri önemli ölçüde düşmüştür. Nitekim tuzluluğun artışına bağlı olarak bitkilerin relatif su içerikleri, su potansiyeli ve ozmotik potansiyellerinin daha negatif hale geldiği bildirilmiştir. Bu çalışmada, SA uygulamaları bitkilerin relatif su içeriği değerlerini önemli ölçüde artırmıştır. Çeşit ortalaması açısından bakıldığında, Altınöz ve Gökkan çeşitlerinin relatif su içeriği değerlerinin diğer iki çeşitten yüksek olduğu ve aynı grupta yer aldığı görülmüştür. Tuz x SA interaksiyonunun önemli olduğu ve aynı grupta yer alan en yüksek relatif su içeriği değerlerinin tuzun uygulanmadığı durumda ortaya çıktığı görülmüştür.

Artan tuz uygulamasına bağlı olarak çeşitlerin ortalama membran permeabilite değerlerinin de önemli oranda arttığı görülmüştür. Kontrol koşullarına göre, tuzun 2.5 ve 5 dS m^{-1} seviyelerinde membran permeabilitesinde önemli bir değişim olmamıştır. Buna karşın, tuzun 10 dS m^{-1} seviyesinde %400'lük bir artış olmuştur. Salisilik asit uygulamalarının etkisi ise önemli olmamıştır. SA x çeşit interaksıyonu açısından değerlendirildiğinde, artan SA uygulamaları Altınöz çeşidinin membran permeabilitesini önemli ölçüde azaltırken, Gökkan çeşidinin membran permeabilitesini arttırmıştır. Buradan hareketle, SA'in özellikle 0.5 ve 1.0 mM dozlarının membran permeabilitesini azaltmada etkili olduğu, bu etkinin tuzun 5 ve 10 dS m^{-1} düzeylerindeki membran permeabilite değerlerindeki değişiklikten kaynaklandığı söylenebilir.

Artan tuz düzeylerine bağlı olarak yeşil aksam sodyum (Na) konsantrasyonu önemli ölçüde yükselmiştir. Bitkilerin yeşil aksam kuru madde verimleriyle Na Konsantrasyonu değerlerinin çarpımı sonucu çeşitlerin bitki başına Na içerikleri hesaplanmıştır. Yeşil aksam Na içeriği değerlerinin kontrole göre tuz uygulamasıyla birlikte önemli ölçüde yükseldiği ve bu yükselişlerin bitki kuru madde üretimleriyle paralel olduğu bulunmuştur. Bu çalışmada, Na alımı en düşük olan çeşit kuru madde üretimiyle de uyumlu olarak, Altınöz çeşidi olmuştur. SA uygulaması Na konsantrasyonu ve içeriğini azaltmıştır. Tuz uygulamalarının 2,5'tan 10 dS m^{-1}'e artan dozlarında yeşil aksam kuru madde verimlerinde ortaya çıkan önemli azalmalarla paralel bir şekilde Na içeriklerinin de önemli ölçüde azaldığı görülmüştür.

Salisilik asit uygulamaları açısından bakıldığında, salisilik asit uygulamalarının N konsantrasyonu üzerinde etkili olmadığı görülmüştür.

Tuz uygulamalarının P konsantrasyonu ve içeriği üzerindeki etkisinin önemli olduğu ortaya çıkmıştır. Tuzun uygulanmadığı durumda tüm çeşitlerin P konsantrasyonlarının aynı grupta ve düşük düzeylerde olduğu görülmüştür. Kontrol koşullarında ve tuzun 2.5 ve 5.0 dS m^{-1} seviyelerinde SA uygulaması hem P konsantrasyonu hem de P içeriğini önemli ölçüde arttırmıştır.

Bu tez çalışmasında tuz stresi K konsantrasyonu ve içeriğinin azalmasına neden olmuştur. Kalsiyum konsantrasyonunun tuz stresiyle arttığı, ancak kalsiyum içeriğinin azaldığı bulunmuştur. Tuz x SA interaksiyonunun K için önemli olduğu, Ca için önemli olmadığı görülmüştür. Kontrol koşullarında ve tuzun 2.5 ve 5 dS m^{-1} seviyelerinde K/Na oranları SA uygulamasıyla birlikte önemli ölçüde yükselmiştir.

Tuzlulukla beraber Mg alımının azalması ile SPAD değerlerinin azalması uyumlu bulunmuştur. Salisilik asit uygulamalarının Mg konsantrasyonu üzerindeki etkisi önemli olurken, Mg içeriği üzerinde önemli olmadığı görülmüştür. Bu çalışmada SA uygulamasıyla Na alımının azalması, buna karşın N, P, K alımının artması hem yeşil aksam hem de kök büyümesinin teşvik edilmesini sağlamıştır.

Artan tuzluluk, Fe ve Cu konsantrasyonlarının azalmasına, Mn konsantrasyonunun artmasına neden olmuştur. Mangan konsantrasyonunda meydan gelen artışın konsantrasyon etkisiyle ilgili olduğu söylenebilir. Bitki başına element içerikleri açısından bakıldığında, tuzlulukla birlikte Fe, Zn, Mn ve Cu içeriklerinin önemli ölçüde azaldığı tespit edilmiştir. SA uygulamasının Fe, Zn, Mn ve Cu içeriklerini önemli ölçüde arttırdığı bulunmuştur. SA uygulamasıyla Fe ve Cu konsantrasyonlarındaki artış önemli olurken, Zn ve Mn konsantrasyonlarındaki artış önemli olmamıştır. Tuzun tüm dozlarında SA uygulaması Mn içeriğini arttırmıştır.

Sonuç olarak, SA'in, özellikle de 1.0 mM dozunun 5 dS m^{-1} ve altındaki tuzluluğun olumsuz etkilerinin giderilmesinde daha etkili olduğu bulunmuştur.

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LIST OF SYMBOLS AND ABBREVIATIONS

Da	: Decares
mm	: Millimeter
mM	: Milimolar
ppm	: Part per million
dS m^{-1}	: Deci Siemens /meter
mS cm^{-1}	: Milli Siemens/ centimeter
SA	: Salicylic Acid
ASA	: Acetyl Salicylic Acid
ABA	: Abscisic Acid
IAA	: Indole Acetic Acid
DAS	: Day after sowing
CAT	: Catalase
POX	: Peroxide
PWC	: Proportional water content
LRWC	: Leaf Relative water content
ROS	: Reactive oxygen species
DW	: Dry weight
FW	: Fresh weight
TW	: Turgid weight
SOD	: Superoxide dismutase
EC	: Electrical conductivity
SAR	: Sodium adsorption ratio
ESP	: Exchangeable sodium percentage
H_2O_2	: Hydrogen peroxide
pH	: Soil pH (Factor of acidity-alkalinity)
N	: Nitrogen

CO_2	: Carbon dioxide
P	: Phosphorus
K	: Potassium
Ca	: Calcium
Na	: Sodium
Mg	: Magnesium
Mn	: Manganese
Fe	: Iron
Zn	: Zinc
Cu	: Copper
Cd	: Cadmium
Al	: Aluminum
Mo	: Molybdenum
Ba	: Barium
Sr	: Strontium
H	: Hydrogen
OH	: Hydroxide
SO_4	: Sulfate
NO_3	: Nitrate
CO_3	: Carbonate
HCO_3	: Bicarbonate
SiO_2	: Silicon dioxide
NaCL	: Sodium Chloride
NaOH	: Sodium Hydroxide

1. INTRODUCTION

Soil salinity is a severe environmental problem that adversely affects the growth and productivity of many plant species. Salinity affects agricultural production negatively in both the irrigated and non- irrigated lands of the world, especially in arid and semi-arid regions (Ashraf, 2010; Zhang et al, 2010). Approximately 20% of the cultivated areas in the world and half of the irrigated areas were reported to be under the influence of salinity (Flowers and Yeo, 1995).

Soil salinity is an ever-increasing problem worldwide and it was estimated that around 7% (930 million hectares) of soils in the world were made up of saline soils (Szabolcs, 1994). Due to soil salinity, about 1/3 of 230 million hectares of the irrigable lands couldn't be sown (Oldeman et al., 1991; Ghassemi et al., 1995). Of such areas, 15.57% are in Africa, 5.07% in Australia, 0.57% in Mexico and Central America, 1.8% in North America, 20.21% in South America, 26.7% in North and Central Asia, 24.25% in South Asia and 5.82% in Southeast Asia. A large number of plant species have been identified in these areas. The salinity tolerances of these species vary greatly not only among the species but also within the species. Among the monocotyledonous culture plants, paddy is the most sensitive, bread wheat is tolerant and barley is the most tolerant species to salinity. Dicotyledonous are more tolerant of saline conditions (Massoud, 1974).

In Turkey, 5 215 million hectares of land is irrigated and there are salinity problems in 19850 hectares of the irrigated area. In Turkey, salinity or alkalinity (infertility) problems were detected in 1.7% of agricultural fields (1 518 722 hectares) (Anonymous, 1987, 2002). These areas contain 614617 hectares of slightly saline, 504 603 hectares of saline, 8. 641 hectares of alkaline, 125863 hectares of slightly saline-alkaline and 264 958 hectares of saline-alkaline lands (Sönmez, 2003).

Salt-affected soils in Sudan fall under three soil orders: Vertisols, Aridisols and Entisols (USDA, 1999). They extend along with vast areas at latitudes 14-22^{o} N, including the White Nile, North Gezira, Khartoum state, crossing the River

Nile, and the northern states. In Sudan, it was estimated that 4.874 million hectares are salt-affected. Elmubark (2007) reported that about 268636 ha of the surveyed and mapped areas in Sudan –until 2007-were found to be affected by salinity and/or sodicity.

Salinity is one of the most critical environmental factors affecting the distribution and life of species (Shannon, 1985). Many cultivated plants (tomatoes, beans, eggplants, etc), which economically significant are not resistant against the increases in soil salt concentrations.

Plants under salt stress struggle with water deficiency and harmful ion toxicity problems (Munns, 2005). The high salt content in the soil affects the soil porosity and reduces the soil water potential and causes physiological drought (Hopkins, 1995). The high salt content also affects the physiology of the plant at the cellular level as well as the whole plant (Murphy and Durako, 2003).

Salinity disrupts the osmotic potential and limits the intake of nutrients such as potassium (K^+), calcium (Ca^{2+}) and phosphorus (P), and leads to a high concentration of Sodium (Na^+) and Chlorine (Cl^-) accumulation in leaf tissues, resulting in changes in physiological and biochemical processes in plants (Parida et al., 2005). Salt stress has a toxic effect on plants and leads to metabolic changes such as loss of chloroplast activity, the decrease in photosynthesis rate, and increased photorespiration leading to the formation of reactive oxygen species (ROS) (Parida and Das, 2005). Reduction in photosynthesis in saline conditions is reported to be one of the most critical factors responsible for the decrease in plant growth and productivity (Ball et al., 1987).

The fact that the rapidly growing world population and agricultural production areas reached their ultimate limits reveals the necessity of obtaining more products from the unit area. Therefore, besides the development of high-yielding new varieties, it is necessary to improve the plant breeding techniques and to use the agricultural inputs at the appropriate time and dose (Sencar et al., 1997). Increasing the stress tolerance of plants has been an important research topic in

recent years. The application of plant growth regulators has a vital role in the control of plants against stress factors (Chakrabarti and Mukherjee, 2003).

Salicylic acid (SA) is named after the first willow (*Salix alba* L.). American Indians and ancient Romans found that the bark and leaves of the willow tree could be useful for pain and fire centuries ago (Raskin, 1992). In 1828, Johann Buchner, a researcher in Munich, was able to isolate very small amounts of salicin from the bark of the willow tree and first isolated in the laboratory in 1838 by Raffaele Piria (Lee et al., 1995; Popova et al., 1997). Salicylic acid is a plant hormone that exists naturally in plants and affects various physiological and biochemical functions of plants. It was proven that this hormone was a vital signal molecule and had different effects on plant tolerance to biotic and abiotic stressors (Arfan et al., 2007; Wang et al., 2010).

Commercial production of SA ($C_7H_6O_3$) was commenced in Germany in 1874. German Bayer company produced salicylic acid in 1898, and in a short time, it became the best-selling drug in the world. Salicylic acid, whose therapeutic effects are still being discussed, is now used in the treatment of many diseases ranging from cold to heart disorders, and it is thought that it prevents the formation of acne in human skin. Salicylic acid or acetylsalicylic acid (ASA) when in contact with water is immediately hydrolyzed and converted into SA. Today some scientists have recognized that salicylic acid existed in many plants and was an essential ingredient (Lynn and Chang, 1990; Raskin, 1992; Arteca, 1996).

Salicylic acid has been demonstrated to have an essential physiological role in plant growth and development (Khan et al, 2003). Although there is no precise information about the transport of SA in plants, there is strong evidence that it can be carried in phloem without deteriorating its physical properties. In particular, when the plants were faced with biotic (disease and harmful organisms) and abiotic (hot, cold, light, drought, salinity, etc.) stressors, they tended quickly to produce SA and SA, which plays a vital role in the defense mechanisms of plants. Besides, it has been proved that SA had stimulating effects on flowering in plants under

adverse conditions (Arteca, 1996; Özeker, 2005; Özdüven and Arın, 2010).

Salicylic acid (SA), as shown in Figure 1.1., which is produced in plants under different physiological and biochemical functions, is considered to be a plant growth regulator (Raskin, 1992).

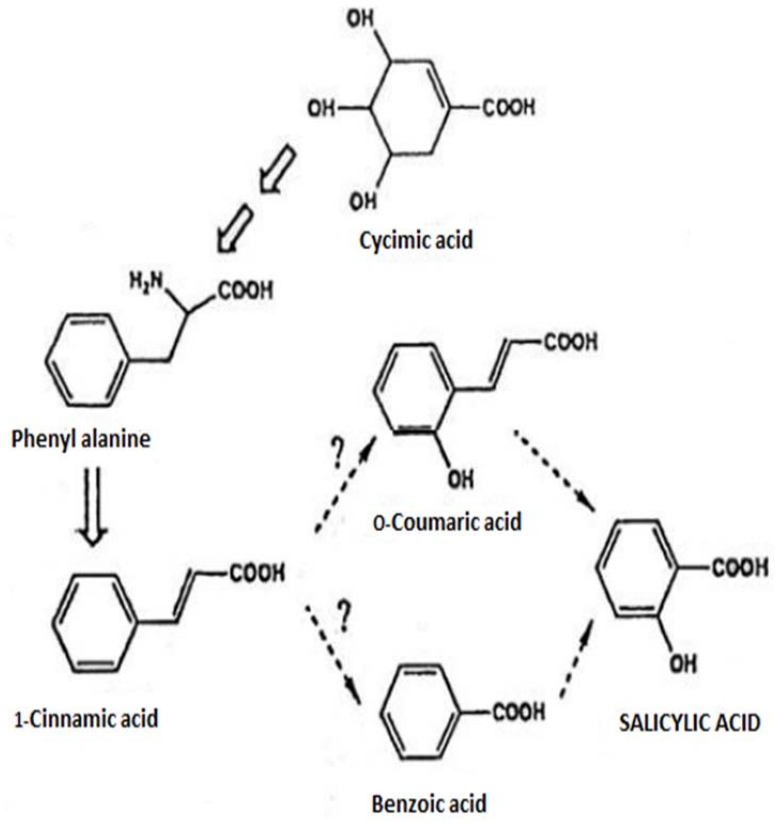

Figure 1.1. Metabolic pathway of salicylic acid biosynthesis in plants (Raskin, 1992) .

Salicylic acid (SA) is a group of plant phenolic with an aromatic chain, generally bearing a hydroxyl group or its functional derivatives. As a result of studies conducted on the biology of SA in plants in recent years, it has emerged that SA played an essential role in the regulation, development, and interaction of

other organisms, such as many other phenolic compounds. As is known, metabolic bifurcation, which leads to the formation of essential amino acids such as tryptophan, tyrosine, and phenylalanine, also plays a critical role in the biosynthesis of phytohormones with different effects on plants. In this metabolic bifurcation, tryptophan biosynthesis leads to the biosynthesis of indole-3-acetic acid, i.e., auxin, for all higher plants. Besides, the metabolic fork is synthesized in the regulatory roles, as well as the phenolic compounds which are species-specific in plants, as well as inhibiting growth and development, on the pathway to the formation of cinnamic acid via phenylalanine. Salicylic acid derived from cinnamic acid, an intermediate product of the shikimic acid pathway, has now taken its place among the herbal hormones. Free SA is rapidly transported to distant tissues from the point where it was first synthesized unless it is actively transported and metabolized. Studies on salicylic acid levels of agriculturally important plant species have revealed that this compound could be distributed at any time and everywhere (Özeker, 2005).

The world's largest crop for human consumption is wheat, followed closely by maize and rice (Payne et al, 1983). The protein content of wheat grains, which usually varies between 9- 15% in dry weight, is small when compared with the leguminous seeds (Altschul et al, 1965). Nevertheless, more wheat protein is consumed by man than protein from any other source (Payne et al, 1983). The most abundant tissue in the grain is the endosperm, which contains the majority of the protein, mostly in the form of prolamins (Shewry and Miflin, 1985).

Wheat grain is a staple food worldwide. Its production is greatly affected by salinity. An enhanced tolerance against salinity stress was observed in wheat seedlings raised from the grains soaked in SA (Hamada and Al-Hakimi, 2001). Exogenous application of SA increases the proline content in wheat seedlings under salinity stress, thereby alleviating the deleterious effects of salinity. Furthermore, the treatment also lowered the level of reactive oxygen species, and

therefore, the activities of superoxide dismutase (SOD) and peroxidase (POX) were also reduced in the roots of young wheat seedlings (Shakirova et al, 2002).

In this study, it was investigated to what extent the degree of tolerance of the bread wheat genotypes grown under different NaCl doses to salt stress was affected by foliar salicylic acid treatments.

2. LITERATURE REVIEW

2.1. Soil Salinity

Salinity is defined as the concentration of dissolved mineral salts present in soils (soil solution) and waters. The dissolved mineral salts constitute a mixed electrolyte of cations and anions. The major cations in saline soil solutions consist of Na^+, Ca^{2+}, Mg^{2+}, and K^+, and the major anions include Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-} and NO_3^-. Other constituents contributing to salinity in hypersaline soils and waters include B, Sr^{2+}, SiO_2, M, Ba^{2+}, and Al^{3+}.

Salinity is one of the environmental factors that significantly restrict agricultural productions implemented to meet the food demands of the ever-increasing human population (Botella et al, 2005). Salinity can be divided into two groups as primary (natural) and secondary salinity, depending on the reasons for formation. The reasons for the establishment of primary salinity is the decomposition of bedrock and salt depot oceans and climatic factors (Munns and Tester, 2008). Moreover, the reasons for the formation of secondary salinity are the increase in the level of groundwater rich in various salts with intensive irrigation in agricultural areas up to the surface of the soil, overgrazing, opening of farmlands by destroying the natural vegetation of a region and the contamination of soils with chemicals causing salinity (Pessarakli and Szabolcs, 1999). Most of the world's salt-affected soils are saline soils generated by Na_2SO_4 and NaCl (Pessarakli and Szabolcs, 1999).

Salinity problems exist in approximately 950 million hectares of the total land in the world, which is equivalent to about 33% of agricultural lands (Lal and Stewart, 1990; Rowel, 1994). Saline soils are generally recognized by salt crystals spread over the land surface or in the soil profile. Based on pH of the saturated soil paste (pHs), total soluble salts or electrical conductivity of the saturated soil paste extract (ECe), and the exchangeable sodium percentage (ESP) or Sodium adsorption ratio (SAR), various attempts have been made to classify salt-affected

soils into different groups. The electrical conductivity (EC) value of saline soils at saturation extract at 25 ºC is 4 dS m^{-1} and pH <8.2. In these soils, the ones with EC> 4 dS m^{-1} and sodium adsorption rate SAR <15 are classified as the only saline, the ones with EC> 4 dS m^{-1} and SAR> 15 are classified as saline-alkaline soils (Mikayilov et al, 1998).

The effects of salinity on plants may vary based on the type and amount or concentration of soluble salts and salt compounds readily taken up by plants. When they exceed certain levels, they may have toxic effects on plants by disrupting nutrition and metabolism. Also, when the concentration of salt in the soil increased, the water absorption of the plant becomes more difficult, plant growth slows down, and even stops (Kanber et al, 1992; Güngör and Erözel, 1994). For healthy plant development, there is a constant level of water in the soil that does not prevent their growth. However, the decrease of water within the root zone decreases the water use of plants. In such cases, salinity is the critical condition preventing plants from quickly receiving water in the soil environment. With the increase in salt concentration in the root environment solution medium, the amount of energy that the plant has to spend to get this water increased, and consequently, as the salinity increases, the water usage decreases. Difficult use and a reduction in water use of plants affect the plant yield and quality (Yurtseven and Bozkurt, 1997; Yurtseven and Baran, 2000; Kara and Apan,2000; Yurtseven et al, 2001).

Although it is necessary to remove soluble salts in the soil to protect the soil from salt damage, if the soil is sodic, the applied processes can lead to the physical degradation of the soil. On the other hand, the Ca^{2+} ion has an effect of preventing this physical degradation induced by sodicity and also protects the plant against the toxic effects of sodium (Lauchli, 1990). The amount of sodium in the earth's crust is 2.8 %, and it is higher than K (K, 2.6 %) when compared to potassium. In arid and semi-arid regions, the Na content of the soil is relatively higher. Sodium is kept very loose on soil complexes and is therefore easily transported with water and washed from the soil. The concentration of Na in soil

solution in the hot zones is 0.1-1.0 mM, similar to or even higher than the K concentration.

Salinity problem arises with the accumulation of excess soluble salts in the plant root zone and decreases depending on the type and amount of the salts. The increase in the salinity level of the salinization root zone has adverse effects on yield and quality of plant and which is a direct factor for the fertility potential of the soil as a result of various outcomes. If the salts delivered to the root site for various reasons are deposited here, plant yield and quality over time will be increasingly influenced. The most critical factor of salinity within the root zone may be the salt concentration of irrigation water or the high salinity of groundwater. Irrigation water, which is delivered to the soil, contains a particular level of salt, and such a salinity starts to decrease with plant use and evaporation. However, the majority of the salts transmitted remains in the soil (Yurtseven, 1999). Soil salinization is mainly influenced by temperature and humidity. Air temperature and air humidity have a controlling effect on both evaporations from the soil surface and transpiration from the plant leaves. Evaporation and transpiration increase with increasing temperatures (Kanber et al, 1992; Yurtseven, 1999).

