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Growth enhancement and alleviation of deleterious effects induced by salt stress in Faba Bean (Vicia Faba) by PGPB

M.Sc. Thesis By

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3. Dr. Tawfiq Qubbaj / Internal Examiner ……

Dedication

Every challenging work needs self-efforts as well as guidance of elders especially those who were very close to our heart.

My humble effort I dedicate to my sweet and loving

Father & mother

Acknowledgment

First of all, I would like to express my Praise to "ALLAH" who gave me the power patience and help me to finish this work.

I extend my deep thanks and sincere gratitude to Dr. Heba Fares, Assistant Professor of Quantitative Genetic in Plant, faculty of Agriculture, An Najah National University, her supervision, kind encouragement, scientific guidance, research facilities, critically reading the manuscript and her personal assistance, help me to right directions, In fact without her help, this thesis would not have been possible.

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الإقرار

أنا الموقع أدناه، مقدم الرسالة التي تحمل عنوان:

Growth enhancement and alleviation of deleterious effects induced by salt stress in Faba Bean (*Vicia Faba*) by PGPB

أقر بأن ما اشتملت عليه هذه الرسالة هو نتاج جهدي الخاص, باستثناء ما تمت الإشارة اليه حيثما ورد, وأن هذه الرسالة كاملة, أو أي جزء منها لم يقدم من قبل لنيل أي درجة او لقب علمي أو بحثي لدى اي مؤسسة تعليمية او بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: **اسم الطالب:**

Signature: **التوقيع:**

Date: **التاريخ:**

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List of Abbreviations

B. megaterium	*Bacillus megaterium*
PGPB	Plant Growth Promoting Bacteria
PGPR	Plant Growth Promoting Rhizobacteria
TDS	Total Dissolved Solids
Ece	Electrical conductivity
ATCC	American Type Culture Collection
FAO	Food and Agriculture Organization
Mm	Millimolar
OD	Optical Density
ml	Millimeter
cfu	Colony Forming Unit
nm	Nanometer
g	Gram
cm	Centimeter
AMF	Arbuscular Mycorrhizae Fungi
wt.	Weight
mg/L	milligram per liter
PAR	Photosynthetic Assimilation Rate

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Abstract

The present investigation was led to evaluate the impact of various levels of sodium chloride (NaCl) on Faba Bean plant in the presence or absence of *Bacillus megaterium* bacteria. Pot experiments were conducted on two varieties of Faba Bean plant under different salinity levels (0, 2,4,6,8 ds/m) with and without *B. megaterium*.

The pots were irrigated with different concentrations of NaCl, each salinity level had both inoculated and non-inoculated *B. megaterium*. Salt stress in pots without *B. megaterium* caused reduction in growth parameters (shoot height, number of leaves, fresh and dry weight, root mass…), reduction in yield parameters, increased sodium and chloride percentage in leaves and reduced the absorption of other important chemical elements which indicates the deleterious effects of salinity.

Plant-growth-promoting bacteria (PGPB) can improve plant growth, development, and stress adaptation even that the mechanism is still largely un clear. Application of *B. megaterium* mitigates the effect of sodium

chloride stress and improved the growth and yield in the present study. The inoculation with remarkably *B. megaterium* increased plant height, number of leaves, number of flowers, plant biomass, early flowering, improved chlorophyll content, root system and in contrast, alleviated sodium chloride accumulation in leaves, increased the absorption of K, Ca, P . Inoculated plants with *B. megaterium* displayed stronger ability to tolerate salt stress than non-inoculated plants.