2.2. Salt in the plant

The occurrence of particular alterations in plant structure depends on the type of salinity. For example, chloride salinity contributes to the succulent forms, while sulfate salinity leads to xeromorphic changes (Strogonov, 1964, 1973). There is a general agreement that whole-plant growth responses to salinity are multigenic and that a better knowledge of the underlying physiology is required to understand why some species and varieties are more salt-resistant or salt-tolerant than the others (Neumann, 1997). Not all cultivated crops show the same response to salinity. While some plants are more sensitive to salinity, some plants are more resistant. Durable plants are the plants that can develop greater force against the

osmotic effect of saline soils to meet water requirements. Investigation of the plant's resistance to salt, especially in areas where the soil salinity cannot be reduced below a certain level, is essential for selecting crops that can yield crops at an economic level (Kotuby et al, 1997).

Stress is a condition that affects or inhibits growth, development, and metabolism in plants (Gürel and Avcioğlu, 2001). When the salt concentration is sufficient to reduce the likelihood of water use (0.5 - 1.0 bar), plant stress is called salt stress (Levitt,1980). The first signs of salt toxicity in plants under salt stress are chlorosis starting from the ends of the old leaves to the top and leaf stem, which then turns into necrosis (Mer et al., 2000). Salt stress prevents the growth and development of plants by causing osmotic and ion stress and osmotic stress occurs firstly with increasing salt content in the root rhizosphere (Parida and Das, 2005). The resulting external osmotic stress causes a decrease in the amount of available water and this phenomenon is also called “physiological drought (Tuteja, 2007). Reduction of the amount of water available causes a decrease in cell expansion and a slowdown of shoot development. In the continuation of the osmotic stress, the stress of the ion, the increasing Na^+ and Cl^- ions in the environment and interactions of K^+, Ca^{+2} and NO^-_3 with the necessary nutrients lead to a nutrient deficiency or imbalance (Hu and Schmidhalter, 2005).

The ability of many cytosolic enzymes to be functional in plant cells depends on a specific Na^+ - K^+ balance (Mahajan et al., 2008). With the increase in the amount of Na^+ in the external environment, the input of Na^+ into the cell increases while the uptake of K^+ to the cell decreases and thus the balance of Na^+ - K^+ is impaired.

Cytosolic K^+ / Na^+ratio, which is usually high, decreases with stress. Na^+ ion competes with K^+ under salty conditions. Expressing specific transport systems for K^+ uptake may help achieve ionic balance by regulating intracellular ion concentrations, which is an important step is taken in salt tolerance of plants. Another essential element for growth, and development is Ca^{+2}. Salt stress

decreases Ca^{+2} uptake like K^+, Na^+ replaces Ca^{+2} in the cell membrane to increase the Na^+ / Ca^{+2} ion ratio in the apoplast portion of the membrane. In this case, the physiological and functional structure of the membrane is disrupted and the Ca^{+2} balance of the cell is affected. Under high Na^+ concentrations, internal membrane structures of the cell are connected to the free state of Ca^{+2}, and thus increase free Ca^{+2} in the cell (Yokoi et al., 2002). Also, NaCl accumulation is thought to cause depolymerization of microtubules and prevent the formation of spindle yarns in cell division (Rengel, 1992).

It has been informed that NaCl toxicity is prevented in plants by facilitating K^+ / Na^+ selectivity in case Ca^{+2} is given to growth medium (Liu and Zhu, 1998; Abdel-Latef, 2011). These studies stated that calcium is an essential plant nutrient for membrane stabilization in metabolic activity, signaling in secondary messages, and controlling enzyme activity. Knowing that Ca is a crucial element for K^+/ Na^+ and Ca^{+2} / Na^+ selectivity, which helps prevent the harmful effects of salinity by regulating ion transport in plants (Renault, 2005). Cerda et al (1995), indicated that the detrimental effect of salt on plant growth is caused by ionic imbalance, in particular, Ca^{+2} and K^+ inequality. Cl^- ion has been reported to be more toxic than Na^+ in some forest tree species (Shannon et al., 1994). Moreover, it has been stated that if the Na^+/ Ca^{+2} and Na^+/ K^+ ratios are high in the saline solution, membrane permeability increases and Na^+ and Cl^- accumulate in the roots and stem + leaves (Lutts et al., 1996). The harmful effects of salt upon plant growth are due to ion cytotoxicity (mainly due to Na^+, Cl^-, and SO_4^{2-} ions) and osmotic stress. Ion toxicity under saline conditions, osmotic stress and metabolic disorders caused by insufficient nutrients may cause oxidative stress (Zhu, 2002).

Accumulation of intracellular Na^+ is toxic for metabolism and the accumulation of excess Na^+ in the soil plays a vital role in the growth inhibition of many susceptible plants (Mengel and Kirkby, 2001). Na^+ inhibits many enzymes when it accumulates in the cytoplasm. These effects are due to a combination of oxidative stress and nutritional imbalance associated with the production of toxic

ROSs, inhibitory effects of salts and ions on cell metabolism and reverse osmotic gradients (Sharma et al., 1997). Salt stress causes an increased respiration rate, ion toxicity, changes in plant growth, mineral disturbances, membrane instability resulting from the replacement of calcium ions with sodium ions, membrane permeability (Marschner, 1986; Gupta et al., 2002), decreased photosynthetic activity (Hasegawa et al., 2000; Munns, 2002). On the other hand, salinity negatively affects nitrogen and carbon metabolism (Mansour, 2000; Balibrea et al., 2000). In besides, salt stress causes a decrease in the photosynthetic activity of the plants and affects the chlorophyll content of plant leaves negatively (Sayed, 2003). In studies conducted on the effects of Ca^{++}, K^{+} and Mg^{++} in salt stress maize plant (*Zea mays*), it was determined that Ca^{++}, $Mg^{++}$and K^{+} compounds given to the maize in addition to salt had a healing effect on membrane permeability and relative water content. It has been observed that the rate of proline increased with the salt application (Yakıt, 2006). The total chlorophyll and carotenoid content of the leaf tissue of the plants are generally reduced under salt stress (Agastian et al., 2000). The decrease in chlorophyll content is due to the harmful effects of salt on membrane stability (Ashraf and Bhatti, 2000).

2.3. Effects of salicylic acid on plants under salinity and various stresses

Effects of salicylic acid on plant growth and yield

Türkyılmaz et al (2005), examined the effects of different concentrations (50, 100, 200 ppm) of SA on plant growth and some physiological and biochemical properties of *Pharsalus vulgaris* seedlings grown under greenhouse and field conditions. In terms of photosynthetic pigments (chlorophyll a, b and carotenoids), the most effective dose was 100 ppm SA in plants grown in the greenhouse and an increase of approximately 30% was observed in all three pigments. It was determined that the amount of chlorophyll a, b and carotenoid increased by 10% in the plants grown in the field with 50 ppm SA application. While the use of 50 and 100 ppm SA increased the total nitrogen content of both groups of plants grown in

the greenhouse and field, the application of 200 ppm SA caused a decrease in both groups of plants as compared to the control.

Kaydan and Yağmur (2006), in their study on green lentils and wheat, used different salicylic acid doses (0, 1.281, 128.1mg / da and 12.810 g / da) and application methods (seed and foliar spray), and examined the effects of experimental treatments on yield and yield components. According to the results obtained, it was found that salicylic acid doses increased all properties except for the number of fertile spikes and thousand-grain weight per square meter. The highest grain yield (276.58 kg/ha) was obtained from 128.1 mg/ha salicylic acid dose, and the increase in grain yield per unit area was found to be 24.8% as compared to the control dose. In lentil experiments, salicylic acid doses and application forms did not have significant effects on the number of plants per square meter, plant height, and thousand-grain weight. It was determined that the total number of branches, the number of seeds per plant, seed yield, and seed yield per unit area increased with the increase of salicylic acid doses; salicylic acid sprays significantly influenced the total number of branches and number of seeds per plant. The highest unit area grain yield (141.60 kg/ha) was obtained from 128.1 mg/ha salicylic acid dose of foliar sprays.

A study was conducted by **Yıldırım and Dursun (2009**), to investigate the effects of salicylic acid treatments on fruit quality, plant growth and yield of tomatoes grown under greenhouse conditions. Different concentrations (0, 0.25, 0.50, 1.00 mM) of SA were applied to tomato plants by spraying 4 times in ten-day intervals during vegetation and the parameters of early yield and total yield, fruit diameter, fruit length, fruit weight, number of fruits per plant, vitamin C content, pH, total soluble dry matter content, titratable acidity, leaf dry matter ratio, stem diameter and chlorophyll content were analyzed. The first application of SA was made ten days after sowing. The results showed that SA applications positively affected some fruit properties, plant growth, chlorophyll content, early yield and total yield. However, the SA applications did not affect titratable acidity and pH

but increased total soluble dry matter content. The greatest stem diameter, leaf dry matter content, and chlorophyll content were observed in 0.5 mM SA treatments. Moreover, the SA applications increased early yield as compared to the control and had a significant effect on total yield. The highest total yield was obtained from 0.5 mM SA.

Effects of salicylic acid on plants under salinity

Salicylic acid (SA) is an internal plant growth regulator that generates many metabolic and physiological responses in plants and thus affects plant growth and development (Hayat et al., 2010). Moreover, SA plays a significant role in plant defense responses to local pathogen attack (hypersensitive response) and systemic acquired resistance (Alverez, 2000). As well as mentioned by Cameron (2000) SA is a plant signaling molecule that plays an important role in growth, development and defense responses under stress conditions. In addition to providing disease resistance in plants, SA can regulate plant responses to many stress conditions (Shirasu et al., 1997).

Salicylic acid (SA) is a real plant hormone that goes beyond the defense reaction in plant immunity and response to abiotic stress.

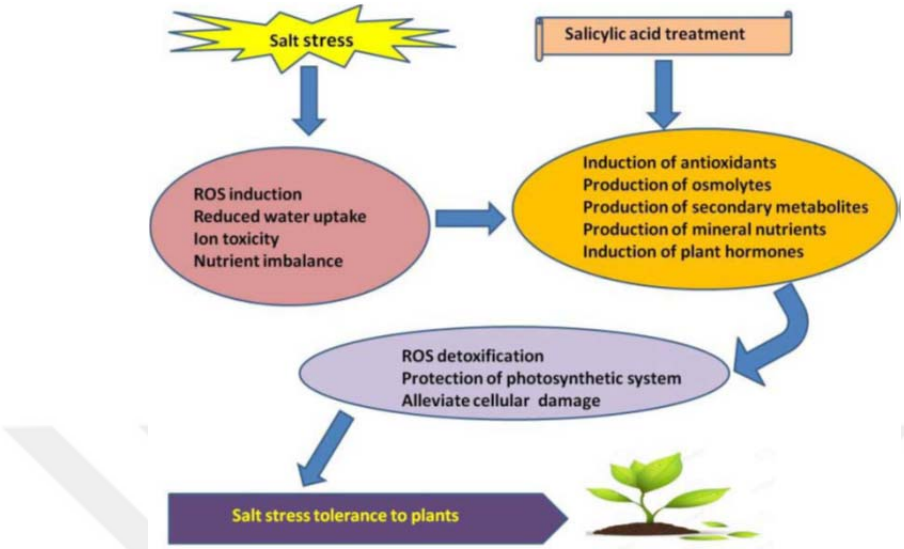

Figure. 2.1. Mechanism of salt stress tolerance induced by salicylic acid in plants (Rajeshwari and Bhuvaneshwari, 2017).

In many plant species, salicylic acid plays an essential role in the defense response to pathogen attack. Salicylic acid mediates the oxidative burst that leads to cell death in the hypersensitive response and acts as a signal for the development of systemic acquired resistance (Shirasu et al., 1997).

Shakirova et al (2002), investigated the **e**ffects of 0.05 mM SA on wheat seedlings and reported increased cell division rates, improved plant growth and development, thus increased yields with increasing SA doses. Researchers also indicated that SA treatments caused an increase in ABA and IAA amounts in wheat seedlings exposed to salt stress (2% NaCl) and prevented a decrease in cytokine content and all of these protected wheat seedlings against salt stress. Another cause of increased tolerance to salt stress was shown to be an increase in the amount of proline caused by increased ABA synthesis.

The salicylic acid was applied to salt-stressed tomatoes by **Tari et al (2002)** and concluded that plants treated with low concentrations (0.01 mM) of SA had tolerated about seven days of salt stress (100 mM NaCl). In addition,

decreasing total sugar contents was reported since SA treatment increased leaf Na^+ contents.

The effects of 1.0 mM SA applications were examined by **El-Tayeb (2005),** on seeded barley seedlings exposed to salt stress (150 mM NaCl) in the seedling period and concluded that SA-treated plants had higher seed weight, chlorophyll, sugar and proline contents. Moreover, lower relative electrical conductivity values were reported for SA-treated plants. Also, as a result of measurements carried out in plants treated with SA. peroxidase enzyme activity, known as an indicator of the adverse effects of salt stress, was found to be lower in SA-treated plants than the control plants.

Erkılıç (2005), examined the effects of various concentrations of salicylic acid on free proline accumulation and some physiological parameters of two pepper cultivars. With the application of 0.1, 0.5 and 1.0 mM SA together with salt to the seedling of salt-resistant Demre-8 varieties, decreasing root and shoot lengths and higher leaf areas were observed. SA-treated seedlings had greater leaf tissue fresh, dry weight and LRWC (Leaf Relative Water Content) and free proline quantities. On the other hand, SA treatments (0.1, 0.5 and 1.0 mM SA) applied to salt-sensitive Kahramanmaraş-bitter variety improved root length, leaf area index and fresh leaf tissue.

Güneş et al (2007), applied different doses of SA (0.01, 0.5 and1.0 mM) to maize-grown soils under NaCl stress for 8 weeks and indicated that SA treatments improved plant growth and development under saline and non-saline conditions.

Tohma (2007), applied different doses of salicylic acid (SA) (0.0,0.1, 0.25, 0.5, 1.0 mM) to Camarosa strawberry varieties pre-treated with varying concentrations of salt (0, 2, 4, 6 mS cm^{-1}) and investigated the effects of SA treatments on physiological changes (membrane permeability, protein, chlorophyll and proline contents), plant nutrient content (N, P, K, Ca, Mg, Na, Cl, Fe, Cu, Mn and Zn) and plant growth. In the experiment, it was found that SA administration in saline conditions decreased membrane permeability and increased protein, proline,

chlorophyll b and total chlorophyll contents. SA applications in saline conditions had a positive effect on plant growth and SA delayed the emergence of toxic effects of salt.

Kaydan et al (2007), investigated the effects of salicylic acid treatments (0.2 mM, 0.4 mM, 0.6 mM) on some physiological characteristics of wheat grown under saline (salinity 8 dS m^{-1}) and salt-free conditions. Researchers reported that salicylic acid application rates of the seedlings under salt stress conditions increased the osmotic potential, vegetative and root weights, K^+/Na^+ ratio, photosynthetic pigment (chlorophyll a, b and carotenoids) contents. It was concluded that salicylic acid affects plant growth positively in salty conditions.

Qing-Mao et al (2007), in their research on cucumber, investigated the effects of foliar and root SA treatments (50 mg/l SA) on the physico-chemical characteristics of the plants under salt stress. It was reported that foliar and root SA treatments increased the amount of sugar by 11.04% and proline content by 82.2% reduced electrolyte leakage. In addition, salicylic acid treatments yielded significant improvements in plant parameters such as plant height, stem diameter and total mass.

Koçer (2007), conducted a study to investigate the effects of different concentrations of abscisic acid (ABA) and salicylic acid (SA) treatments on maize (*Zea mays* L.) plants grown under salt stress. A high-performance liquid chromatography (HPLC) device was used to determine sugar, fatty acid, and hormone levels and a spectrophotometer was used to determine chlorophyll a and b, carotenoid and proline levels. It was observed that high salt concentrations had adverse effects on morphological development. Abscisic acid treatments improved the morphological development of the plants better than salicylic acid treatments. Total carotenoid levels were found to be high in almost all ABA treatments, and endogenous hormone, sugar, and fatty acid levels were significantly altered with both salt treatments and exogenous hormone treatments. Proline levels increased

with salt treatments, and rising proline levels were also observed with increasing hormone doses.

Hamid et al (2008), measured the effects of SA treatments on salinity stress and immersed the seeds of two wheat varieties in 100 mg/L SA solution before planting and grew these seeds under different salinity levels. It was observed that SA treatments reduced the harmful effects of salinity on seedlings.

Yıldırım et al (2008), investigated the effects of foliar salicylic acid treatments on plant mineral content, chlorophyll content, and plant growth of cucumber grown under salt stress. The study was carried out in pots under greenhouse conditions. Different doses of salicylic acid (0, 0.25, 0.50, and 1 mM SA) were applied to plants grown under two different salinity (0.6 and 1.2 mM NaCl) levels. Salinity treatments adversely affected plant growth, chlorophyll levels and nutrient flow in plants. Salicylic acid treatments, on the other hand, had positive effects on plant fresh and dry weight, root fresh and dry weight. However, lower stem diameters, number of leaves per plant and leaf relative water content values were observed under salt stress.

Dolatabadıan et al (2009), investigated the effects of salicylic acid treatments on wheat (*Triticum aestivum* L. cv. Roshan) seed germination, lipid peroxidation, superoxide dismutase, catalase, polyphenol oxidase and peroxidase activity under salt stress conditions. Salicylic acid treatments were found to have a scavenging effect on reactive oxygen species and thus reduced membrane damages. Salicylic acid treatments efficiently reduced the damaging action of salinity on embryo growth and accelerated restoration of growth processes. It was concluded that SA was quite efficient in the improvement of seed germination in arid and semi-arid regions.

Erdal et al (2011), investigated the effects of foliar SA treatments on salt sensitivity, hydrogen peroxide (H_2O_2) generation and activities of antioxidant enzymes like peroxidase (POX) and catalase (CAT) in plant tissues under salt stress. It was observed that SA treatments significantly increased the fresh and dry

weights in both root and shoots of wheat plants under salt stress. Similarly, POX and CAT activities were also augmented by SA treatments. In parallel to increasing antioxidative activity. SA treatments decreased H_2O_2 content as compared to plants grown under salt stress without SA. The results revealed that the SA treatments alleviated the salt-induced deleterious effects on wheat seedlings.

Tufail et al (2013), investigated the effects of different doses of salicylic acid treatments (0.25 and 0.50 mM) on growth and development of two different corn varieties (Sahiwal 2002 and EV-20) grown under saline condition. According to the results of the study, the application of 0.50 mM salicylic acid was more effective in salinity tolerance. Besides, two doses of salicylic acid increased photosynthesis rate, stomal conductance, transpiration rates and chlorophyll-b content of both cultivars.

Tufail et al (2013), investigated the effects of salicylic acid treatments on various morphological, physiological and biochemical attributes of two maize genotypes (Sahiwal-2002 and EV-20) under saline and non-saline conditions. All pots were irrigated with Hoagland nutrient solution for 20-days. Afterward, 21-day old plants were salinized with 0 and 120 mM NaCl along with three salicylic acid concentrations (0, 0.25 and 0.50 mM) were given through rooting medium. Results revealed that the application of 0.50 mM salicylic acid was most useful to reduce Na^+ and increased K^+ and Ca^{2+} concentrations, the biomass of plant as well as yield under salt stress. The photosynthetic rate, transpiration rate, stomatal conductance, sub-stomatal CO_2 concentration, chlorophyll b contents and carotenoids were enhanced with the exogenous application of different levels of SA in both genotypes of maize under salt stress.

Howladar and Dennett (2014), investigated the effects of different doses of SA (0, 0.1 and 0.5 mM) provided through foliar sprays on various attributes of wheat plants grown under saline (NaCl) conditions. Salinity stress reduced gas exchange parameters, growth parameters, yield and yield components, but foliar

SA sprays, especially 0.5 mM improved the majority of the parameters investigated.

Karami Chame et al (2016), conducted a study to investigate the effects of three different salinity levels (0, 2, and 4 ds/m) and two levels of bacterium Pseudomonas putida (inoculated and non-inoculated) and salicylic acid (0 and 1 mM) on the growth of beans under greenhouses conditions. The interaction of salinity and salicylic acid had a significant effect on leaf relative water content. Also, salinity x Pseudomonas x salicylic acid interaction had a substantial impact on the chlorophyll index, 100-seed weight and seed protein content. Generally, salicylic acid and Pseudomonas reduced the detrimental effects of salinity on plants.

Rajabi Dehnavi et al (2019), investigated the effects of salinity and foliar application of salicylic acid (SA) on sorghum biomass and nutrient contents. Treatments were comprised of salinity levels (0 and 100mM NaCl) and SA concentrations (0.3, 0.7, 1.1, and 1.5mM). Research findings revealed that for growth of sorghum plants, 0.7 mM SA was the most effective concentration under normal conditions and 1.1 mM was the most effective dose under saline conditions.

Abbas et al (2016), investigated the effects of different salicylic acid concentrations on growth parameters, chlorophyll and soluble protein content, antioxidant enzyme activities of cultured mature embryos of different wheat varieties. Three levels of NaCl (0, 75, 100 and 150mM) and salicylic acid (0 mM, 0.25, 0.50 and 0.75 mM) were used in regeneration media in different combinations. The cultures were maintained at 26 ± 2°C at 16 hours' photoperiod, 40 μmoles m^{-2} s^{-1} light intensity from cool white fluorescent tube light. The results of this study showed that all NaCl stress levels significantly reduced plant growth by reducing chlorophyll content and K^+ concentrations. The supply of salicylic acid increased the growth of the plant under salt and salt-free conditions.

Effects of salicylic acid on plant under various stresses

The effects of 0, 0.1, 0.25, 0.5, and 1.00 mM aspirin were examined by **Uzunlu (2006),** on seeds and leaves of melon seedlings that were exposed to different stress factors (drought, chill-cold, and salt). Aspirin-treated plants generally had lower visual damage with higher chlorophyll content and stomal conductance, dry biomass and carbohydrate content than the control plants. On the other hand, electrical conductivity values were determined at the treatments with different aspirin concentrations and the concentrations of 0.25 - 0.5 mM yielded the best outcomes and the highest aspirin concentration (1.00 mM SA) was found to be less effective in lowering the tolerance to stress factors than the lower concentrations. It was concluded that aspirin application increased tolerance to stress factors applied to melon seedlings and there was no significant difference between the aspirin application methods.

Sevimay (2009), investigated the effects of different salicylic acid doses (0, 0.1, 0.5 mM SA) and treatment methods (leaf, soil, seed) on physico-chemical parameters of lettuce seedlings exposed to drought stress. Lettuce seeds were kept in water containing 0, 0.1 and 0.5 mM SA for one day and planted into viols with other untreated (control group) seeds. When the lettuce seedlings had 3-4 leaves, they were treated with the same doses of salicylic acid by irrigation and foliar spraying. Control groups were supplied only with regular tap water. Damage index, chlorophyll (a, b and carotenoid) content, electrical conductivity, seedling wet and dry weights were determined two days after the end of the stress in the lettuce seedlings exposed to drought stress (through not irrigating for seven days). Significant differences were observed in chlorophyll contents of both the different salicylic acid doses and application methods as compared to the control plants.

Sharafizad et al (2012), applied three different salicylic acid doses (0.7, 1.2 and 2.7 mmol) during sowing and flowering periods of wheat and examined the yield and yield components of wheat under drought stress. The highest yield was obtained from 0.7 mmol salicylic acid treatment applied in the vegetative period.

The most significant biological yield was also obtained from 0.7 mmol salicylic acid treatment.

Hamada and Al-Hakimi (2001), applied 100 ppm SA on wheat seeds to investigate the effects of these applications on drought and salt stress in the seedling period. Wheat seedlings were irrigated with water containing 160 mM NaCl (salt stress) for 2 weeks at 30% of field capacity for 2 weeks (water stress). As a result of the experiment, researchers concluded that SA-treated seedlings survived and reported increased photosynthesis rate, decreased Na^{+} absorption and greater K^{+}, Ca^{+2} and Mg^{+2} uptakes for SA-treated plants as compared to the control plants.

Singh and Usha (2003), applied 1, 2, 3 mM SA solutions to wheat seedlings grown under water stress. The first dose was used ten days after the seed planting phase and the second one was used thirteen days later through foliar sprays. It was determined that many enzymes affected the synthesis of ribulose diphosphate and superoxide dismutase enzymes, which play an active role in the protection of photosynthesis and stress in plants. According to the results obtained, it was concluded that SA had an essential role in providing drought resistance in plants.

Hayat et al (2008), sprayed tomato seedlings with distilled water and 10 mM SA 45 days after sowing. Plants were also exposed to water stress and analyses were conducted on 10, 20 and 30^{th} day of water stress. SA treatments yielded better outcomes on the 20^{th} day than on the 30^{th} day. They found that water stress in plants significantly reduced leaf water potential, chlorophyll and leaf relative water content. However, SA applications increased the number of antioxidant enzymes and protein content in dry conditions.

Güneş et al (2005), applied different doses of SA to soil and corn seeds and investigated the plant response to salt and boron stress. Previous studies reported that SA applications of 0.1 and 0.5 mM to soil and 1 mM to seed

increased nutrient uptake of plants living under stress conditions, while reducing toxic ion uptake and thereby increasing tolerance to stress.

Eraslan et al (2007), applied 0.5 mmol SA to salt and boron stress-exerted carrots and reported positive impacts of SA treatment on root dry weight, carotene and anthocyanin contents.

Pal et al (2002), investigated the effects of salicylic acid on cadmium (Cd)-induced stress in maize. It was found that when SA and Cd were administered simultaneously, the reduction was significantly high as compared to those without SA. The application of SA caused as by oxidative stress in plants and generated damages in the root system while preventing the synthesis of phytochelatin hormone. It was concluded that damage was accelerated when SA was administered before Cd stress.

Çanakçı and Dursun (2012), looked into the physiological and biochemical effects of SA on tomato seedlings before cadmium stress. They applied 1.5 mM SA for 16 and 24 hours in tomato seedlings for 25 days and then applied 0, 10, 25, and 50 mM cadmium solution for 5 days. It has been concluded that SA pretreatment mitigated the harmful effects of different Cd concentrations.

It was reported in a study on the tolerance of winter wheat to cold stress (**Taşgın et al., 2003),** that there were high levels of internal SA in wheat leaves. Researchers also studied the adaptation of wheat plants to cold stress (15 days at 15-10 °C, 15 days at 10-5 ° C, 15 days at 5-3 °C) and then the freezing stress. It was found that plants could tolerate cold stress until - 10 °C and SA was helpful in in plants air conditioning under stress conditions. It was also indicated that 0.1 mM of SA increased leaf tolerance to the frost since SA stimulated the synthesis of apoplastic antioxidant enzymes and antifreeze proteins.

Erwin et al (2005), applied the SA (0.5 kg ha^{-1}) through foliar sprays to grass (Kentucky blue grass. *Poa pratensis*) exposed to heat stress (40 °C. 96 hours) and reported increased photosynthesis rates and yields and observed visual damage of heat stress.

Shi et al (2006), applied 1 mM of SA and aspirin to cucumber leaves for 30 and 40 hours and stated that the relative electrical conductivity values, superoxide dismutase enzyme activity, and H_2O_2 concentrations decreased in the tissues of cucumber seedlings exposed to heat stress through an increase in the number of photons captured in photosynthesis system.

Mahvadian et al (2007), examined the effects of 0, 0.1,0.7,1.5, 3, 6 and 9 mM foliar SA sprays on antioxidant enzymes of pepper seedlings. Application of 0.7, 1.5, and 3 mM salicylic acid doses decreased catalase. Ascorbate peroxidase and glutathione reductase activities and 1.5, 3, 6, and 9 mM SA doses increased polyphenol oxidase and peroxidase activities. It was concluded that the application of different concentrations of salicylic acid to the leaf had different effects on enzyme activity.

3. MATERIALS AND METHODS

3.1. Materials

In present experiments, 4 different bread wheat (*Triticum aestivum*, cvs. Altınöz, Candaş, Gökkan, Yakamoz) genotypes were used as the plant material. Wheat genotypes were supplied from by Dr. Hakan ÖZKAN, who is a Faculty Member of the Çukurova University Field Crops Department.

3.2. Method

3.2.1. Plant materials and growing conditions

The experiments were conducted at the Research and Implementation Greenhouses of Soil Science and Plant Nutrition Department. The experiment was carried out in plastic pots filled with 1900 g soil. Soil analyses revealed that experimental soils had 200 mg kg^{-1} N ($CaNO_3.4H_2O$),100 mg kg^{-1} P and 125 mg kg^{-1} K (KH_2PO_4), 2.5 mg kg^{-1} Zn ($ZnSO_4.7H_2O$) and 2.5 mg kg^{-1} Fe (Fe-EDTA). During the advanced stages of plant growth, 50 ppm N was added. In each pot, 14 seeds of all genotypes were planted, and this number was reduced to 7 after germination.

Table 3.1. Some physical and chemical properties of soils used in greenhouse experiments.

pH	**EC**	**$CaCO_3$**	**O.M.**	**Sand**	**Silt**	**Clay**
	(dS m^{-1})	(%)				
7.6	0.241	29.08	1.29	20.03	62.46	17.5
N	**P**	**K**	**Cu**	**Fe**	**Mn**	**Zn**
%	mg kg^{-1}					
0.12	11.01	357.37	1.59	2.93	8.80	0.54

3.2.2. NaCl treatments

The soil was salinized by NaCl and four salt levels (control, 2.5, 5 and 10 dS m^{-1}) were used. Present NaCl level (0.241 dS m^{-1}) was completed to the concentration of 2.5, 5.0 and 10 dS m^{-1} in pots. About 1/3 of each salt dose was initially mixed into the soil and the remaining doses were completed for four weeks with irrigation water. Irrigations were performed with distilled water.

3.2.3. Salicylic Acid Treatments

Salicylic acid has a molecular weight of 138.123 g/mol beta-hydroxy acid (BHA). After dissolving the salicylic acid in concentrated ethyl alcohol, the concentration of ethyl alcohol / pure water was diluted to 1/1000 (v / v) to provide the intended concentration (Williams et al., 2003) and the pH was adjusted at 5.5-6.0 with NaOH (0.1 M). For foliar SA application, each plant was sprayed three times (30, 35 and 45 DAS) with SA solution using a manual sprayer.

The salicylic acid concentration in leaf: 0.01% surfactant (Tween 20) was used in a salicylic acid solution which was applied in 4 doses (0, 0.25, 0.5 and 1 mM) (Babar et al., 2014). Only distilled water was used to control plants. SA-treated plants were harvested 3 weeks after the completion of SA doses.

3.2.4. Shoot and Root Dry Weight

At the end of the experiments, the shoots of the plants were harvested after SPAD readings and collected samples were dried in an oven at 70 °C for 72 hours until constant weight to get their dry weights.

After harvesting the shoot, the soil in the pots was removed with the help of tap water, and the roots were washed delicately. With the help of a paper towel, the water on the roots was removed, and it was made ready for drying in an oven.

Following the complete drying of the leaves and roots, they were weighed in a precision balance (±0.001 g) (Güneş et al., 2007).

3.2.5. Determination of chlorophyll

To assess chlorophyll concentrations, SPAD readings (SPAD 502, Konica Minolta, Japan) were taken on the third youngest fully developed leaves.

3.2.6. Membrane Permeability

Membrane permeability was determined following Yan et al (1996). According to this method, 1 cm diameter disc-shaped leaves (2 cm in wheat) were incubated at room temperature in deionized water for 24 hours and then the electrical conductivity (EC) of the medium was measured. After this measurement, the same medium was heated to 100 °C with leaf samples and the EC was re-measured after heating and the rate of membrane permeability was expressed as a percentage (%) with the first EC value and the second EC value.

3.2.7. Determination of Leaf Relative Water Content (LRWC)

Relative water content (RWC) is defined as the ratio of the amount of water in the leaf tissue at the sampling to that present when fully turgid, and determined by the method of Smart and Bingham (1974). Leaf segments of about 5-6 cm were sampled and immediately weighed for fresh weight (FW) determination. After FW determination, leaf segments were placed through two layers of filter paper and immersed in deionized water. After 5 h, leaf segments were gently dried with tissue paper for turgid weight (TW) measurements. Finally, dry weight (DW) of the segments was measured after incubation of the segments for 48 h at 70^{o}C. For determining the RWC of leaves, calculations were made using the formula:

$$RWC\% = ((FW-DW) / (TW-DW)) X 100$$

3.2.8. Determination of Ion Concentrations

Dried shoot samples were ground and ashed in the microwave oven using 2 ml of 35% H_2O_2 and 5 ml of 65% HNO_3. Following the digestions, Na, P, K, Mg, Ca, Fe, Zn, Mn, and Cu were analyzed by an inductively coupled plasma optical emission spectrometer (ICP-OES; Varian-Vista Pro). Nitrogen (N) was determined with the Kjeldahl method (Bremner, 1965). Nutrient contents were calculated multiplying shoot dry weights and nutrient concentrations. To check related elemental measurements, reference leaf samples from the National Institute of Standards and Technology (Gaithersburg, MD, USA) were used.

3.3.Statistical Analysis

The experiment was conducted in a completely randomized plot design with 3 replicates. Analysis of variance was performed using JMP v.10.0. Mean values were compared by Tukey HSD (Tukey Honest Significant Difference) test at 5% probability level.

4. RESULTS AND DISCUSSIONS

4.1. Results

Effects of SA and NaCl on bread wheat genotypes, their interactions on investigated parameters are given in Table 4.1.

Table 4.1. Analysis of variance for the traits investigated in bread wheat genotypes in response to SA and NaCl

Source	df	SDW	RDW	SPAD	RWC	MP	Na	N	P	K	Ca	K/Na	Ca/Na	Mg	Zn	Fe	Cu	Mn
							Conc.,Cont.,Conc.,Cont.	Conc.,Cont.,Conc.,Cont.	Conc.,Cont.,Conc.,Cont.	Conc.,Cont.,Conc.,Cont.	Conc.,Cont.,Conc.,Cont.	Conc.,Cont.		Conc.,Cont.,Conc.,Cont.	Conc.,Cont.,Conc.,Cont.	Conc.,Cont.,Conc.,Cont.	Conc.,Cont.,Conc.,Cont.	Conc.,Cont.,Conc.,Cont.
NaCl (A)	3	***	***	***	***	***	*** *** *** ***	*** *** *** ***	*** *** *** ***	*** *** *** ***	*** *** *** ***	***	***	*** *** *** ***	*** *** *** ***	*** *** *** ***	*** *** *** ***	*** *** *** ***
SA (B)	3	***	***	***	ns	***	*** **	ns	*** *** *** ***	ns	***	ns	***	ns	ns	**	ns	ns
A x B	9	***	***	*	***	ns	**	ns ns ns ns	*** **	***	ns ns	**	ns	ns ns	*	ns ns	ns	*
Genotypes (C)	3	***	***	***	***	***	*** *** *** ***	** *** *** ***	*** *** *** ***	*** *** *** ***	ns	ns	ns	*** *** *** ***	*** *** *** ***	*** *** *** ***	** *** *** ***	***
A x C	9	***	***	***	***	***	*** *** *** *	ns	*** *** ***	*** *** ***	*** ** ***	ns	ns	**	***	ns ns ns	ns	*
B x C	9	**	ns	**	***	*	***	ns ns ns ns	ns ns ns	*** *** ***	ns ns ns	ns	ns	ns ns ns	ns ns ns	ns ns ns	ns ns ns	ns ns
A x B x C	27	**	*	ns	***	ns	**	ns ns ns ns	ns ns ns	ns ns ns	ns ns ns	ns	ns	ns ns ns	ns ns ns	ns ns ns	ns ns ns	ns ns

*: p<0.05; **: p<0.01; ***: p<0.001; ns: non-significant

SDW: Shoot Dry Weight; RDW: Root Dry Weight; RWC: Relative Water Content; MP: Membrane Permeability; Conc: Concentration; Cont: Content

4.1.1. Shoot and Root Dry Matter Production

In this thesis, the effects of foliar salicylic acid treatments on Altınöz, Candaş, Gökkan, and Yakamoz bread wheat genotypes grown under saline conditions were investigated under greenhouse conditions. Increasing salt treatments reduced shoot (Table 4.2; Figures 4.1- 4.4) and root (Table 4.3) dry matter productions of the genotypes.

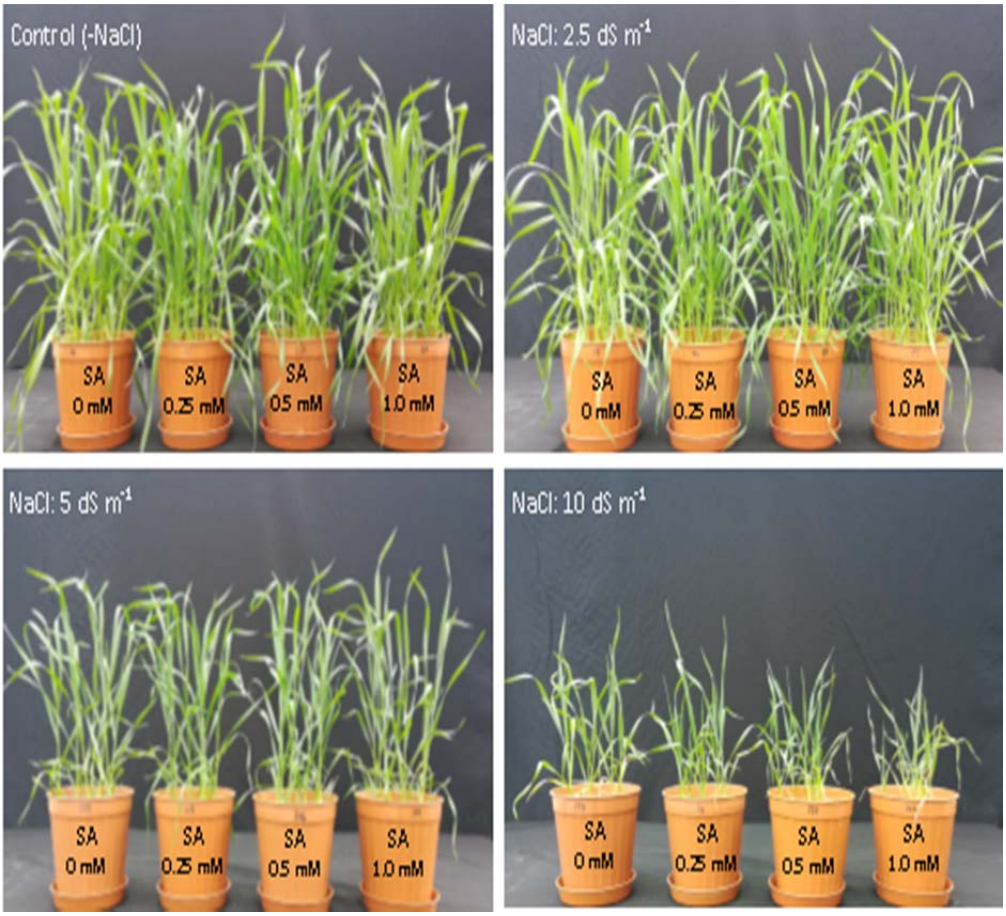

Figure 4.1. Effect of salicylic acid (0, 0.25, 0.5, 1.0 mM) on the growth of Altınöz genotype under different salt levels (control, 2.5, 5.0, and 10 dS m^{-1}).

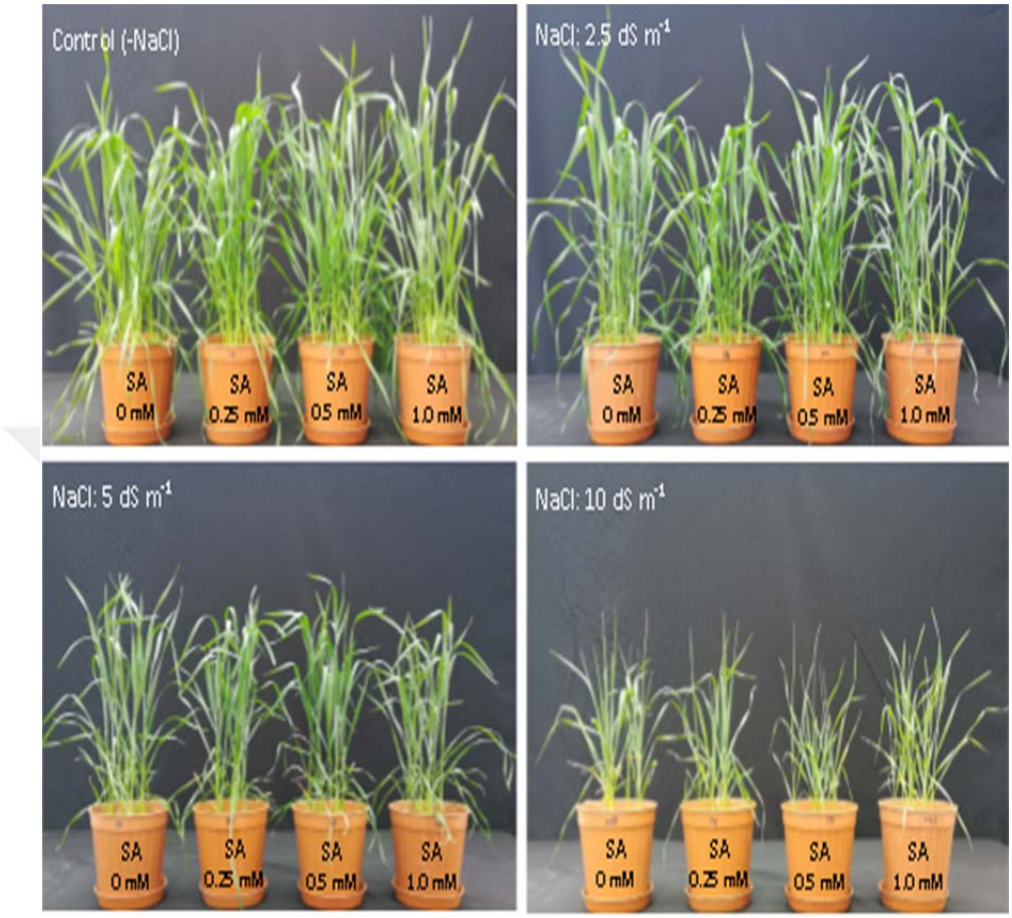

Figure 4.2. Effect of salicylic acid (0, 0.25, 0.5, 1.0 mM) on the growth of Candaş genotype under different salt levels (control, 2.5, 5.0, and 10 dS m^{-1}).

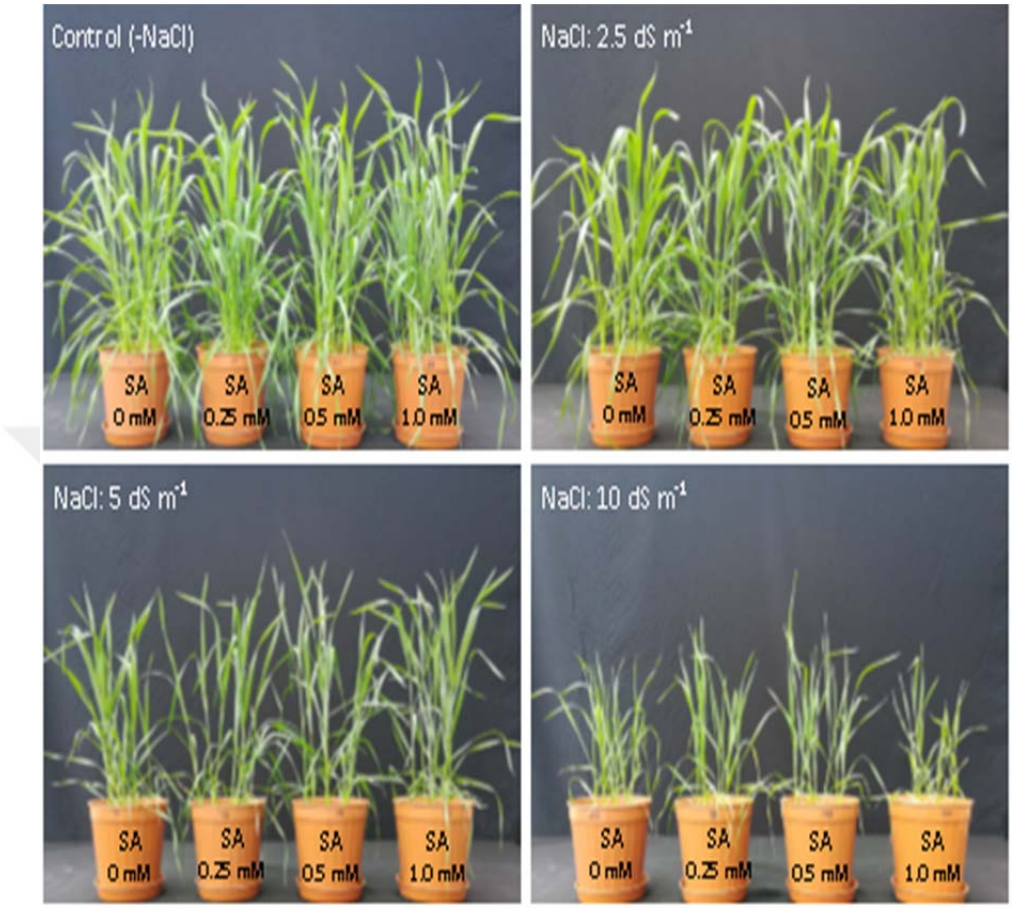

Figure 4.3. Effect of salicylic acid (0, 0.25, 0.5, 1.0 mM) on the growth of Gökkan genotype under different salt levels (control, 2.5, 5.0, and 10 dS m^{-1}).

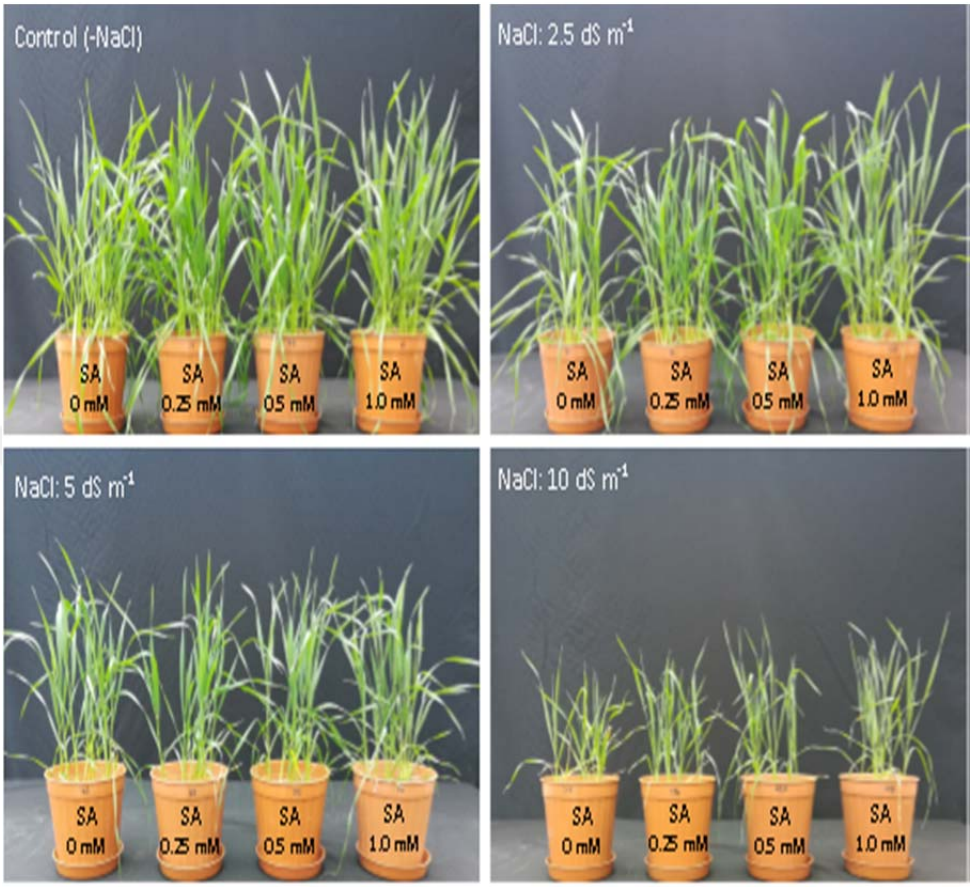

Figure 4.4. Effect of salicylic acid (0, 0.25, 0.5, 1.0 mM) on the growth of Yakamoz genotype under different salt levels (control, 2.5, 5.0, and 10 dS m^{-1}).

The average shoot dry matter yield of 1319 mg in control treatments decreased respectively by 21, 60, and 82% to 1048, 522, and 234 mg at 2.5, 5.0, and 10 dS m^{-1} salinity levels. A similar case was also observed in roots. The average root dry matter yield of 346 mg at control treatments decreased respectively by 36, 70, and 88% to 223, 81, and 41 mg at 2.5, 5.0, and 10 dS m^{-1} salinity levels (Table 4.3). The rate of decrease at the same salinity doses was higher in root dry matter productions than in shoot dry matter productions. The decreasing trends with increasing salinity levels in both shoot (Table 4.2) and root

(Table 4.3) dry matter productions were similar and close to each other in all genotypes.

Salicylic acid treatments significantly changed both the shoot and the root dry matter productions of the genotypes (Table 4.1). The average shoot dry matter yield of 28 mg plant^{-1} at control treatments increased respectively by 4, 10, and 15% to 757, 800, and 837 mg plant^{-1} at 0.25, 0.5, and 1.00 mM salicylic acid treatments (Table 4.2). The average root dry matter yield of 161 mg plant^{-1} at control treatments increased respectively by 9 and 17% to 176 and 191 mg plant^{-1} at 0.5 and 1.00 mM salicylic acid treatments, but the values did not change with 0.25 mM SA treatments (Table 4.3).

As the average of genotypes, both the shoot and the root dry matter productions were significantly different from each other (Table 4.1). The most significant shoot dry matter yields were obtained from Candaş (813 mg plant^{-1}) and Gökkan (822 mg plant^{-1}) genotypes, which were placed in the same group (Table 4.2). They were followed by Yakamoz (770 mg plant^{-1}) and Altınöz (717 mg plant^{-1}) genotypes. The highest root dry matter yield was obtained from Candaş, and the lowest root dry matter yield was obtained from Gökkan (Table 4.3). Considering the shoot dry matter yields, it was remarkable that Gökkan had the lowest root dry matter yield.

Considering the salt x SA interactions, it was observed that the highest shoot dry matter yield was obtained from the treatment without salt and with 1.0 mM SA. A similar case was also observed at 2.5 and 5,0 dS/m salinity levels (Table 4.1 and Table 4.2). Salt x SA interactions were also found to be significant for root dry matter productions (Table 4.1). The highest root dry matter yield was obtained from the treatment without salt and with 1.0 mM SA. A similar case was also observed at 2.5 and 5.0 dS m^{-1} salinity levels (Table 4.3).

Table 4.2. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on the shoot dry weight (mg plant^{-1}) in bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	Shoot Dry Weight (mg plant^{-1})					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
Control	0.00	1214 e-j	1252 b-ı	1304 a-f	1278 a-h		1262 c
	0.25	1221 d-j	1274 a-h	1316 a-f	1299 a-g		1278 bc
	0.50	1246 c-ı	1345 a-e	1394 a-d	1403 abc		1347 ab
	1.00	1270 a-h	1439 a	1427 a	1422 ab		1389 a
	Mean (AxC)	1238 b	1328 a	1360 a	1350 a	**Mean (A)**	**1319 A**
2.5	0.00	949 l-o	1117 h-l	914 no	861 op		960 f
	0.25	939 mno	1113 h-m	966 k-o	1049 j-n		1017 ef
	0.50	964 k-o	1112 h-m	1106 h-m	1094 ı-m		1069 e
	1.00	1081 ı-n	1143 f-j	1229 c-ı	1128 g-k		1145 d
	Mean (AxC)	983 d	1121 c	1054 cd	1033 d	**Mean (A)**	**1048 B**
5	0.00	424 s-w	468 stu	570 q-t	376 u-x		459 ı
	0.25	417 t-w	533 q-u	582 q-t	457 stu		497 hı
	0.50	430 s-v	577 q-t	666 qr	510 r-u		546 gh
	1.00	500 r-u	592 qrs	704 pq	542 q-u		584 g
	Mean (AxC)	443 g	542 f	631 e	471 fg	**Mean (A)**	**522 C**
10	0.00	220 xy	250 wxy	253 wxy	193 y		229 j
	0.25	210 xy	264 v-y	275 v-y	202 y		238 j
	0.50	203 xy	259 v-y	281 v-y	219 xy		240 j
	1.00	192 y	276 v-y	170 y	282 v-y		230 j
	Mean (AxC)	206 h	262 h	245 h	224 h	**Mean (A)**	**234 D**
Mean (BxC)	0.00	702 efg	772 cde	760 def	677 g		**728 D**
	0.25	697 fg	796 bcd	785 cde	752 def	**Mean (B)**	**757 C**
	0.50	711 efg	823 a-d	862 ab	806 bcd		**800 B**
	1.00	760 def	862 ab	882 a	844 abc		**837 A**
	Mean (C)	**717 C**	**813 A**	**822 A**	**770 B**		

Table 4.3. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on the root dry weight (mg plant^{-1}) in bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	Root Dry Weight (mg plant^{-1})					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
Control	0.00	341 ab	334 abc	320 a-e	339 ab		334 b
	0.25	341 ab	332 a-d	303 b-f	327 a-d		326 b
	0.50	362 ab	340 ab	334 abc	353 ab		347 ab
	1.00	369 ab	382 a	390 a	366 ab		377 a
	Mean (AxC)	353 a	347 a	337 a	346 a	**Mean (A)**	**346 A**
2.5	0.00	203 ghı	255 d-g	172 hıj	151 ıjk		195 e
	0.25	213 ghı	259 c-g	175 hı	208 ghı		213 de
	0.50	225 ghı	248 e-h	207 ghı	236 fgh		229 cd
	1.00	320 a-e	246 e-h	230 fgh	215 ghı		253 c
	Mean (AxC)	240 b	252 b	196 c	202 c	**Mean (A)**	**223 B**
5	0.00	71 l	74 kl	80 kl	75 kl		75 f
	0.25	71 l	77 kl	67 l	72 l		72 fg
	0.50	81 kl	89 kl	91 kl	88 kl		88 f
	1.00	90 kl	88 kl	95 jkl	91 kl		91 f
	Mean (AxC)	78 de	82 d	84 d	81 d	**Mean (A)**	**81 C**
10	0.00	43 l	45 l	44 l	32 l		41 g
	0.25	39 l	46 l	42 l	37 l		41 g
	0.50	34 l	44 l	48 l	38 l		41 g
	1.00	40 l	55 l	35 l	41 l		42 g
	Mean (AxC)	39 f	47 ef	42 f	37 f	**Mean (A)**	**41 D**
Mean (BxC)	0.00	165	177	154	149		**161 C**
	0.25	166	179	147	161	**Mean (B)**	**163 C**
	0.50	176	180	170	179		**176 B**
	1.00	204	193	188	178		**191 A**
	Mean (C)	**178 AB**	**182 A**	**165 C**	**167 BC**		

When the salt x genotype interactions are considered, Altınöz had the highest shoot dry matter production under control conditions. All genotypes exhibited similar shoot dry matter productions at 10 dS m^{-1} salinity level (Table 4.2). Under control conditions, salt x genotype interactions did not have significantly different root dry matter productions (Table 4.3).

Considering salicylic acid x genotype interactions, shoot and root dry matter productions of all genotypes increased with increasing SA doses (Table 4.2 and Table 4.3). While SA x genotype interactions were found to be significant for shoot dry matter productions (Table 4.2), they were not found to be substantial for root dry matter productions (Table 4.3). The highest shoot dry matter production (882 mg $plant^{-1}$) was obtained from 1.0 mM SA treatment of Gökkan genotype. The lowest shoot dry matter production (677 mg $plant^{-1}$) was obtained from Yakamoz without salicylic acid treatments (Table 4.2).

Salt x salicylic acid x genotype interactions were found to be significant for both shoot and root dry matter productions (Table 4.1). In treatment without salt and with 1.0 mM SA, Candaş and Gökkan genotypes had the most significant shoot dry matter productions respectively with 1439 and 1427 mg $plant^{-1}$ (Table 4.2). At 0, 2.5, and 5 dS m^{-1} salinity levels, shoot dry matter productions of all genotypes increased with increasing salicylic acid doses. Such a case was observed at 10 dS m^{-1} levels only in Candaş and Yakamoz genotypes (Table 4.2). As it was in shoot dry matter productions (Table 4.2), Candaş and Gökkan genotypes had the highest root dry matter productions in treatments without salt and with 1.0 SA level (Table 4.3). At 10 dS m^{-1} salinity level, salicylic acid treatments were not sufficient, and all genotypes were placed into the same statistical group (Table 4.3).

4.1.2. SPAD

The average SPAD value of 44.5 in control treatments significantly increased at 2.5 and 5.0 dS m^{-1} salinity levels, respectively, to 47.5 and 47.0 but decreased to 39.8 with 10 dS m^{-1} salinity treatment (Table 4.4).

Table 4.4. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on SPAD in bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{1}).

NaCl (dS m^{-1})	SA (mM)	SPAD Values					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
Control	0.00	42.2	43.6	42.1	43.4		42.8 de
	0.25	43.9	44.8	42.9	42.7		43.6 cd
	0.50	44.6	46.1	44.9	45.2		45.2 bc
	1.00	43.9	46.6	46.4	48.3		46.3 ab
	Mean (AxC)	43.6 efg	45.3 cde	44.1 def	44.9 cde	**Mean (A)**	**44.5 B**
2.5	0.00	46.5	49.8	45.2	46.0		46.9 ab
	0.25	47.7	48.7	47.2	45.6		47.3 ab
	0.50	47.0	48.4	47.9	46.8		47.5 ab
	1.00	47.5	51.0	47.5	47.2		48.3 a
	Mean (AxC)	47.2 bc	49.5 ab	46.9 c	46.4 cd	**Mean (A)**	**47.5 A**
5	0.00	43.9	45.4	44.6	49.6		45.9 bc
	0.25	44.0	45.0	45.8	50.9		46.4 ab
	0.50	44.4	44.9	47.4	51.9		47.2 ab
	1.00	45.2	48.3	46.7	53.9		48.5 a
	Mean (AxC)	44.4 def	45.9 cde	46.2 cd	51.6 a	**Mean (A)**	**47.0 A**
10	0.00	39.5	42.3	39.9	34.1		39.0 f
	0.25	38.4	43.4	41.3	37.7		40.2 f
	0.50	37.8	43.7	43.0	38.4		40.7 ef
	1.00	36.9	40.1	41.5	39.5		39.5 f
	Mean (AxC)	38.2 h	42.4 fg	41.4 g	37.4 h	**Mean (A)**	**39.8 C**
Mean (BxC)	0.00	43.0 e	45.3 a-e	43.0 e	43.3 de		**43.6 C**
	0.25	43.5 cde	45.5 a-d	44.3 b-e	44.2 b-e	**Mean (B)**	**44.4 BC**
	0.50	43.4 cde	45.8 abc	45.8 abc	45.6 a-d		**45.2 AB**
	1.00	43.4 de	46.5 ab	45.5 a-d	47.2 a		**45.7 A**
	Mean (C)	**43.3 C**	**45.8 A**	**44.7 B**	**45.1 AB**		

The average SPAD values of the genotypes significantly increased with salicylic acid treatments. The SPAD value of 43.6 in non-SA treated plants

increased respectively to 44.4, 45.2, and 45.7 with 0.25, 0.50 and 1.0 mM SA doses.

Concerning an average of genotypes, the highest SPAD value (45.8) was obtained from Candaş, and the lowest SPAD value (43.3) was obtained from Altınöz (Table 4.4).

Salt x SA interactions were found to be significant for the SPAD values of the genotypes (Table 4.1). The highest SPAD value was obtained from 2.5 and 5.0 dS m^{-1} salt doses and 1.0 mM SA dose and the lowest SPAD values were collected at 10 dS m^{-1} salt level (Table 4.4).

Concerning salt x genotype interactions, the highest SPAD value (51.6) was obtained from 5.0 dS m^{-1} of Yakamoz genotype, and the lowest SPAD values were obtained from 10 dS m^{-1} of Altınöz and Yakamoz genotypes (Table 4.4).

Salicylic acid x genotype interactions were also found to be significant for SPAD values of the genotypes (Table 4.1). The most significant SPAD value (47.2) was obtained at 1.0 mM SA treatment of Yakamoz genotype, and the lowest SPAD values were observed at non-SA treatments (Table 4.4).

4.1.3. Leaf Relative Water Content (LRWC)

The Relative water content of the genotypes significantly decreased with increasing salinity treatments (Table 4.1 and Table 4.5).

The average relative water content of 90.7% in control treatments decreased respectively by 3.74, 14.3, and 20.5% to 87.3, 77.7 and 72.1% at 2.5, 5.0 and 10 dS m^{-1} salinity levels.

Table 4.5. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on the Leaf Relative Water Content (%) in bread wheat genotypes grown under different salt levels (control, 2.5, 5.0.,10 dS m^{-1}).

NaCl	SA	Relative Water Content (%)					Mean
(dS m^{-1})	(mM)	Altınöz	Candaş	Gökkan	Yakamoz		(AxB)
Control	0.00	91.3 a	90.2 a-d	91.4 a	89.9 a-d		90.7 a
	0.25	91.3 a	90.3 a-d	89.9 a-d	90.9 abc		90.6 a
	0.50	91.2 a	91.1 ab	88.6 a-d	91.0 ab		90.5 a
	1.00	91.5 a	89.7 a-d	91.2 a	91.5 a		91.0 a
	Mean (AxC)	91.3 a	90.3 ab	90.3 ab	90.8 ab	**Mean (A)**	**90.7 A**
2.5	0.00	88.7 a-d	87.4 a-f	85.3 d-h	88.1 a-e		87.4 b
	0.25	87.8 a-f	87.0 a-f	86.3 a-h	87.6 a-f		87.2 b
	0.50	87.5 a-f	85.4 c-h	86.4 a-g	88.6 a-d		87.0 b
	1.00	87.6 a-f	85.6 b-h	87.4 a-f	90.3 a-d		87.7 b
	Mean (AxC)	87.9 cd	86.4 d	86.4 d	88.7 bc	**Mean (A)**	**87.3 B**
5	0.00	76.8 j-n	71.4 n-t	78.3 ı-l	75.1 l-q		75.4 ef
	0.25	77.6 ı-m	70.8 o-t	79.3 ı-l	78.7 ı-l		76.6 de
	0.50	79.5 ı-l	72.7 m-s	79.6 ı-l	80.8 h-k		78.2 d
	1.00	82.5 f-ı	75.4 k-p	81.0 g-j	82.8 e-ı		80.5 c
	Mean (AxC)	79.1 e	72.6 gh	79.6 e	79.3 e	**Mean (A)**	**77.7 c**
10	0.00	78.4 ı-l	68.5 st	75.9 j-o	62.9 u		71.4 g
	0.25	72.8 m-s	69.9 q-t	77.0 j-m	67.0 tu		71.7 g
	0.50	71.4 n-t	71.4 n-t	79.6 ı-l	70.2 p-t		73.2 fg
	1.00	69.2 rst	72.8 m-s	74.3 l-r	72.6 m-s		72.3 g
	Mean (AxC)	73.0 g	70.7 h	76.7 f	68.2 ı	**Mean (A)**	**72.1** D
Mean (BxC)	0.00	83.8 a	79.4 d	82.7 ab	79.0 d	**Mean (B)**	**81.2 C**
	0.25	82.4 abc	79.5 d	83.1 ab	81.1 bcd		**81.5 BC**
	0.50	82.4 abc	80.2 cd	83.5 a	82.7 ab		**82.2 AB**
	1.00	82.7 ab	80.9 bcd	83.5 a	84.3 a		**82.9 A**
	Mean (C)	**82.8 A**	**80.0 C**	**83.2 A**	**81.8 B**		

The relative water content of the genotypes significantly increased with increasing SA treatment (Table 4.1 and Table 4.5). The average LRWC of 81.2% under non-SA treatment increased to 82.9% with 1.0 mM SA treatment (Table 4.5).

About genotype averages, Altınöz and Gökkan had higher LRWC values than the other two genotypes, but they were placed into the same statistical group (Table 4.5).

Salt x SA interactions were found to be significant for LRWC of the genotypes. The highest LRWC numbers were observed in non-salinity treatments, but they were placed in the same group (Table 4.1 and Table 4.5). The lowest LRWC value was observed at 10 dS/m salinity level. The LRWC value of 80.5% at 5 dS m^{-1} and 1.0 mM SA treatment was significantly higher than the LRWC values of the same salinity level of the other SA treatments (Table 4.5).

Salt x genotype interactions were found to be significant for the LRWC of the genotypes (Table 4.1). The greatest LRWC (91.3%) was obtained from the non-salinity treatment of Altınöz, and the lowest LRWC (68.2%) was obtained from 5 dS m^{-1} of Yakamoz (Table 4.5).

Salicylic acid x genotype interactions were also found to be significant for LRWC of the genotypes (Table 4.1). The LRWC values decreased in Altınöz genotype but increased in the other genotypes with increasing SA treatments (Table 4.5). The most remarkable effect of salicylic acid on LRWC was observed in Yakamoz. The LRWC value of 79.0% in control treatments increased by 6.7% to 84.3% at 1.0 mM SA treatment (Table 4.5).

Salt x SA x genotype interactions were found to be significant for LRWC (Table 4.1). LRWC values of the genotypes increased at non-salt treated cases. At 5 dS m^{-1} salinity level, the LRWC values of all genotypes increased dramatically with enhancing SA treatments (Table 4.5). The lowest LRWC value (62.9%) was obtained from 10 dS m^{-1} and no-SA treatment of Yakamoz (Table 4.5).

4.1.4. Membrane Permeability

Membrane permeability of the genotypes significantly increased with increasing salinity treatments (Table 4.1 and Table 4.6).

Table 4.6. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on membrane permeability (%) in bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl	SA	Membrane Permeability (%)					Mean
(dS m^{-1})	(mM)	Altınöz	Candaş	Gökkan	Yakamoz		(AxB)
Control	0.00	3.3	6.1	4.0	5.1		4.6
	0.25	4.6	3.0	3.3	5.3		4.0
	0.50	4.1	3.4	3.8	5.3		4.2
	1.00	4.6	3.2	3.9	5.6		4.4
	Mean (AxC)	4.1 d	3.9 d	3.8 d	5.3 d	**Mean (A)**	**4.3 B**
2.5	0.00	5.4	3.6	2.2	5.9		4.3
	0.25	6.6	3.3	2.0	5.4		4.3
	0.50	5.5	3.0	2.9	5.6		4.3
	1.00	3.8	3.2	4.1	4.3		3.9
	Mean (AxC)	5.3 d	3.3 d	2.8 d	5.3 d	**Mean (A)**	**4.2 B**
5	0.00	10.1	11.9	3.1	5.3		7.6
	0.25	7.5	7.8	4.9	6.0		6.5
	0.50	5.5	4.6	4.4	4.9		4.8
	1.00	5.6	5.9	4.7	5.2		5.4
	Mean (AxC)	7.2 cd	7.5 cd	4.3 d	5.4 d	**Mean (A)**	**6.1 B**
10	0.00	34.4	19.1	16.7	12.0		20.5
	0.25	33.3	17.8	17.4	15.4		21.0
	0.50	28.9	20.4	22.2	12.4		21.0
	1.00	25.7	24.0	34.7	12.8		24.3
	Mean (AxC)	30.6 a	20.3 b	22.8 b	13.1 c	**Mean (A)**	**21.7 A**
Mean (BxC)	0.00	13.3 a	10.2 abc	6.5 c	7.1 bc	**Mean (B)**	**9.3**
	0.25	13.0 ab	8.0 abc	6.9 c	8.0 abc		**9.0**
	0.50	11.0 abc	7.9 abc	8.3 abc	7.0 bc		**8.6**
	1.00	9.9 abc	9.1 abc	11.9 abc	7.0 bc		**9.5**
	Mean (C)	**11.8 A**	**8.8 B**	**8.4 B**	**7.3 B**		

The 0, 2.5, and 5.0 dS m^{-1} salt levels were placed into the same statistical group, but membrane permeability values significantly increased at 10 dS m^{-1} salt treatment and reached 21.7% (Table 4.6).

Salicylic acid treatments did not have significant effects on membrane permeability of the genotypes (Table 4.1). Altınöz (11.8%) had significantly higher membrane permeability than the other genotypes (Table 4.6). The average membrane permeability of Candaş, Gökkan, and Yakamoz genotypes was around 8% (Table 4.6).

Salt x genotype interactions were found to be significant for membrane permeability (Table 4.1). The highest membrane permeability (30.6%) was obtained from 10 dS m^{-1} of Altınöz, and the lowest membrane permeability (13.1%) was obtained from the same salt level of Yakamoz genotype. In the same salinity level, Candaş and Gökkan genotypes had close membrane permeability values to each other (Table 4.6).

Salicylic acid x genotype interactions were also found to be significant for membrane permeability (Table 4.1). Independent from salt treatments, SA treatments slightly reduced membrane permeability of Altınöz (Table 4.6). Accordingly, membrane permeability of 13.3% at non-SA treatment decreased to 9.9% at 1.0 mM SA treatment. On the other hand, membrane permeability of Gökkan at the same dose increased from 6.5% to 11.9%. A significant change was not observed in the other genotypes (Table 4.6).

4.1.5. Sodium (Na)

Shoot sodium (Na) concentrations significantly increased with increasing salt treatments (Table 4.1, Table 4.7, and 4.8). Average shoot Na concentration of 1.03 mg/g in control treatments increased respectively to 3.37, 4.59 and 7.06 mg/g at 2.5, 5.0 and, 10 dS m^{-1} salt levels (Table 4.7and 4.8).

Shoot dry matter yields of the plants were multiplied by Na concentrations to get Na content of the plants. Parallel to decreasing shoot dry matter yields of the genotypes with increasing salt levels from 2.5 to 10 dS m^{-1} (Table 4.2), Na contents also significantly decreased with increasing salt levels (Table 4.8).

Salicylic acid treatments had significant effects on Na concentrations and contents of the genotypes (Table 4.1, Table 4.7and 4.8). The average Na concentration of 4.5 mg/g in control treatments decreased respectively to 4.10, 3.77 and 3.68 mg/g at 0.25, 0.5 and 1.0 mM SA levels. Similarly, the average Na content of 2.36 mg $plant^{-1}$ in control treatments decreased respectively to 2.24, 2.17 and 2.08 mg $plant^{-1}$ at 0.25, 0.5 and 1.0 mM SA doses (Table 4.7and 4.8).

Na concentrations and contents of the genotypes were significantly different from each other (Table 4.1, Table 4.7and 4.8). Na concentrations of Gökkan and Yakamoz genotypes were placed in the same statistical group and were more significant than the Na concentrations of Altınöz and Candaş genotypes which were also placed into the same group (Table 4.7). The highest Na content (2.51 mg $plant^{-1}$) was obtained from Gökkan genotype. The lowest Na content (1.86 mg $plant^{-1}$) was derived from Altınöz. The other two genotypes were placed in the same group (Table 4.8).

Salt x SA interactions were found to be significant for Na concentrations but were not found to be substantial for Na contents (Table 4.1). The highest Na concentrations were observed at the highest salt level, but SA treatments did not have significant effects at the same salt level. On the other hand, Na concentration decreasing effects of SA were remarkable at 2.5 and 5.0 dS m^{-1} salt levels (Table 4.7).

Table 4.7. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on Na^+ concentration (mg g^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	Na Concentration of Shoot (mg g^{-1})					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
0	0.00	1.7 r-u	1.20 p-u	1.20 p-u	1.20 p-u		1.17 g
	0.25	1.03 stu	1.07 r-u	1.12 q-u	1.02 stu		1.06 g
	0.50	0.98 tu	1.03 stu	0.98 tu	1.02 stu		1.00 g
	1.00	0.95 tu	0.90 tu	0.83 u	0.80 u		0.86 g
	Mean (AxC)	1.01 f	1.05 f	1.03 f	1.01 f	**Mean (A)**	**1.03 D**
2.5	0.00	3.40 mn	3.67 k-o	4.17 ı-o	4.67 f-o		3.98 cde
	0.25	3.17 n-r	3.27 m-p	3.83 k-o	3.73 k-o		3.50 def
	0.50	2.87 n-u	3.20 n-a	3.13 n-s	3.37 mno		3.14 ef
	1.00	2.77 o-u	2.90 n-u	2.80 o-u	2.97 n-t		2.86 f
	Mean (AxC)	3.05 e	3.26 de	3.48 de	3.68 de	**Mean (A)**	**3.37 C**
5	0.00	4.23 h-o	4.53 g-o	6.13 b-j	6.77 a-f		5.42 b
	0.25	3.83 k-o	4.10 j-o	5.35 d-m	5.77 c-k		4.76 bc
	0.50	3.63 l-o	3.97 k-o	4.97 e-n	470 f-o		4.32 cd
	1.00	3.33 mno	3.83 k-o	4.43 h-o	3.80 k-o		3.85 de
	Mean (AxC)	3.76 de	4.11 d	5.22 c	5.26 c	**Mean (A)**	**4.59 B**
10	0.00	6.30 b-h	7.43 a-d	7.87 abc	8.13 ab		7.43 a
	0.25	7.27 a-d	6.90 a-e	7.03 a-e	7.03 a-e		7.06 a
	0.50	7.40 a-d	6.13 b-j	6.63 a-g	6.27 b-ı		6.61 a
	1.00	8.73 a	5.63 d-l	8.50 a	5.70 d-l		7.14 a
	Mean (AxC)	7.43 a	6.53 b	7.51 a	6.78 ab	**Mean (A)**	**7.06 A**
Mean (BxC)	0.00	3.75 cd	4.21 bc	4.84 ab	5.19 a	**Mean (B)**	**4.50 A**
	0.25	3.83 cd	3.83 cd	4.33 abc	4.39 abc		**4.10 B**
	0.50	3.72 cd	3.58 cd	3.93 cd	3.84 cd		**3.77 BC**
	1.00	3.95 cd	3.32 d	4.14 bcd	3.32 d		**3.68 C**
	Mean (C)	**3.81 B**	**3.74 B**	**4.31 A**	**4.18 A**		

Table 4.8. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on Na^+ content (mg $plant^{-1}$) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	Na Content of Shoot (µg $plant)^{-1}$					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
0	0.00	1.29	1.49	1.56	1.54		1.47
	0.25	1.26	1.36	1.46	1.32		1.35
	0.50	1.23	1.38	1.38	1.43		1.35
	1.00	1.20	1.29	1.19	1.14		1.20
	Mean (AxC)	1.25 e	1.38 e	1.40 e	1.36 e	**Mean (A)**	**1.34 D**
2.5	0.00	3.22	4.10	3.80	3.97		3.77
	0.25	3.01	3.64	3.71	3.92		3.57
	0.50	2.77	3.53	3.44	3.68		3.35
	1.00	2.99	3.31	3.43	3.35		3.27
	Mean (AxC)	3.00 b	3.64 a	3.59 a	3.73 a	**Mean (A)**	**3.49 A**
5	0.00	1.77	2.12	3.49	2.56		2.49
	0.25	1.59	2.16	3.14	2.62		2.38
	0.50	1.56	2.27	3.29	2.40		2.38
	1.00	1.68	2.27	3.09	2.04		2.27
	Mean (AxC)	1.65 de	2.21 cd	3.25 ab	2.41 c	**Mean (A)**	**2.38 B**
10	0.00	1.41	1.86	2.00	1.56		1.71
	0.25	1.52	1.82	1.93	1.41		1.67
	0.50	1.51	1.59	1.86	1.36		1.58
	1.00	1.68	1.56	1.44	1.61		1.57
	Mean (AxC)	1.53 e	1.71 de	1.81 de	1.49 e	**Mean (A)**	**1.63 C**
Mean (BxC)	0.00	1.92	2.39	2.71	2.41	**Mean (B)**	**2.36 A**
	0.25	1.84	2.24	2.56	2.32		**2.24 AB**
	0.50	1.77	2.19	2.49	2.22		**2.17 AB**
	1.00	1.89	2.11	2.29	2.04		**2.08 B**
	Mean (C)	**1.86 C**	**2.23 B**	**2.51 A**	**2.25 B**		

Salt x genotype interactions were found to be significant for both Na concentrations and Na contents (Table 4.1, 4.7 and 4.8). The highest Na concentrations were observed at 10 dS m^{-1} salt level of Altınöz and Gökkan genotypes. Related to plant dry matter yields, the highest Na contents were found at 2.5 dS m^{-1} level of Candaş, Gökkan, and Yakamoz genotypes.

Salt x SA x genotype interactions were also found to be significant for Na concentrations (Table 4.1). Shoot Na concentrations of all genotypes significantly decreased at 0, 2.5, and 5.0 dS m^{-1} salinity levels with increasing SA treatments, and Na concentrations of Candaş and Yakamoz genotypes significantly decreased at 10 dS m^{-1} level with enhancing SA treatments (Table 4.7 and 4.8).

4.1.6. Nitrogen (N)

Shoot nitrogen (N) concentrations and contents significantly decreased with increasing salinity treatments (Table 4.9 and 4.10). The average N concentration of 41.2 mg/g in control treatments respectively reduced to 37.8 and 35.7 mg/g at 5.0 and 10 dS m^{-1} salt levels. Similarly, the average N content of 54.3 mg $plant^{-1}$ in control treatments respectively decreased to 42.4, 19.7, and 8.4 mg $plant^{-1}$ at 2.5, 5.0, and 10 dS m^{-1} salt levels (Table 4.9 and 4.10).

Salicylic acid treatments did not have significant effects on N concentrations. On the other hand, the impact of SA treatments on N contents was found to be substantial. The N content of 29.5 mg $plant^{-1}$ in non-SA treatment increased to 32.7 mg $plant^{-1}$ at 1.0 mM dose (Table 4.9 and 4.10).

As the average of the genotypes, N concentrations and contents significantly changed (Table 4.1, 4.9, and 4.10). N concentration and content of Candaş and Gökkan were higher than N concentration and content of Altınöz and Yakamoz genotypes.

The effects of salt x genotype interactions on N concentrations were found to be significant (Table 4.1). The highest N concentration (43.1 mg/g) was obtained from 2.5 dS m^{-1} level of Gökkan, and the lowest N concentration (32.7 mg/g) was obtained from 10 dS m^{-1} level of Yakamoz (Table 4.9 and 4.10).

Table 4.9. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on N concentration (mg g^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	N Concentration of Shoot (mg g^{-1})					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
0	0.00	41.1	40.7	43.3	41.4		41.6
	0.25	41.6	41.0	42.3	42.4		41.8
	0.50	41.4	40.9	39.5	41.0		40.7
	1.00	43.2	41.2	40.0	38.5		40.7
Mean (AxC)		41.8 ab	40.9 ab	41.3 ab	40.8 ab	**Mean (A)**	**41.2 A**
2.5	0.00	40.4	39.7	44.1	40.2		41.1
	0.25	40.6	40.0	43.8	38.6		40.8
	0.50	40.7	39.7	43.6	39.5		40.9
	1.00	38.0	40.5	40.9	37.8		39.3
Mean (AxC)		39.9 ab	40.0 ab	43.1 a	39.0 ab	**Mean (A)**	**40.5 A**
5	0.00	38.6	39.5	39.0	39.3		39.1
	0.25	39.3	39.3	38.1	38.1		38.7
	0.50	37.0	39.1	36.8	38.0		37.7
	1.00	33.4	39.5	36.7	33.6		35.8
Mean (AxC)		37.1 bcd	39.3 ab	37.7 bcd	37.3 bcd	**Mean (A)**	**37.8 B**
10	0.00	35.9	36.5	36.4	31.5		35.1
	0.25	35.7	37.6	36.4	33.2		35.7
	0.50	32.9	38.4	38.9	33.8		36.0
	1.00	30.1	38.6	42.5	32.2		35.8
Mean (AxC)		33.7 cd	37.8 bcd	38.6 abc	32.7 d	**Mean (A)**	**35.7 C**
Mean (BxC)	0.00	39.0	39.1	40.7	38.1	**Mean (B)**	**39.2**
	0.25	39.3	39.5	40.2	38.1		**39.3**
	0.50	38.0	39.5	39.7	38.1		**38.8**
	1.00	36.2	39.9	40.0	35.5		**37.9**
Mean (C)		**38.1 BC**	**39.5 AB**	**40.1 A**	**37.4 C**		

Table 4.10. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on N content (mg plant^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl	SA	N Content of Shoot (µg plant)$^{-1}$					Mean
(dS m^{-1})	(mM)	Altınöz	Candaş	Gökkan	Yakamoz		(AxB)
0	0.00	49.9	51.3	56.4	52.8		52.6
	0.25	50.8	52.3	55.9	55.0		53.5
	0.50	51.5	54.8	55.1	57.3		54.6
	1.00	54.8	59.3	57.1	54.8		56.5
Mean (AxC)		51.7	54.4	56.1	55.0	**Mean (A)**	**54.3** A
2.5	0.00	38.3	44.5	40.3	34.6		39.4
	0.25	38.1	44.5	42.2	40.5		41.3
	0.50	39.2	44.1	48.1	43.2		43.7
	1.00	41.0	46.3	50.5	42.7		45.1
Mean (AxC)		39.2	44.9	45.3	40.2	**Mean (A)**	**42.4** B
5	0.00	16.3	18.5	22.2	14.6		17.9
	0.25	16.4	20.9	22.2	17.4		19.2
	0.50	15.9	22.5	24.6	19.4		20.6
	1.00	16.7	23.3	25.8	18.5		21.1
Mean (AxC)		16.3	21.3	23.7	17.5	**Mean (A)**	**19.7** C
10	0.00	7.9	9.1	9.2	6.1		8.1
	0.25	7.5	9.9	10.0	6.7		8.5
	0.50	6.7	10.0	10.9	7.4		8.7
	1.00	5.8	10.6	7.2	9.1		8.2
Mean (AxC)		7.0	9.9	9.3	7.3	**Mean (A)**	**8.4** D
Mean (BxC)	0.00	28.1	30.8	32.0	27.0		**29.5** B
	0.25	28.2	31.9	32.6	29.9	**Mean (B)**	**30.6** AB
	0.50	28.3	32.8	34.7	31.8		**31.9** AB
	1.00	29.6	34.9	35.1	31.3		**32.7** A
Mean (C)		**28.5 B**	**32.6 A**	**33.6 A**	**30.0 B**		

4.1.7. Phosphorus (P)

Salt treatments had significant effects on phosphorus (P) concentrations and contents (Table 4.1). The average P concentration of 4.07 mg/g in control treatments decreased respectively to 3.81, 3.60 and 3.79 mg/g at 2.5, 5.0 and 10 dS m^{-1} salt levels (Table 4.11 and 4.12). A gradual decrease was observed in phosphorus contents with increasing salinity levels. The average P content of 5.38

mg plant^{-1} in control treatments decreased respectively to 4.01, 1.89 and 0.88 mg plant^{-1} at 2.5, 5.0 and 10 dS m^{-1} salinity levels.

Salicylic acid treatments had significant effects on P concentrations and contents of the genotypes (Table 4.1). P concentrations significantly increased with increasing SA treatments. Accordingly, the average P concentration of 3.55 mg/g in non-SA treatments increased to 4.03 mg/g at 1.0 mM SA treatment. Similarly, P contents increased with increasing SA treatments. The average P content of 2.69 mg plant^{-1} in control treatments increased to 3.47 mg plant^{-1} at 1.0 mM SA dose (Table 4.11 and 4.12).

P concentrations and contents of the genotypes were significantly different from each other (Table 4.11 and 4.12). For P concentrations, while Candaş, Gökkan and Yakamoz genotypes were placed into the same group, Altınöz genotype had higher P concentrations than these three genotypes (Table 4.9). The highest P content (3.19 mg plant^{-1}) was obtained from Gökkan, and the lowest P content (2.85 mg plant^{-1}) was derived from Altınöz (Table 4.12).

Salt x SA interactions were not found to be significant for P concentrations but were found to be substantial for P contents (Table 4.1). At 0, 2.5, and 5.0 dS m^{-1} salt level, increasing P contents were observed with enhancing SA treatments (Table 4.11 and 4.12). The highest P content (6.11 mg plant^{-1}) was obtained from 1.0 mM SA dose without salt treatment, and the lowest P contents were obtained from 10 dS m^{-1} treatments (Table 4.12).

Salt x genotype interactions were found to be significant for P concentrations and contents (Table 4.1). In non-salt treated cases, P concentrations of all genotypes were at low levels and placed into the same statistical group (Table 4.11). The highest P concentration (5.46 mg/g) was obtained from 10 dS m^{-1} of Altınöz genotype (Table 4.11). In non-salt treated cases, P contents of all genotypes were at high levels and placed into the same statistical group. The lowest P content was observed at 10 dS m^{-1} salt level (Table 4.12).

Table 4.11. Effect of salicylic acid levels (0, 0.25, 0.5.,1.0 mM) on P concentration (mg g^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	P Concentration of Shoot (mg g^{-1})					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
0	0.00	3.89	4.00	3.91	3.82		3.90
	0.25	3.78	3.93	3.94	3.87		3.88
	0.50	4.09	3.97	4.16	4.12		4.09
	1.00	4.77	4.24	4.30	4.31		4.41
	Mean (AxC)	4.13 b	4.03 b	4.08 b	4.03 b	**Mean (A)**	**4.07 A**
2.5	0.00	3.41	3.80	3.76	3.68		3.66
	0.25	3.48	3.66	3.74	3.67		3.64
	0.50	3.76	3.87	3.93	3.88		3.86
	1.00	4.00	4.03	4.20	4.08		4.08
	Mean (AxC)	3.66 bcd	3.84 bc	3.91 bc	3.83 bc	**Mean (A)**	**3.81 AB**
5	0.00	3.13	3.51	3.53	3.44		3.40
	0.25	3.39	3.63	3.59	3.57		3.55
	0.50	3.48	3.68	3.76	3.63		3.64
	1.00	3.71	3.78	3.89	3.81		3.80
	Mean (AxC)	3.43 bcd	3.65 bcd	3.69 bcd	3.61 bcd	**Mean (A)**	**3.60 B**
10	0.00	4.25	2.89	2.81	2.94		3.22
	0.25	5.96	3.48	3.05	3.19		3.92
	0.50	5.96	3.64	3.68	3.47		4.19
	1.00	5.69	3.70	2.42	3.59		3.85
	Mean (AxC)	5.46 a	3.43 bcd	2.99 d	3.30 cd	**Mean (A)**	**3.79 B**
Mean (BxC)	0.00	3.67	3.55	3.50	3.47		**3.55 C**
	0.25	4.15	3.68	3.58	3.57	**Mean (B)**	**3.75 BC**
	0.50	4.33	3.79	3.88	3.78		**3.94 AB**
	1.00	4.54	3.94	3.70	3.95		**4.03 A**
	Mean (C)	**4.17 A**	**3.74 B**	**3.67 B**	**3.69 B**		

Table 4.12. Effect of salicylic acid levels (0, 0.25, 0.5.,1.0 mM) on P content (mg plant^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	P Content of Shoot (µg plant)$^{-1}$					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
0	0.00	4.74	5.00	5.10	4.89		**4.93** c
	0.25	4.62	5.02	5.18	5.02		**4.96** c
	0.50	5.12	5.34	5.80	5.79		**5.51** b
	1.00	6.06	6.10	6.13	6.13		**6.11** a
	Mean (AxC)	5.13 a	5.37 a	5.55 a	5.46 a	**Mean (A)**	**5.38 A**
2.5	0.00	3.24	4.24	3.43	3.17		**3.52** f
	0.25	3.27	4.07	3.62	3.85		**3.71** ef
	0.50	3.64	4.32	4.35	4.24		**4.14** de
	1.00	4.33	4.61	5.16	4.61		**4.67** cd
	Mean (AxC)	3.62 c	4.31 b	4.14 bc	3.97 bc	**Mean (A)**	**4.01 B**
5	0.00	1.33	1.64	2.01	1.30		**1.57** h
	0.25	1.41	1.93	2.10	1.64		**1.77** gh
	0.50	1.50	2.12	2.47	1.86		**1.99** gh
	1.00	1.86	2.24	2.74	2.07		**2.23** g
	Mean (AxC)	1.52 ef	1.98 de	2.33 d	1.71 e	**Mean (A)**	**1.89 C**
10	0.00	0.99	0.72	0.71	0.56		**0.75** ı
	0.25	1.24	0.92	0.84	0.64		**0.91** ı
	0.50	1.20	0.94	1.03	0.76		**0.98** ı
	1.00	1.10	1.02	0.41	1.01		**0.89** ı
	Mean (AxC)	1.13 fg	0.90 g	0.75 g	0.74 g	**Mean (A)**	**0.88 D**
Mean (BxC)	0.00	2.57	2.90	2.81	2.48	**Mean (B)**	**2.69** C
	0.25	2.64	2.99	2.94	2.79		**2.84** C
	0.50	2.87	3.18	3.41	3.16		**3.16** B
	1.00	3.34	3.49	3.61	3.45		**3.47** A
	Mean (C)	**2.85 C**	**3.14 AB**	**3.19 A**	**2.97 BC**		

4.1.8. Potassium (K)

Salt treatments had significant effects on shoot potassium (K) concentrations and contents (Table 4.1). Both K concentrations and contents decreased with increasing salt treatments. The average K concentration of 54.3 mg/g in control treatments respectively reduced to 51.7, 47.1, and 37.3 mg/g at 2.5, 5.0, and 10 dS m^{-1} salt level (Table 4.13). The average K content of 71.7 mg $plant^{-1}$ in control treatments decrease respectively to 54.3, 24.8, and 8.8 mg $plant^{-1}$ in the same salt levels (Table 4.14).

The effects of salicylic acid treatments on K concentrations and contents were also found to be significant (Table 4.1). Both K concentrations and K contents significantly increased with increasing SA treatments (Table 4.13 and 4.14). The average K concentration of 45.4 mg/g in control treatments without SA increased respectively to 47.1, 48.5, and 49.5 mg/g at 0.25, 0.5, and 1.0 mM SA doses (Table 4.13). Similarly, the average K content of 35.5 mg $plant^{-1}$ in control treatments increased respectively to 38.2, 41.5 and 44.5 mg $plant^{-1}$ at 0.25, 0.5 and 1.0 mM SA doses (Table 4.14).

The K concentrations of the genotypes were significantly different from each other (Table 4.1). The highest K concentrations were obtained from Candaş and Gökkan, which were placed into the same group. A similar case was also observed in K contents. The lowest K content (36.0 mg $plant^{-1}$) was obtained from Altınöz (Table 4.13 and 4.14).

Salt x SA interactions were found to be significant for K concentrations and contents (Table 4.1). Especially in control and 2.5 and 5.0 dS m^{-1} salt treatments, both K concentrations and K contents significantly increased with increasing SA doses (Table 4.13 and 4.14). The highest K concentration and content were observed at 1.0 mM SA dose without salt treatment. At the most fabulous salt dose, different SA doses did not have significant effects on K concentrations and contents (Table 4.13 and 4.14).

Table 4.13. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on K^+ concentration (mg g^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	K Concentration of Shoot (mg g^{-1})					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
0	0.00	51.8	52.3	54.6	52.1		52.7 bcd
	0.25	52.6	54.1	54.8	53.3		53.7 abc
	0.50	53.3	54.8	55.5	55.2		54.7 ab
	1.00	54.3	56.7	56.1	56.8		56.0 a
	Mean (AxC)	53.0 ab	54.5 ab	55.3 a	54.4 ab	**Mean (A)**	**54.3 A**
2.5	0.00	50.0	48.6	52.5	43.1		48.6 ef
	0.25	51.8	53.5	52.9	46.5		51.2 cde
	0.50	52.1	54.6	53.4	52.0		53.0 abc
	1.00	53.0	55.1	54.1	54.1		54.1 abc
	Mean (AxC)	51.7 bc	53.0 ab	53.2 ab	48.9 cde	**Mean (A)**	**51.7 B**
5	0.00	43.0	45.6	46.4	38.9		43.5 g
	0.25	44.9	48.3	49.4	44.3		46.7 f
	0.50	47.7	48.5	50.2	48.4		48.7 ef
	1.00	48.9	49.3	51.7	48.9		49.7 def
	Mean (AxC)	46.1 ef	47.9 def	49.4 cd	45.1 f	**Mean (A)**	**47.1 C**
10	0.00	35.6	38.2	37.7	35.4		36.7 h
	0.25	34.0	37.9	38.4	36.4		36.7 h
	0.50	33.2	38.8	40.2	38.0		37.6 h
	1.00	30.8	41.5	37.6	43.1		38.3 h
	Mean (AxC)	33.4 h	39.1 g	38.5 g	38.3 g	**Mean (A)**	**37.3 D**
Mean (BxC)	0.00	45.1 de	46.2 bcd	47.8 a-d	42.4 e	Mean (B)	**45.4** C
	0.25	45.8 cd	48.5 abc	48.9 ab	45.1 de		**47.1** B
	0.50	46.6 bcd	49.2 ab	49.8 a	48.4 abc		**48.5** A
	1.00	46.7 bcd	50.7 a	49.9 a	50.7 a		**49.5** A
	Mean (C)	**46.1 B**	**48.6 A**	**49.1 A**	**46.7 B**		

Table 4.14. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on K^+ content (mg $plant^{-1}$) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	K Content of Shoot (µg plant)$^{-1}$					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
0	0.00	62.9	65.5	71.2	66.6		66.6 b
	0.25	64.3	69.0	72.2	69.3		68.7 b
	0.50	66.4	73.6	77.4	77.5		73.7 a
	1.00	68.9	81.7	80.0	80.8		77.9 a
	Mean (AxC)	65.6 b	72.5 a	75.2 a	73.5 a	**Mean (A)**	**71.7 A**
2.5	0.00	47.4	54.4	48.0	37.0		46.7 f
	0.25	48.6	59.5	51.2	48.7		52.0 e
	0.50	50.2	60.6	59.1	56.9		56.7 d
	1.00	57.3	63.1	66.5	61.0		62.0 c
	Mean (AxC)	50.9 d	59.4 c	56.2 c	50.9 d	**Mean (A)**	**54.3 B**
5	0.00	18.3	21.4	26.4	14.8		20.2 ı
	0.25	18.7	25.7	28.8	20.3		23.4 hı
	0.50	20.5	28.0	33.4	24.6		26.7 gh
	1.00	24.4	29.2	36.3	26.6		29.1 g
	Mean (AxC)	20.5 g	26.1 f	31.2 e	21.6 g	**Mean (A)**	**24.8 C**
10	0.00	7.8	9.6	9.5	6.8		8.4 j
	0.25	7.1	10.0	10.5	7.3		8.8 j
	0.50	6.7	10.1	11.3	8.3		9.1 j
	1.00	5.9	11.4	6.4	12.2		9.0 j
	Mean (AxC)	6.9 h	10.3 h	9.4 h	8.7 h	**Mean (A)**	**8.8 D**
Mean (BxC)	0.00	34.1 ıj	37.7 f-ı	38.8 fgh	31.3 j	**Mean (B)**	**35.5 D**
	0.25	34.7 hıj	41.0 def	40.7 ef	36.4 ghı		**38.2 C**
	0.50	36.0 ghı	43.1 b-e	45.3 abc	41.8 c-f		**41.5 B**
	1.00	39.1 efg	46.3 ab	47.3 a	45.2 a-d		**44.5 A**
	Mean (C)	**36.0 C**	**42.0 A**	**43.0 A**	**38.7** B		

Salt x genotype interactions had significant effects on K concentrations and contents (Table 4.1). K concentrations and contents of the genotypes significantly decreased with increasing salt treatments. At 10 dS m^{-1} salt level, Altınöz genotype had lower K concentration and K content than the other genotypes (Table 4.13 and 4.14).

Salicylic acid x genotype interactions also had significant effects on K concentrations and contents (Table 4.1). As compared to the control conditions without salicylic acid treatments, the most considerable increase in K concentration and content with 1.0 mM SA treatments were observed in Yakamoz (Table 4.13 and 4.14).

4.1.9. K/Na ratio

Increasing salinity levels significantly decreased the K/Na ratio. The average K/Na ratio of 55.75 in control treatments respectively reduced to 16.01, 10.97, and 5.46 at 2.5, 5.0, and 10 dS m^{-1} salt levels. SA treatments significantly increased shoot K/Na ratios of the genotypes.

Salt x SA interactions were found to be significant for K/Na ratios. At 0, 2.5, and 5.0 dS m^{-1} salt levels, SA treatments significantly increased K/Na ratios. As compared to non-salt treatments, SA treatments increased K/Na ratios by 46% at 10 dS m^{-1} level salinity level, and such increases were respectively observed as 51 and 57% at 2.5 and 5 dS m^{-1} salinity levels (Table 4.15).

Table 4.15. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on K^+/Na^+ ratio in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	K / Na					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
Control	0.00	48.74	45.65	45.50	44.57		46.11 c
	0.25	51.06	52.82	56.11	53.17		53.29 bc
	0.50	54.23	58.47	57.30	55.78		56.44 b
	1.00	57.94	63.75	75.38	71.56		67.16 a
	Mean (AxC)	52.99	55.17	58.57	56.27	**Mean (A)**	55.75 **A**
2.5	0.00	15.34	13.27	12.68	9.38		12.67 def
	0.25	17.38	16.54	13.83	12.48		15.06 def
	0.50	18.30	17.35	17.44	15.54		17.16 de
	1.00	19.16	19.15	19.85	18.55		19.18 d
	Mean (AxC)	17.54	16.58	15.95	13.99	**Mean (A)**	**16.01 B**
5	0.00	10.48	10.17	7.61	5.70		8.49 ef
	0.25	11.75	11.88	9.50	8.07		10.30 def
	0.50	13.15	12.58	10.90	10.36		11.75 def
	1.00	15.23	12.96	11.96	13.29		13.36 def
	Mean (AxC)	12.65	11.90	9.99	9.36	**Mean (A)**	**10.97 C**
10	0.00	5.68	5.14	4.88	4.37		5.02 f
	0.25	4.70	5.53	5.52	5.23		5.25 f
	0.50	4.50	6.34	6.13	6.26		5.81 f
	1.00	3.54	7.43	4.46	7.61		5.76 f
	Mean (AxC)	4.60	6.11	5.25	5.87	**Mean (A)**	**5.46 D**
Mean (BxC)	0.00	20.06	18.56	17.67	16.00	**Mean (B)**	**18.07 C**
	0.25	21.22	21.69	21.24	19.74		**20.97 BC**
	0.50	22.54	23.69	22.94	21.99		**22.79 AB**
	1.00	23.97	25.82	27.91	27.75		**26.36 A**
	Mean (C)	**21.95**	**22.44**	**22.44**	**21.37**		

4.1.10. Calcium (Ca)

Salt treatments had significant effects on calcium (Ca) concentrations and contents (Table 4.1). Increased Ca concentrations and decreasing Ca contents were observed with increasing salinity levels (Table 4.16 and 4.17). The average Ca concentration of 6.2 mg/g in control treatments increased to 12.3 mg/g at 10 dS m^{-1} salt treatment. On the other hand, the average Ca content of 8.2 mg $plant^{-1}$ decreased to 2.9 mg $plant^{-1}$ at 10 dS m^{-1} salt level (Table 4.16 and 4.17).

Salicylic acid treatments had a significant effect on Ca concentrations, but the effects on Ca contents were not found to be significant (Table 4.16 and 4.17). The average Ca level of 9.6 mg/g decreased significantly with SA treatments and recessed to 8.3 mg/g at 1.0 mM SA dose (Table 4.16).

While Ca concentrations of the genotypes were not significantly different from each other, there were significant differences in Ca contents of the genotypes (Table 4.1). While the greatest Ca content (6.4 mg $plant^{-1}$) was obtained from Gökkan, the lowest one (5.3 mg $plant^{-1}$) from Altınöz genotype (Table 4.17).

Salt x genotype interactions were found to be significant for both Ca concentrations and Ca contents (Table 4.1). The greatest Ca concentrations were observed at 10 dS m^{-1} salt dose of Altınöz, Candaş, and Gökkan genotypes (Table 4.16). On the other hand, the greatest Ca contents were observed in non-salt treatments of Gökkan and Yakamoz genotypes (Table 4.17). At 10 dS m^{-1} salt treatments, all genotypes were placed into the same group and had low Ca content levels (Table 4.17).

Salicylic acid x genotype interactions were found to be significant for Ca concentrations, but insignificant for Ca contents (Table 4.1). In Altınöz, increasing SA treatments increased slightly Ca concentrations (Table 4.16). On the other hand, Ca concentrations of the other genotypes decreased with enhancing SA treatments, and such decreases were more evident in Gökkan and Yakamoz genotypes in comparison to others (Table 4.16).

Table 4.16. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on Ca^{2+} concentration (mg g^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	Ca Concentration of Shoot (mg g^{-1})					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
0	0.00	6.1	5.4	7.0	7.6		**6.6**
	0.25	6.5	6.2	6.5	6.3		**6.4**
	0.50	6.1	6.0	6.0	5.9		**6.0**
	1.00	5.5	6.5	5.9	5.8		**5.9**
Mean (AxC)		6.1 ef	6.0 f	6.4 ef	6.4 ef	**Mean (A)**	**6.2 D**
2.5	0.00	7.5	7.8	8.6	8.7		8.2
	0.25	6.9	7.6	7.6	7.6		7.4
	0.50	7.5	6.9	6.9	6.9		7.0
	1.00	7.3	7.9	6.0	6.3		6.9
Mean (AxC)		7.3 def	7.6 de	7.3 def	7.4 def	**Mean (A)**	**7.4 C**
5	0.00	8.8	11.2	11.3	11.6		10.7
	0.25	8.9	9.9	10.5	10.8		10.0
	0.50	8.6	9.6	9.7	9.5		9.3
	1.00	8.2	9.2	8.5	8.5		8.6
Mean (AxC)		8.6 cd	10.0 bc	10.0 bc	10.1 bc	**Mean (A)**	**9.7 B**
10	0.00	12.0	13.1	13.9	13.1		13.0
	0.25	12.3	13.3	12.5	11.9		12.5
	0.50	13.2	12.1	11.6	11.0		12.0
	1.00	14.5	10.7	12.1	10.0		11.8
Mean (AxC)		13.0 a	12.3 a	12.5 a	11.5 ab	**Mean (A)**	**12.3 A**
Mean (BxC)	0.00	8.6 bc	9.4 ab	10.2 a	10.3 a	**Mean (B)**	**9.6 A**
	0.25	8.6 bc	9.2 ab	9.3 ab	9.1 abc		**9.1 AB**
	0.50	8.8 abc	8.6 bc	8.5 bc	8.3 bc		**8.6 BC**
	1.00	8.9 abc	8.6 bc	8.1 bc	7.6 c		**8.3 C**
Mean (C)		**8.7**	**9.0**	**9.0**	**8.8**		

Table 4.17. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on Ca^{2+} content (mg $plant^{-1}$) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl	SA	Ca Content of Shoot (µg plant)$^{-1}$					Mean
(dS m^{-1})	(mM)	Altınöz	Candaş	Gökkan	Yakamoz		(AxB)
0	0.00	7.4	6.8	9.2	9.8		8.3
	0.25	7.9	7.9	8.6	8.1		8.1
	0.50	7.6	8.0	8.4	8.3		8.1
	1.00	7.0	9.4	8.4	8.2		8.3
Mean (AxC)		7.5 abc	8.0 ab	8.7 a	8.6 a	**Mean (A)**	**8.2 A**
2.5	0.00	7.1	8.8	7.9	7.4		7.8
	0.25	6.4	8.5	7.3	7.9		7.5
	0.50	7.2	7.6	7.7	7.6		7.5
	1.00	7.9	9.0	7.4	7.1		7.8
Mean (AxC)		7.2 bc	8.5 a	7.6 ab	7.5 abc	**Mean (A)**	**7.7 B**
5	0.00	3.8	5.2	6.5	4.4		5.0
	0.25	3.7	5.3	6.1	4.9		5.0
	0.50	3.7	5.6	6.4	4.8		5.1
	1.00	4.1	5.5	6.0	4.6		5.0
Mean (AxC)		3.8 fg	5.4 de	6.2 cd	4.7 ef	**Mean (A)**	**5.0 C**
10	0.00	2.7	3.3	3.5	2.5		3.0
	0.25	2.6	3.5	3.4	2.4		3.0
	0.50	2.7	3.1	3.3	2.4		2.9
	1.00	2.8	2.9	2.0	2.8		2.6
Mean (AxC)		2.7 g	3.2 g	3.1 g	2.5 g	**Mean (A)**	**2.9 D**
Mean (BxC)	0.00	5.2	6.0	6.8	6.0	**Mean (B)**	**6.0**
	0.25	5.1	6.3	6.4	5.8		**5.9**
	0.50	5.3	6.1	6.4	5.8		**5.9**
	1.00	5.4	6.7	6.0	5.7		**5.9**
Mean (C)		**5.3 C**	**6.3 AB**	**6.4 A**	**5.8** B		

4.1.11. Ca/Na ratio

Increasing salinity levels significantly decreased the Ca/Na ratio. The average Ca/Na ratio of 6.31 in control treatments, respectively, dropped to 2.25, 2.20, and 1.77 with increasing salinity levels. An increase in Ca/Na ratios with SA treatments was not found to be significant. Salt x SA interactions were found to be insignificant for Ca/Na ratios (Table 4.18).

Table 4.18. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on Ca^{2+}/Na^{+} ratio in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl	SA	Ca / Na					Mean
(dS m^{-1})	(mM)	Altınöz	Candaş	Gökkan	Yakamoz		(AxB)
Control	0.00	5.73	4.77	5.88	6.44		5.71
	0.25	6.24	6.05	6.48	6.32		6.27
	0.50	6.19	6.42	6.15	5.90		6.17
	1.00	5.87	7.39	7.75	7.32		7.08
Mean (AxC)		6.01	6.16	6.56	6.50	**Mean (A)**	6.31 **A**
2.5	0.00	2.33	2.14	2.07	1.86		2.10
	0.25	2.30	2.37	1.96	2.04		2.17
	0.50	2.61	2.17	2.28	2.07		2.28
	1.00	2.64	2.72	2.20	2.16		2.43
Mean (AxC)		2.47	2.35	2.13	2.04	**Mean (A)**	**2.25 B**
5	0.00	2.17	2.50	1.85	1.72		2.06
	0.25	2.33	2.43	2.03	1.96		2.19
	0.50	2.38	2.52	2.11	2.03		2.26
	1.00	2.54	2.42	1.97	2.27		2.30
Mean (AxC)		2.36	2.47	1.99	1.99	**Mean (A)**	**2.20 BC**
10	0.00	1.91	1.75	1.81	1.61		1.77
	0.25	1.70	1.94	1.79	1.71		1.78
	0.50	1.79	1.96	1.78	1.82		1.84
	1.00	1.67	1.91	1.46	1.75		1.70
Mean (AxC)		1.77	1.89	1.71	1.72	**Mean (A)**	**1.77 C**
Mean (BxC)	0.00	3.03	2.79	2.90	2.91	**Mean (B)**	**2.91**
	0.25	3.14	3.20	3.07	3.01		**3.10**
	0.50	3.24	3.27	3.08	2.96		**3.14**
	1.00	3.18	3.61	3.34	3.37		**3.38**
Mean (C)		**3.15**	**3.22**	**3.10**	**3.06**		

4.1.12. Magnesium (Mg)

The effects of salt treatments on magnesium (Mg) concentrations and content were found to be significant (Table 4.1). Shoot Mg concentrations increased with increasing salt treatments (Table 4.19 and 4.20). On the other hand, plant Mg contents significantly decreased with salt treatments. The average mg content of 2.70 mg plant^{-1} in control treatments decreased to 0.70 mg/plant^{-1} at 10 dS m^{-1} salt level (Table 4.20).

Salicylic acid treatments had significant effects on Mg concentrations, but the effects on Mg contents were not found to be significant (Table 4.1). Mg concentrations significantly decreased with increasing SA treatments. Accordingly, the average Mg concentration of 2.81 mg/g in non-SA treatments decreased respectively to 2.59, 2.53, and 2.30 mg/g at 0.25, 0.50, and 1.0 mM SA doses (Table 4.19).

There were significant differences in Mg concentrations and contents of the genotypes (Table 4.20). The highest Mg concentration (2.78 mg/g) was obtained from Altınöz, and the lowest Mg concentration (2.35 mg/g) was obtained from Gökkan (Table 4.19 and 4.20). On the other hand, the highest Mg content was derived from Candaş, and the lowest Mg contents were obtained from Gökkan and Yakamoz genotypes (Table 4.20).

Salt x genotype interactions were not found to be significant for Mg concentrations, but notable for Mg contents (Table 4.1). The highest Mg content was obtained from non-salt treatment of Candaş, and the lowest Mg contents were obtained from 10 dS m^{-1} salt treatments, but there were not any remarkable differences in Mg contents of the genotypes in this salt level (Table 4.20).

Table 4.19. Effect of salicylic acid levels (0,0.25, 0.5, 1.0 mM) on Mg^{2+} concentration (mg g^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0,10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	Mg Concentration of Shoot (mg g^{-1})					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
0	0.00	2.51	2.28	1.96	2.08		2.21
	0.25	2.29	2.33	1.89	1.95		2.12
	0.50	2.21	2.27	1.84	1.85		2.04
	1.00	2.03	2.15	1.45	1.83		1.86
	Mean (AxC)	2.26	2.26	1.78	1.93	**Mean (A)**	**2.06 C**
2.5	0.00	3.11	2.63	2.75	2.62		2.78
	0.25	2.89	2.53	2.16	2.46		2.51
	0.50	2.85	2.48	2.07	2.37		2.44
	1.00	2.51	2.23	1.55	2.12		2.10
	Mean (AxC)	2.84	2.47	2.13	2.39	**Mean (A)**	**2.46 B**
5	0.00	3.29	2.88	3.00	2.93		3.03
	0.25	2.95	2.73	2.53	2.77		2.75
	0.50	2.90	2.65	2.43	2.64		2.66
	1.00	2.75	2.63	1.97	2.46		2.45
	Mean (AxC)	2.97	2.73	2.48	2.70	**Mean (A)**	**2.72 B**
10	0.00	3.37	3.02	3.33	3.19		3.23
	0.25	3.01	2.99	3.00	2.99		3.00
	0.50	2.95	3.13	2.90	2.88		2.96
	1.00	2.88	2.97	2.72	2.56		2.78
	Mean (AxC)	3.05	3.03	2.99	2.91	**Mean (A)**	**2.99 A**
Mean (BxC)	0.00	3.07	2.70	2.76	2.71	**Mean (B)**	**2.81 A**
	0.25	2.79	2.65	2.39	2.55		**2.59 AB**
	0.50	2.73	2.63	2.31	2.43		**2.53 BC**
	1.00	2.54	2.50	1.92	2.24		**2.30 C**
	Mean (C)	**2.78 A**	**2.62 AB**	**2.35 C**	**2.48 BC**		

Table 4.20. Effect of salicylic acid levels (0,0.25, 0.5, 1.0 mM) on Mg^{2+} content (mg $plant^{-1}$) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0,10 dS m^{-1}).

NaCl	SA	Mg Content of Shoot (µg plant)$^{-1}$					Mean
(dS m-1)	(mM)	Altınöz	Candaş	Gökkan	Yakamoz		(AxB)
0	0.00	3.04	2.87	2.56	2.65		2.78
	0.25	2.80	2.97	2.48	2.54		2.70
	0.50	2.76	3.05	2.55	2.60		2.74
	1.00	2.55	3.10	2.07	2.60		2.58
Mean (AxC)		2.79 ab	3.00 a	2.42 bc	2.60 abc	**Mean (A)**	**2.70 A**
2.5	0.00	2.95	2.95	2.55	2.24		2.67
	0.25	2.71	2.82	2.09	2.57		2.55
	0.50	2.75	2.76	2.28	2.59		2.60
	1.00	2.72	2.54	1.92	2.39		2.39
Mean (AxC)		2.78 ab	2.77 ab	2.21 c	2.45 bc	**Mean (A)**	**2.55 A**
5	0.00	1.38	1.35	1.72	1.10		1.39
	0.25	1.23	1.46	1.45	1.27		1.35
	0.50	1.25	1.53	1.62	1.35		1.44
	1.00	1.38	1.56	1.38	1.33		1.41
Mean (AxC)		1.31 d	1.47 d	1.54 d	1.26 de	**Mean (A)**	**1.40 B**
10	0.00	0.75	0.76	0.85	0.62		0.74
	0.25	0.63	0.79	0.83	0.60		0.72
	0.50	0.60	0.81	0.80	0.63		0.71
	1.00	0.55	0.82	0.46	0.72		0.64
Mean (AxC)		0.63 f	0.79 ef	0.74 f	0.64 f	**Mean (A)**	**0.70 C**
	0.00	2.03	1.98	1.92	1.65		**1.90**
Mean	0.25	1.84	2.01	1.71	1.74	**Mean (B)**	**1.83**
(BxC)	0.50	1.84	2.04	1.81	1.79		**1.87**
	1.00	1.80	2.00	1.46	1.76		**1.76**
Mean (C)		**1.88 AB**	**2.01 A**	**1.73 B**	**1.74 B**		

4.1.13. Iron (Fe)

Salt treatments had significant effects on iron (Fe) concentrations and contents (Table 4.1). Both shoot Fe concentrations and Fe contents significantly decreased with increasing salt treatments (Table 4.21 and 4.22). The average Fe concentration of 76.9 mg/kg in control treatments decreased by 12.3% to 67.4 mg/kg at 10 dS m^{-1} salt level. The decrease rates in Fe contents with salt treatments were greater than the concentrations of it. Accordingly, the average Fe content of 101.7 µg $plant^{-1}$ in control treatments decreased respectively to 78.4, 37.9, and 16.1 µg $plant^{-1}$ at 2.5, 5.0, and 10 dS m^{-1} salt levels (Table 4.21 and 4.22).

The effects of salicylic acid treatments on Fe concentrations and contents were also found to be significant (Table 4.1). Fe concentrations and contents significantly increased with increasing SA treatments (Table 4.21 and 4.22). As compared to the control conditions, Fe concentration increased by 11.1% with 1.0 mM SA treatment. On the other hand, under the same conditions, Fe content increased by 25.1% (Table 4.21 and 4.22).

The Fe concentrations and contents of the genotypes were significantly different from each other (Table 4.1). The highest Fe concentration (79.6 mg/kg) was obtained from Candaş genotype, and the lowest Fe concentration (63.5 mg/kg) was obtained from Altınöz genotype. Concerning Fe contents, it was observed that Candaş and Gökkan genotypes had high Fe contents and the lowest Fe content (48.1 µg $plant^{-1}$) was observed in Altınöz genotype (Table 4.21 and 4.22).

Table 4.21. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on Fe concentration (mg kg^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl	SA	Fe Concentration of Shoot (mg kg^{-1})					Mean
(dS m^{-1})	(mM)	Altınöz	Candaş	Gökkan	Yakamoz		(AxB)
0	0.00	71.6	81.5	81.3	74.4		77.2
	0.25	67.8	79.5	78.8	74.5		75.2
	0.50	65.4	79.8	76.9	76.0		74.5
	1.00	71.3	87.1	82.7	81.3		80.6
Mean (AxC)		69.0	82.0	79.9	76.5	**Mean (A)**	**76.9 A**
2.5	0.00	67.7	77.8	71.5	68.3		71.3
	0.25	68.3	74.7	74.1	72.4		72.4
	0.50	71.3	79.6	80.7	72.8		76.1
	1.00	71.4	84.0	81.2	76.6		78.3
Mean (AxC)		69.7	79.0	76.9	72.5	**Mean (A)**	**74.5 A**
5	0.00	54.7	76.3	70.5	66.3		66.9
	0.25	58.1	77.9	72.4	71.3		69.9
	0.50	56.1	77.9	78.0	74.5		71.6
	1.00	69.3	83.7	80.0	77.1		77.5
Mean (AxC)		59.5	79.0	75.3	72.3	**Mean (A)**	**71.5 AB**
10	0.00	52.5	70.1	67.0	57.9		61.9
	0.25	55.0	72.2	70.6	65.0		65.7
	0.50	57.7	81.8	79.7	63.7		70.7
	1.00	58.1	89.0	63.9	74.7		71.4
Mean (AxC)		55.8	78.3	70.3	65.3	**Mean (A)**	**67.4 B**
Mean (BxC)	0.00	61.6	76.4	72.6	66.7	**Mean (B)**	**69.3 B**
	0.25	62.3	76.1	74.0	70.8		**70.8 B**
	0.50	62.6	79.8	78.8	71.8		**73.2 AB**
	1.00	67.5	86.0	76.9	77.4		**77.0 A**
Mean (C)		**63.5 C**	**79.6 A**	**75.6 AB**	**71.7 B**		

Table 4.22. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on Fe content (µg plant^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl	SA	Fe Content of Shoot (µg plant)$^{-1}$					Mean
(dS m^{-1})	(mM)	Altınöz	Candaş	Gökkan	Yakamoz		(AxB)
0	0.00	87.0	101.9	105.9	95.1		97.5
	0.25	82.8	101.1	103.7	96.8		96.1
	0.50	81.4	106.8	107.2	107.3		100.7
	1.00	90.5	126.2	118.0	115.4		112.5
Mean (AxC)		85.4	109.0	108.7	103.7	**Mean (A)**	**101.7 A**
2.5	0.00	64.3	86.9	64.6	58.5		68.6
	0.25	64.2	83.2	71.3	76.0		73.7
	0.50	68.6	89.4	88.9	79.7		81.6
	1.00	77.4	96.3	99.4	86.4		89.9
Mean (AxC)		68.6	88.9	81.1	75.1	**Mean (A)**	**78.4 B**
5	0.00	23.6	35.8	40.2	24.9		31.1
	0.25	24.3	41.6	42.1	32.8		35.2
	0.50	24.1	44.8	51.8	38.2		39.7
	1.00	34.5	49.6	56.4	41.9		45.6
Mean (AxC)		26.6	42.9	47.6	34.4	**Mean (A)**	**37.9 C**
10	0.00	11.6	17.5	17.0	11.1		14.3
	0.25	11.7	19.1	19.4	12.9		15.8
	0.50	11.7	21.2	22.3	14.0		17.3
	1.00	11.2	24.8	10.8	21.1		17.0
Mean (AxC)		11.5	20.7	17.4	14.8	**Mean (A)**	**16.1 D**
Mean (BxC)	0.00	46.6	60.5	56.9	47.4		**52.9 C**
	0.25	45.8	61.2	59.1	54.6	**Mean (B)**	**55.2 BC**
	0.50	46.5	65.5	67.5	59.8		**59.8 B**
	1.00	53.4	74.2	71.1	66.2		**66.2 A**
Mean (C)		**48.1 C**	**65.4 A**	**63.7 A**	**57.0 B**		

4.1.14. Zinc (Zn)

The effects of salt treatments on shoot zinc (Zn) concentrations and contents were found to be significant (Table 4.1). The average Zn concentration of 29.8 mg/kg in control treatments increased to 32.8 mg/kg at 2.5 dS m^{-1} level. However, the values decreased respectively to 29.6 and 19.9 mg/kg at 5 and 10 dS m^{-1} salt levels (Table 4.23). On the other hand, a gradual decrease was observed in Zn contents with increasing salt doses. Accordingly, the average Zn content of 39.3 µg $plant^{-1}$ decreased respectively to 34.4, 15.7, and 4.7 µg $plant^{-1}$ at 2.5, 5.0, and 10 dS m^{-1} salt levels (Table 4.24).

While the effects of salicylic acid treatments on Zn concentrations were not found to be significant, effects on Zn contents were found to be significant (Table 4.1). Zn contents at 0.5 and 1.0 mM doses of SA were about 10% greater than the Zn contents at 0 and 0.25 mM SA doses (Table 4.24).

There were significant differences in Zn concentrations and contents of the genotypes (Table 4.23 and 4.24). The highest Zn concentration (30.1 mg/kg) was obtained from Gökkan, and the lowest Zn concentration (25.0 mg/kg) was obtained from Altınöz. A similar case was also observed in Zn contents (Table 4.23 and 4.24). Salt x SA interactions were found to be significant for Zn concentrations, but insignificant for Zn contents (Table 4.1). The highest Zn contents were observed at 0 and 0.25 mM SA treatments with 2.5 dS m^{-1} salt level (Table 4.24). The lowest Zn concentrations were observed in the highest salt dose, and SA treatments were not found to be effective in this salt level (Table 4.23).

Salt x genotype interactions were found to be significant for both Zn concentrations and Zn contents (Table 4.1). The highest Zn concentration (35.6 mg/kg) was found at 2.5 dS m^{-1} level of Gökkan, and the lowest Zn concentration (16.7 mg/kg) was found at 10 dS m^{-1} level of Altınöz (Table 4.23). The highest Zn content (43.1 µg $plant^{-1}$) was seen in the non-salt treated Gökkan genotype. At 2.5 dS m^{-1} salt level, Candaş, Gökkan, and Yakamoz genotypes were placed into the same group and had more fabulous Zn contents than Altınöz (Table 4.24). At 10 dS m^{-1} level, all genotypes were placed into the same statistical group.

Table 4.23. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on Zn concentration (mg kg^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	Zn Concentration of Shoot (mg kg^{-1})					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
0	0.00	28.9	29.3	30.7	30.4		29.8 a-d
	0.25	28.2	28.8	31.2	32.2		30.1 a-d
	0.50	28.0	28.0	33.4	30.3		29.9 a-d
	1.00	27.1	28.1	31.5	30.6		29.3 bcd
Mean (AxC)		28.0 cd	28.5 cd	31.7 bc	30.9 bc	**Mean (A)**	**29.8 B**
2.5	0.00	29.8	33.6	36.1	34.2		33.4 a
	0.25	31.4	31.4	36.8	32.9		33.1 a
	0.50	29.8	33.1	35.4	32.6		32.7 ab
	1.00	28.5	33.4	34.2	31.9		32.0 abc
Mean (AxC)		29.9 bc	32.9 ab	35.6 a	32.9 ab	**Mean (A)**	**32.8 A**
5	0.00	24.0	29.1	31.5	27.1		27.9 d
	0.25	23.4	29.4	31.9	29.0		28.4 cd
	0.50	26.0	30.8	33.5	31.0		30.3 a-d
	1.00	27.5	35.0	34.8	30.4		31.9 abc
Mean (AxC)		25.2 de	31.1 bc	32.9 ab	29.4 bc	**Mean (A)**	**29.6 B**
10	0.00	20.8	19.6	17.1	17.0		18.6 e
	0.25	16.4	22.2	21.1	17.9		19.4 e
	0.50	14.6	23.3	23.2	19.3		20.1 e
	1.00	15.1	27.9	20.2	22.2		21.3 e
Mean (AxC)		16.7 h	23.3 ef	20.4 fg	19.1 gh	**Mean (A)**	**19.9 C**
Mean (BxC)	0.00	25.8	27.9	28.9	27.2	**Mean (B)**	**27.4**
	0.25	24.8	28.0	30.2	28.0		**27.8**
	0.50	24.6	28.8	31.3	28.3		**28.3**
	1.00	24.6	31.1	30.1	28.8		**28.6**
Mean (C)		**25.0 C**	**28.9 AB**	**30.1 A**	**28.1 B**		

Table 4.24. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on Zn content (µg plant^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl	SA	Zn Content of Shoot (µg plant)$^{-1}$					Mean
(dS m^{-1})	(mM)	Altınöz	Candaş	Gökkan	Yakamoz		(AxB)
0	0.00	35.0	36.9	40.1	38.7		37.7
	0.25	34.4	36.6	41.0	41.8		38.4
	0.50	34.9	37.6	46.5	42.6		40.4
	1.00	34.5	40.4	44.9	43.5		40.8
Mean (AxC)		34.7 c	37.9 bc	43.1 a	41.7 ab	**Mean (A)**	**39.3 A**
2.5	0.00	28.3	37.5	33.0	29.5		32.1
	0.25	29.5	34.9	35.5	34.6		33.6
	0.50	28.7	36.9	39.0	35.7		35.1
	1.00	31.0	38.2	41.9	36.1		36.8
Mean (AxC)		29.4 d	36.9 c	37.3 c	33.9 c	**Mean (A)**	**34.4 B**
5	0.00	10.2	13.6	18.0	10.2		13.0
	0.25	9.8	15.7	18.4	13.3		14.3
	0.50	11.2	17.8	22.2	15.9		16.8
	1.00	13.6	20.7	24.4	16.3		18.8
Mean (AxC)		11.2 g	17.0 ef	20.8 e	13.9 fg	**Mean (A)**	**15.7 C**
10	0.00	4.5	4.9	4.3	3.3		4.3
	0.25	3.4	5.9	5.8	3.6		4.7
	0.50	3.0	6.1	6.5	4.2		4.9
	1.00	2.9	7.7	3.4	6.3		5.1
Mean (AxC)		3.5 h	6.1 h	5.0 h	4.3 h	**Mean (A)**	**4.7 D**
Mean (BxC)	0.00	19.5	23.2	23.8	20.4		**21.7 B**
	0.25	19.3	23.3	25.2	23.3	**Mean (B)**	**22.8 B**
	0.50	19.4	24.6	28.5	24.6		**24.3 A**
	1.00	20.5	26.7	28.7	25.5		**25.4 A**
Mean (C)		**19.7 C**	**24.5 B**	**26.6 A**	**23.5 B**		

4.1.15. Manganese (Mn)

Salt treatments had significant effects on manganese (Mn) concentrations and contents (Table 4.1). Mn concentrations increased, and Mn contents decreased with enhancing salt treatments. The average Mn concentration of 60.3 mg/kg in control treatments increased respectively to 70.2, 73.1, and 74.8 mg/kg at 2.5, 5.0, and 10 dS m^{-1} salt levels, and these three values were placed into the same group (Table 4.25). There was a gradual decrease in Mn contents with salt treatments. The average Mn content of 79.7 µg $plant^{-1}$ in control treatments decreased respectively to 73.9, 38.1, and 17.6 µg $plant^{-1}$ at 2.5, 5.0, and 10 dS m^{-1} salt levels (Table 4.26). Salicylic acid treatments did not have significant effects on Mn concentrations, but significantly increased Mn contents (Table 4.1, Table 4.25, and 4.26). The average Mn content of 45.8 µg $plant^{-1}$ in control treatments increased to 59.7 µg $plant^{-1}$ at 10 dS m^{-1} salt level (Table 4.26).

Mn concentrations and contents of the genotypes were significantly different from each other (Table 4.1). Altınöz and Gökkan genotypes with an average Mn concentration of 75 mg $plant^{-1}$ were placed into the same group and had higher Mn concentrations than the other two genotypes (Table 4.25). The highest Mn content (59.5 µg $plant^{-1}$) was obtained from Gökkan. The average of the Mn contents of the other three genotypes was 50 µg $plant^{-1,}$ and they were placed into the same group (Table 4.26).

Salt x SA treatments were not found to be significant for Mn concentrations, but notable for Mn contents (Table 4.1). The highest Mn content was observed at 1.0 mM SA treatments with no and 2.5 dS m^{-1} salt levels. The lowest Mn content was found at 0 and 1.0 mM SA treatments with 10 dS m^{-1} salt level (Table 4.26).

Salt x genotype interactions did not have any significant effects on Mn concentrations but significantly influenced Mn contents (Table 4.1). The highest Mn content (93.3 µg $plant^{-1}$) was obtained from the non-salt treatment of Gökkan genotype. At 10 dS m^{-1} salt level, Altınöz and Yakamoz genotypes had lower Mn contents than the other genotypes (Table 4.26).

Table 4.25. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on Mn concentration (mg kg^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	Mn Concentration of Shoot (mg kg^{-1})					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
0	0.00	60.6	48.3	66.0	51.9		56.7
	0.25	63.3	47.8	66.7	56.8		58.6
	0.50	67.8	51.4	69.9	55.7		61.2
	1.00	69.8	59.0	71.3	59.2		64.8
Mean (AxC)		65.4	51.6	68.5	55.9	**Mean (A)**	**60.3 B**
2.5	0.00	66.1	61.5	68.4	61.6		64.4
	0.25	68.2	65.3	69.4	66.9		67.5
	0.50	76.5	73.2	73.2	69.2		73.0
	1.00	79.9	72.5	77.6	74.3		76.1
Mean (AxC)		72.7	68.1	72.1	68.0	**Mean (A)**	**70.2 A**
5	0.00	77.9	63.6	74.5	67.4		70.9
	0.25	80.2	63.7	77.3	65.2		71.6
	0.50	81.2	65.5	73.8	70.4		72.7
	1.00	84.6	73.1	78.3	72.1		77.0
Mean (AxC)		81.0	66.5	76.0	68.8	**Mean (A)**	**73.1 A**
10	0.00	85.0	71.9	82.7	59.1		74.7
	0.25	79.1	70.5	83.2	63.3		74.0
	0.50	82.2	75.3	84.4	64.3		76.6
	1.00	77.2	76.5	75.7	67.3		74.1
Mean (AxC)		80.8	73.5	81.5	63.5	**Mean (A)**	**74.8 A**
Mean (BxC)	0.00	72.4	61.3	72.9	60.0		**66.7**
	0.25	72.7	61.8	74.1	63.1	**Mean (B)**	**67.9**
	0.50	76.9	66.4	75.3	64.9		**70.9**
	1.00	77.9	70.3	75.7	68.2		**73.0**
Mean (C)		**75.0 A**	**64.9 B**	**74.5 A**	**64.1 B**		

Table 4.26. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on Mn content (µg plant^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl (dS m^{-1})	SA (mM)	Mn Content of Shoot (µg plant)$^{-1}$					Mean (AxB)
		Altınöz	Candaş	Gökkan	Yakamoz		
0	0.00	73.6	60.3	86.1	66.4		71.6 bc
	0.25	77.1	60.8	87.9	73.7		74.9 abc
	0.50	84.5	69.2	97.4	78.1		82.3 ab
	1.00	88.8	84.9	101.6	84.3		89.9 a
Mean (AxC)		81.0 ab	68.8 b	93.3 a	75.6 b	**Mean (A)**	**79.7 A**
2.5	0.00	62.8	68.1	62.6	53.6		61.8 c
	0.25	64.2	72.7	67.0	70.2		68.5 bc
	0.50	73.5	80.7	81.8	76.2		78.0 ab
	1.00	86.3	82.6	95.5	83.9		87.1 a
Mean (AxC)		71.7 b	76.0 b	76.7 b	71.0 b	**Mean (A)**	**73.9 B**
5	0.00	33.1	29.4	42.1	25.3		32.5 de
	0.25	33.3	34.4	45.0	29.9		35.6 d
	0.50	34.9	38.3	49.1	35.9		39.5 d
	1.00	42.3	43.0	55.1	38.2		44.7 d
Mean (AxC)		35.9 cd	36.3 cd	47.8 c	32.3 de	**Mean (A)**	**38.1 C**
10	0.00	18.8	17.9	20.8	11.4		17.2 f
	0.25	16.5	18.2	22.8	12.6		17.6 ef
	0.50	16.9	19.6	23.6	14.2		18.6 ef
	1.00	14.9	21.1	12.8	19.1		17.0 f
Mean (AxC)		16.8 f	19.2 ef	20.0 ef	14.3 f	**Mean (A)**	**17.6 D**
Mean (BxC)	0.00	47.1	43.9	52.9	39.2		**45.8 C**
	0.25	47.8	46.5	55.7	46.6	**Mean (B)**	**49.2 BC**
	0.50	52.5	52.0	63.0	51.1		**54.6 AB**
	1.00	58.1	57.9	66.3	56.4		**59.7 A**
Mean (C)		**51.3 B**	**50.1 B**	**59.5 A**	**48.3 B**		

4.1.16. Copper (Cu)

Salt treatments had significant effects on copper (Cu) concentrations and contents (Table 4.1). Both Cu concentrations and Cu contents increased with increasing salt treatments (Table 4.27 and 4.28). The average Cu concentration of 8.5 mg/kg in control treatments decreased respectively by 5.8, 15.3 and 25.8% to 8.0, 7.2 and 6.3 mg/kg at 2.5, 5.0 and 10 dS m^{-1} salt doses (Table 4.27). Similarly, the average Cu content of 11.2 µg $plant^{-1}$ in control treatments decreased respectively by 25.0, 66.0, and 86.6% to 8.4, 3.8, and 1.5 µg $plant^{-1}$ at 2.5, 5.0, and 10 dS m^{-1} salt levels (Table 4.28). Salicylic acid treatments had significant effects on Cu concentrations and contents (Table 4.1). Both Cu concentrations and Cu contents increased with increasing SA treatments (Table 4.27 and 4.28). The average Cu concentration of 7.1 mg/kg in control treatments increased respectively to 7.3, 7.6 and 7.9 mg/kg at 0.25, 0.5 and 1.0 mM salt levels (Table 4.27). Similarly, the average Cu contents of 5.5 and 5.9 µg $plant^{-1}$ at 0 and 0.25 mM SA treatments increased respectively to 6.4 and 7.1 µg $plant^{-1}$ at 0.5 and 1.0 mM SA treatments (Table 4.28).

There were significant differences in Cu concentrations and contents of the genotypes (Table 4.1). The highest Cu concentration (7.8 mg/kg) and Cu content (6.8 µg $plant^{-1}$) were observed in Gökkan genotype (Table 4.27 and 4.28). The other three genotypes were placed in the same group (Table 4.27 and 4.28).

Salt x SA treatments were not found to be significant for Cu concentrations but vital for Cu contents (Table 4.1). At 0, 2.5, and 5.0 dS/m salt doses, Cu contents significantly increased with increasing SA treatments, and the highest Cu content (12.4 µg $plant^{-1}$) was observed at 1.0 mM SA treatment without salt (Table 4.28). At 10 dS m^{-1} salt level, increasing SA treatments did not influence Cu contents (Table 4.28). Salt x genotype interactions were not found to be significant for Cu concentrations, but notable for Cu contents (Table 4.1). In non-salt treatments, the highest Cu content (12.0 µg $plant^{-1}$) was obtained from Gökkan. At 2.5 dS m^{-1} salt level, all genotypes were placed into the same group. At 5.0 dS m^{-1} salt level, Gökkan had the highest Cu content. At 10 dS m^{-1} salt level, Cu contents

of the genotypes significantly decreased, and all of them were placed in the same group (Table 4.18).

Table 4.27. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on Cu concentration (mg kg^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl	SA	Cu Concentration of Shoot (mg kg^{-1})					Mean
(dS m^{-1})	(mM)	Altınöz	Candaş	Gökkan	Yakamoz		(AxB)
0	0.00	8.7	7.5	8.7	8.2		8.3
	0.25	8.7	7.7	8.6	8.3		8.3
	0.50	8.2	7.7	8.9	8.7		8.4
	1.00	9.5	8.1	9.2	8.9		8.9
Mean (AxC)		8.8	7.8	8.8	8.5	**Mean (A)**	**8.5 A**
2.5	0.00	7.2	7.1	7.9	7.6		7.4
	0.25	8.0	7.2	8.0	7.8		7.7
	0.50	8.3	7.6	8.5	8.1		8.1
	1.00	9.1	8.1	8.7	8.4		8.6
Mean (AxC)		8.2	7.5	8.3	8.0	**Mean (A)**	**8.0 B**
5	0.00	6.5	6.6	7.2	6.9		6.8
	0.25	7.0	6.8	7.4	6.9		7.0
	0.50	7.2	7.2	7.6	7.2		7.3
	1.00	7.6	7.9	8.2	7.7		7.8
Mean (AxC)		7.1	7.1	7.6	7.2	**Mean (A)**	**7.2 C**
10	0.00	6.0	5.5	6.5	6.0		6.0
	0.25	6.1	6.1	6.6	6.2		6.2
	0.50	6.1	6.4	6.9	6.4		6.5
	1.00	5.3	7.2	6.4	6.8		6.4
Mean (AxC)		5.9	6.3	6.6	6.3	**Mean (A)**	**6.3 D**
Mean (BxC)	0.00	7.1	6.7	7.6	7.2		**7.1 C**
	0.25	7.4	6.9	7.7	7.3	**Mean (B)**	**7.3 BC**
	0.50	7.5	7.2	8.0	7.6		**7.6 AB**
	1.00	7.9	7.8	8.1	7.9		**7.9 A**
Mean (C)		**7.5 AB**	**7.2 B**	**7.8 A**	**7.5 AB**		

Table 4.28. Effect of salicylic acid levels (0, 0.25, 0.5, 1.0 mM) on Cu content (µg plant^{-1}) in shoot of bread wheat genotypes grown under different salt levels (control, 2.5, 5.0, 10 dS m^{-1}).

NaCl	SA	Cu Content of Shoot (µg plant)$^{-1}$					Mean
(dS m^{-1})	(mM)	Altınöz	Candaş	Gökkan	Yakamoz		(AxB)
0	0.00	10.6	9.4	11.3	10.5		10.4 bc
	0.25	10.6	9.8	11.3	10.8		10.6 bc
	0.50	10.2	10.4	12.4	12.1		11.3 ab
	1.00	12.1	11.7	13.1	12.6		12.4 a
Mean (AxC)		10.9 ab	10.3 b	12.0 a	11.5 ab	**Mean (A)**	**11.2 A**
2.5	0.00	6.9	7.9	7.2	6.6		7.1 f
	0.25	7.5	8.0	7.8	8.2		7.9 ef
	0.50	8.0	8.4	9.4	8.9		8.7 de
	1.00	9.8	9.3	10.7	9.6		9.8 cd
Mean (AxC)		8.1 c	8.4 c	8.8 c	8.3 c	**Mean (A)**	**8.4 B**
5	0.00	2.8	3.1	4.1	2.6		3.1 h
	0.25	2.9	3.6	4.3	3.2		3.5 gh
	0.50	3.1	4.2	5.1	3.7		4.0 gh
	1.00	3.8	4.6	5.7	4.2		4.6 g
Mean (AxC)		3.1 e	3.9 de	4.8 d	3.4 e	**Mean (A)**	**3.8 C**
10	0.00	1.3	1.4	1.6	1.1		1.4 ı
	0.25	1.3	1.6	1.8	1.2		1.5 ı
	0.50	1.3	1.7	2.0	1.4		1.6 ı
	1.00	1.0	2.0	1.1	1.9		1.5 ı
Mean (AxC)		1.2 f	1.7 f	1.6 f	1.4 f	**Mean (A)**	**1.5 D**
Mean (BxC)	0.00	5.4	5.4	6.1	5.2	**Mean (B)**	**5.5 C**
	0.25	5.6	5.7	6.3	5.9		**5.9 C**
	0.50	5.7	6.2	7.2	6.5		**6.4 B**
	1.00	6.7	6.9	7.7	7.1		**7.1 A**
Mean (C)		**5.8 B**	**6.1 B**	**6.8 A**	**6.2 B**		

4.2. Discussions

Salt stress is among the most significant abiotic stress factors with negative impacts on plant growth and development. The plants under salt stress continuously struggle with water deficiency and harmful ion toxicity (Munns, 2005). Therefore, improvement of salt tolerance of the plants has recently become an important research topic. In this sense, salicylic acid (SA) can act as an important signaling molecule and has diverse effects on tolerance to biotic and abiotic stresses (Arfan et al., 2007; Wang et al., 2010). SA is an endogenous plant growth regulator and has been found to generate a wide range of metabolic and physiological responses in plants thereby affecting their growth and development (Hayat et al., 2010). Exogenous application of SA enhanced plant tolerance to various abiotic stresses such as water (Singh and Usha, 2003), low temperature (Tasgin et al., 2003), high temperature (He et al., 2005), heavy metal (Metwally et al., 2013) and salt (Yousuf et al., 2008; Babar et al., 2014; Kaya and Inan, 2017).

In present study, effects of foliar SA treatments on salt tolerance of different bread wheat genotypes were investigated.

Shoot and Root Dry Matter Productions: Both shoot (Table 4.2) and root (Table 4.3) dry matter yields of the genotypes decreased with increasing salt treatments. As compared to control treatments, shoot dry matter yields respectively reduced by 21, 60, and 82% at 2.5, 5.0, and 10 dS m^{-1} salinity levels (Table 4.2; Figures 4.1- 4.4). In the same salinity levels, decrease rates in root dry matter productions were 36, 70, and 88%, respectively (Table 4.3). Concerning both the shoot and root dry matter productions, Altınöz genotype was influenced the most from 5 dS m^{-1} salinity level.

Among the genotypes, Candaş exhibited the most fabulous shoot and root growth. It was observed that salinity-induced recess in root growth was higher than the recess in shoot growth (Table 4.2 and Table 4.3). Roots are faced with salt stress first; thus, a decrease in root growth is generally more significant than the reduction in shoot growth (Lazof and Bernstein, 1999). Salt stress-induced

decreases in plant dry matter productions were reported for different plant species, i.e., for wheat (Alsahli et al., 2019), soybean (Farhangi- Abriz and Ghossemi-Golezani, 2018) and cotton (El- Beltagi et al., 2017). The adverse effects of salinity may occur due to the low osmotic potential of the soil solution (water stress), nutritional imbalance, specific ion effect (salt stress), or a combination of these factors (Parvaiz and Satyawati, 2008).

Foliar SA treatments significantly increased both the shoot (Table 2) and the root (Table 4.3) dry matter yields. The increase in shoot and root dry matter yields was the highest at 1.0 mM dose of SA. Considering the SA x Genotype interactions, Yakamoz genotype had the most significant increase in shoot and root dry matter production as compared to the control treatments.

Considering the salt x SA interactions, it was observed that SA treatments without salt increased both the shoot and the root dry matter productions. Dry matter production increasing effects of salicylic acid were found at 2.5 and 5.0 dS m^{-1} salinity levels for shoots and 2.5 dS m^{-1} salinity level for roots (Table 4.2 and Table 4.3). Considering salt x SA x genotype interactions, it was observed that increasing SA doses and especially 1.0 mM SA treatments significantly increased shoot dry matter yields of all genotypes at control, 2.5 and 5.0 dS m^{-1} salinity levels and increased shoot dry matter yields of Candaş and Yakamoz genotypes at 10 dS m^{-1} salinity level. Similar findings were reported for wheat (Kaydan et al., 2007), strawberry (Karlıdağ et al., 2009), and sorghum (Rajabi Dehnavi et al., 2019).

SPAD Readings: As compared to the control conditions, 2.5 and 5.0 dS m^{-1} salinity levels increased SPAD values (Table 4.4). Such a case may be related to the saturated nature of the chlorophyll with the salt stress-induced recess in shoot growth. However, at 10 dS m^{-1} salinity level, a 10.6% decrease was observed in SPAD values as compared to the control (Table 4.4). The decline in photosynthetic pigments under salt stress may be related to inhibition of pigment biosynthesis. Like this, increasing chlorophyllase enzyme under salt stress also reduces

chlorophyll content (Rao and Rao, 1981). Salt stress-induced decrease in chlorophyll contents was also reported by Tufail et al. (2013) and Li et al. (2014).

It was observed in this thesis that SA treatments significantly increased SPAD values. SPAD increasing effects of SA were observed at control, 2.5, and 5.0 dS m^{-1} salinity levels. Such increases were more significant especially at 1.0 mM SA dose as compared to the control (Table 4.4). Both under saline and non-saline conditions, SA increased chlorophyll (Yıldırım et al., 2008). Increasing chlorophyll contents with SA treatments under salt stress may be related to the stimulation of chlorophyll biosynthesis or inhibition of chlorophyll degradation by SA (Li et al., 2014). El-Tayeb (2005) reported that exogenous application SA increased the photosynthetic rate and also maintained the stability of membranes, thereby improved the growth of barley under salinity.

Among the present genotypes, Altınöz was remarkable with low SPAD values. The highest increase in SPAD values with 1.0 mM SA treatments was observed in Yakamoz genotype (Table 4.4).

Leaf Relative Water Content (LRWC): Leaf relative water contents significantly decreased with increasing salt levels. The average LRWC value of 90.7% in control conditions respectively reduced by 87.3, 77.7 and 72.1% at 2.5, 5.0 and 10 dS m^{-1} salt levels (Table 4.5). It was reported that LRWC, water potential and osmatic potentials became more negative with increasing salinity levels (Parida and Das, 2005). In the present study, SA treatments significantly increased LRWC values. At 5 dS m^{-1} salinity level, SA treatments increased LRWC numbers by about 6.8% (Table 4.5). Under salt stress, increasing LRWC values were reported with enhancing SA treatments in different plant species, i.e. in cucumber (Yıldırım et al., 2008), strawberries (Karlıdağ et al., 2009) and cabbage (Sunaina and Sign, 2014). This role of SA may be attributed to its ability to improve some parameters related to plant water status. In cases without salt stress, SA treatments increased leaf diffusive resistance and such a situation was found to be related to decreased transpiration and leaf water potential (Barkosky

and Einhelling, 1993). It was reported that LRWC values dropped and leaf diffusive resistance values increased with salt stress (Mahedran and Jeyaproba, 2014).

Gökkan genotypes had the most excellent LRWC value at the highest salt stress level. Considering salt x SA x genotype interactions, it was observed that at 10 dS m^{-1} salinity level, Altınöz genotype had the most significant decrease, and Yakamoz had the greatest increase in LRWC values (Table 5).

Membrane Permeability: As compared to the control treatments, there were no significant changes in membrane permeability of the genotypes at 2.5 and 5 dS m^{-1} salinity levels. On the other hand, there was about a 400% increase in membrane permeability in 10 dS m^{-1} level (Table 6).

Considering salt x genotype interactions, it was observed that at 10 dS m^{-1} salinity level, Altınöz genotype had the greatest (30.6%) and Yakamoz genotype had the lowest (13.1%) membrane permeability (Table 6). Such a case indicates the sensitivity of Altınöz genotype to salt stress and the high tolerance of Yakamoz to salt stress. Similar increases in membrane permeability with salt stress were also reported in wheat (Alsahli et al., 2019), mung bean (Khan et al., 2010) and maize (Güneş et al., 2007). Salinity causes membrane damage via membrane lipid peroxidation (Mishra and Choudhuri, 1999) and lipid peroxidation is the indicator of oxidative stress intensity in plants (Hernandez and Almansa, 2002). A positive correlation between membrane permeability and lipid peroxidation was found under salt stress (Güneş et al., 2007; Khan et al., 2010; Alsahli et al., 2019).

Considering SA x genotype interactions, it was observed that increasing SA treatments significantly reduced membrane permeability of Altınöz genotype, but increased membrane permeability of Gökhan genotype. It can then be stated that SA was effective in lowering membrane stability especially at 0.5 and 1.0 mM doses, and such an effects was attributed to changes in membrane permeability at 5 and 10 dS m^{-1} salt levels (Table 6).

Although salt x SA x genotype interactions were not found to be significant, SA treatments remarkably reduced membrane permeability of Altınöz genotype at 5 and 10 dS m^{-1} salinity levels and membrane permeability of Candaş genotype at 5 dS m^{-1} salinity level as compared to the control treatments (Table 6). Such a case indicated that SA was effective in alleviation salt stress-induced oxidative damage.

Sodium (Na) and Macronutrients (N, P, K, Ca, Mg): The shoot sodium (Na) concentrations significantly increased with increasing salt treatments (Table 4.7). The average Na concentration of 1.03 mg g^{-1} in control treatments respectively increased to 3.37, 4.59 and 7.06 mg g^{-1} at 2.5, 5.0 and 10 dS m^{-1} salt levels. The shoot Na contents also significantly increased with the salt treatments as compared to the control treatments and such increases were parallel to dry matter productions (Table 4.8). Increasing Na levels were reported with increasing NaCl concentrations (Alpaslan and Güneş, 2001; Eker et al., 2006). In this study, complying with dry matter productions, Altınöz genotype had the least Na uptake.

Salicylic acid treatments decreased Na concentrations and contents. Considering salt x SA interactions, it was observed that Na concentrations significantly reduced with increasing SA treatments at 2.5 and 5.0 dS m^{-1} salinity levels (Table 4.7 and 4.8). Decreasing Na concentrations in relevant salt doses indicate the positive/rehabilitating effects of SA. Despite irrelevant results, Na contents decreased with increasing SA treatments in all salt levels. Such a case showed that besides Na dilution in plant tissues, SA treatments also reduced Na uptakes of the plants. Yıldırım et al. (2008) reported that the reduction of Na content might result in low membranes injury, high water content, and dry matter yield. Parallel to Na, both K concentrations and contents significantly increased with SA treatments under control conditions and at 2.5 and 5 dS m^{-1} salinity levels (Table 4.13 and 4.14). In the same salinity levels, K/Na ratios significantly increased with SA treatments (Table 4.15). Salt stress decreased K concentration and content (Table 4.13 and 4.14).

Calcium concentrations increased, but calcium contents decreased with salt stress (Table 4.16 and 4.17).

Salt x SA interactions were found to be significant for K (Table 4.13 and 4.14), but insignificant for Ca (Table 4.16 and 4.17). It was reported that K^+/Na^+ and Ca^{2+}/Na^+ ratios played a significant role in plant tolerance to salt stress (Gorham, 1993; Sharma and Gill, 1994). However, in the present study, except for 10 dS m^{-1} salinity level, K/Na ratios significantly increased in all salinity levels with SA treatments (Table 4.15), the increase in Ca/Na ratios were not found to be significant (Table 4.18). It can then be stated that in relevant salt doses, increased K/Na ratios with SA treatments may be useful in the improvement of plant tolerance to salt stress. Like this, K provides osmotic potential required for water uptake of the plants (Claussen et al., 1997). Relatively higher selective absorption of K than Na is suggested to be one of the crucial physiological mechanisms contributing to salt tolerance in many plant species (Greenway and Munns., 1980).

Nitrogen (N) concentrations and contents of the genotypes significantly decreased with increasing salt treatments (Table 4.9 and 4.10). N uptake under salt stress is directly related to interactions between NO_3^- and Cl^- or between Na^+ and NH_4^+ (Rozeff, 1995). In this study, NO_3^- and Cl^- interactions were prominent. Salinity results in degradation in plant N assimilation and metabolism (Starck, 2005). SA treatments significantly increased shoot N contents (Table 4.9 and 4.10). Such a case was resulted from rising shoot dry matter productions with SA treatments (Table 4.2).

Phosphorus is an essential nutrient that plays a vital role in several processes including photosynthesis, respiration, storage and energy transfer, cell division and growth (Schochtman et al., 1998). Both P concentrations and P contents significantly decreased with increasing salt treatments (Table 4.11 and 4.12). Salinity reduces the activity of PO_4^{3-} by ionic strength and as a result decreases the absorption and content of P in plant tissues (Talke et al., 2003).

In control treatments and 2.5 and 5.0 dS m^{-1} salinity levels, SA treatments significantly increased both P concentrations and P contents (Table 4.11 and 4.12). The positive effect of SA on the P content was due to its impact on the production and transfer of photosynthetic materials from source to sink (El–Hedek, 2013). Under saline conditions, SA also increases the H^{+}- ATP ise activity by retraining membrane potential and reducing K leakage (Jaya Kannon et al., 2013).

An increase in Mg concentration with salt treatments is resulted from salt-induced recess in plant growth and resultant concentration. Like this, Mg contents decreased with increasing salinity levels (Table 19 and 4.20). Decreasing Mg levels with salinity (Table 4.19 and 4.20) comply with the decreasing SPAD values (Table 4). Thus, Mg has a well-known role in the photosynthesis process as it is a building block of chlorophyll and cofactor for enzymes involved in photosynthesis (Cakmak and Kirkly, 2008; Hermans et al., 2013). Significant decreases were reported for the shoot and root N, P, K, Ca and Mg concentrations of strawberry plants (Karlıdağ et al., 2009). In this study, decreasing Na uptake and increasing N, P and K uptakes with SA treatments stimulated both the shoot and the root growth of the genotypes.

Micronutrients (Fe, Zn, Mn, Cu): Iron (Fe) and copper (Cu) concentrations increased (Table 4.21 and 4.28) and manganese (Mn) concentrations decreased with increasing salt treatments (Table 4.25 and4.26). The increase in Mn concentration may be related to the concentration effect. As compared to control treatments, zinc (Zn) concentrations increased at 2.5 dS m^{-1} salinity, but increased dramatically at 10 dS m^{-1} salinity level (Table 4.23 and 4.24. Considering the element content of the plants, Fe, Zn, Mn and Cu contents significantly decreased with increasing salt treatments (Table 4.21 and 4.28). Reducing Mn, Zn and Fe concentrations and increasing Cu concentrations were reported with salt stress in sorghum (Rajabi Dehnavi et al., 2019). In another study conducted with maize, salinity significantly increased Zn, Fe, Cu and Mn concentrations (Güneş et al., 2007).

The relationship between salinity and micronutrients is complicated, and salinity stress may decrease, not change or increase these elements in plant tissues, but the reduction in the availability of micronutrients due to high pH is usually observed (Zhu et al., 2004).

SA treatments significantly increased Fe, Zn, Mn and Cu contents (Table 4.21 and 4.28). While the increases in Fe and Cu concentrations with SA treatments were found to be significant (Table 4.21,4.22 and 4.27, 4.28), increases in Zn and Mn concentrations were not found to be significant (Table 4.23 and 4.25,). At all salt levels, SA treatments increased Mn contents (Table 4.26).

The effects of increasing SA treatments on Mn content were higher at 2.5 dS m^{-1} salinity level than the other salinity levels (Table 4.26). At control, 2.5 and 5.0 dS m^{-1} salinity levels, increasing SA treatments increased Cu contents. However, the effects of enhancing SA treatments on Cu contents were more prominent at 5.0 dS m^{-1} salinity level (Table 4.28). Different findings were reported in previous studies. For instance, SA supply inhibited Na accumulation, but stimulated Fe, Mn and Cu uptake by salt-stressed maize and cucumber plants compered to non – treated ones (Güneş et al., 2006; Yıldırım et al., 2008). Foliar application of SA increased Fe, Zn, Mn and Cu concentrations under both normal and saline conditions (Rajabi Dehnavi et al., 2019).

Present findings revealed that both under control conditions and salt stress, SA treatments increased Mn and Cu uptakes. The most significant increase in element contents was achieved with 1.0 mM SA dose at 2.5 dS m^{-1} salinity level for Mn and 5 dS m^{-1} salinity level for Cu. The change in Mn and Cu uptakes with salicylic acid treatments may be considered as an effective mechanism to combat salinity stress.

5. CONCLUSION AND RECOMMENDATIONS

- ✓ Salt treatments significantly decreased both the shoot and the root dry matter yields. Salt stress resulted in a more significant decrease in root dry matter yields as compared to shoot dry matter yields. Concerning shoot and root dry matter productions, Altınöz genotype influenced from 5 dS m^{-1} salinity level the most. Candaş had the most fabulous shoot and root growth at the same time. Foliar SA treatments significantly increased both the shoot and the root dry matter yields. The increases in shoot and root dry matter yields with SA treatments were at high levels at1.0 mM SA dose. Dry matter production increasing effects of salicylic acid were observed in shoots at 2.5 and 5.0 dS m^{-1} salinity levels and in roots at 2.5 dS m^{-1} salinity level.
- ✓ SPAD increasing effects of SA were observed at control, 2.5 and 5.0 dS m^{-1} salinity levels. As compared to the control treatments, the increases at 1.0 mM SA dose were more significant.
- ✓ Leaf relative water contents (LRWC) significantly decreased with increasing salt treatments. It was observed that at10 dS m^{-1} salinity level, the most considerable decrease in LRWC values was observed in Altınöz, and the most significant increase was observed in Yakamoz.
- ✓ Altınöz had the highest membrane permeability (30.6%) and Yakamoz had the lowest membrane permeability (13.1%) at 10 dS m^{-1} salinity level.
- ✓ Shoot sodium (Na) concentrations significantly increased with increasing salt treatments. SA treatments decrease Na concentrations and contents. Na concentrations reduced considerably with enhancing SA treatments under 2.5 and 5.0 dS m^{-1} salinity levels.
- ✓ In control treatments and at 2.5 and 5 dS m^{-1} salinity levels, both K concentrations and K contents significantly increased with SA treatments. In the same salinity levels, K/Na ratios also considerably increased with

SA treatments. Salt stress resulted in decreasing K concentrations and contents.

- ✓ Calcium (Ca) concentrations increased, but Ca contents (uptakes) decreased with salt stress. Salt x SA interactions were found to be significant for K, but insignificant for Ca. Except for 10 dS m^{-1} salinity level, K/Na ratios significantly increased with SA treatments in the other salinity levels, but the increase in Ca/Na ratios was not found to be significant.
- ✓ The average nitrogen (N) concentration and content of the genotypes significantly decreased with increasing salt treatments. SA treatments significantly increased shoot N contents.
- ✓ Increasing salt treatments significantly decreased both P concentrations and P contents of the genotypes. In control treatments and at 2.5 and 5.0 dS m^{-1} salt levels, enhancing SA treatments significantly increased both P concentrations and P contents of the genotypes.
- ✓ The increase in Mg concentrations with increasing salinity is a result of concentration effect, which is induced by reduced plant growth. Mg contents decreased with increasing salinity levels. The decrease in Mg uptake with salinity complies with the reduction of SPAD values.
- ✓ Considering the element content of the plants, Fe, Zn, Mn and Cu contents significantly decreased with increasing salt treatments. SA treatments significantly increased Fe, Zn, Mn and Cu contents. The increase in Fe and Cu concentrations with SA treatments was found to be significant; the increase in Zn and Mn concentrations was not found to be substantial. In both control treatments and salt stress treatments, SA treatments increased Mn and Cu uptakes. The 1.0 mM SA dose yielded the most significant increase in Mn content at 2.5 dS m^{-1} salinity level, and in Cu content at 5 dS m^{-1} salinity level.

In brief, SA treatments (especially 1.0 mM dose) increased LRWC values at 5 dS m^{-1} salinity level, and SPAD values at control, 2.5 and 5.0 dS m^{-1} salinity levels, decreased Na uptake, on the other hand, increased K/Na ratio, P, K, Mn and Cu uptake and were quite effective in stimulation of both the shoot and the root growth of the plants. SA treatments (especially 1.0 mM) were quite effective in alleviation of negative impacts of 5 dS m^{-1} and lower salinity levels. Since plant affection by salt stress is closely related to salt dose, plant type and salt exposure durations, the role of SA in alleviating salt stress also varied with these parameters. The changes in uptake of relevant elements with salicylic acid treatments might have played a role to combat salt stress. It is recommended that the effects of SA treatments on salt stress should be further investigated over the nutrient uptakes and nutrient uptake of salt stress-tolerant and sensitive wheat genotypes should be monitored at different growth stages of the plants and assessments should be made accordingly.

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CURRICULUM VITAE

I was born in Marawi / Sudan on 26.11.1992. I completed my primary, secondary, and high school education in Sudan. In 2014, I graduated with honors (first degree) in Soil and Environmental Sciences at the University of Khartoum, Faculty of Agriculture. In 2015, I received the title of Agricultural Engineer. In the same year, I was appointed to the role of Teaching Assistant at the Department of Soil Science and Environment, Faculty of Agriculture, Khartoum University. In the year of 2016, I was accepted in the Turkish Scholarship Program to support my studies at Çukurova University in the Department of Soil Science and Plant Nutrition, and in 2017, I started my MSc study.