Result revealed that incubation led to higher induction of plant height 39 % at 8ds/m of salinity, the noticed increase in the height of the stem could be due to the positive changes in enzyme activity and growth hormones. The maximum fresh weight was 159.27 g at 8 ds/m in plants with *B. megaterium* compared to plant without *B. megaterium* the fresh weight 85.77 at 8 ds/m. The effect of *B. megaterium* increase Faba Bean root fresh weight 35.99%. In relation to flowering periods, results revealed that salinity slightly reduced the days to flowering in non-inoculated plants, in contrast *Vicia Faba* inoculated with *B. megaterium* revealed early flowering by 19 % at 6 ds/m which combined with highest nodule formation 5, pod weight 38.7 g, seed number 27.8, pod number 11.66, seed fresh weight 11.06g and dry weight 1.85g. . Potassium and Calcium content increased by 5% in plants treated with *B. megaterium* compared to non-inoculated plants.

Many studies claimed that salinity negatively affects soil bacterial activity by high osmotic strength and toxic effects by salts, but that salt-tolerant bacteria (*B. megaterium*) can survive and proliferate in the soil and

in the rhizosphere in a harsh environment. The study revealed that the soil salinity could be reduced by using *B. megaterium* with plants, this led to reduction in about 10% of soil salinity compared to soil without *B. megaterium*.

Chapter One
Introduction

"Who eats beans paces the world recklessly and who eats meat hides behind the door."

Faba Bean (Vicia Faba) is a herbaceous plant belongs to the leguminosae family. It is an annual legume with one or more strong, hollow, erect stems and strong tap root system. It is originated from east of Asia and Mediterranean region and its cultivation started before around 6000 - 7000 years B.C.

Faba Bean grown primarily for its edible seeds for human consumption, livestock feed, fodder it also serves as being a cover crop to prevent the soil erosion during winter and fixes the nitrogen in the soil.

Faba Bean plant is cultivated in around 58 countries around the world and is considered as the third most important crop in the worldwide in legumes family (Singh, A. et all 2013). It is implanted on about 2.5 million hectares of lands around the world in the year 2010 with roughly a production of 4.2 million ton. It reaches at central and east Asia about 36% and in Sub-Saharan Africa about 21% of the total area under Faba Bean cultivation (Nedumaran, S et all 2013).

Palestine like other above-mentioned countries is also famous for Faba Beans and it is considered one of the main legumes crops due to its nutritive value specially the carbohydrate and protein content. The estimated area

which is implanted with Faba Bean in Palestine in the years 2009, 2010 is about 779.670 dunums (Palestinian Central Bureau of Statistics, 2010).

One of the main obstacles that limit the spread of the Faba Beans around the world is the soil over salinity. Such problem is increasing and widely spreading in the arid and semi-arid regions (Marulanda, A., et all 2010). In 2008, and according to Food and Agriculture Organization (FAO), about 800 million hectares of used lands around the world were affected by saline conditions. Like other lands around the world, Palestine had the same problem with the over salinity of soil which makes growing conditions of this crop very hard.

The same is there in Jericho city which located near Jordan River in the West Bank; the salinity problem is rapidly spreading due to the huge accumulation of chemicals such as fertilizers and pesticides in addition to the low rainfall percentage what makes the dilution very slow. Furthermore; the irrigation water in use had also a high percentage of salinity, all of these caused the Faba Bean delimitation since it is a sensitive crop for salinity in both soil and water.

As a result of the above-mentioned problem , many organisms been used to reduce the effect of salinity or to increase the tolerance of the plants that are sensitive to even low concentrations of salinity in soil and water , such organisms the Mycorrhiza create a symbiotic association with many of soil fungi called Arbuscular Mycorrhizal Fungi (AMF) and plants. A strategy to improve the nutritional status of both associates created by a successful

association between plants and AMF constitutes, which reduces the use of fertilizers especially phosphorus nutrition (Almagrabi, O. A., Abdelmoneim, T. S. 2012).

Arbuscular Mycorrhizal fungi (AMF) widely occur in saline soils (Aliasgharzadeh, N et all 2001). These fungi exploit water and mineral salts from soils more effectively than plant roots (Asenov, A et all 2003). Many studies have demonstrated that Arbuscular Mycorrhizal fungi (AMF) improve the growth of plants under salt stress condition by protecting the host plants (Trimble, M. R., & Knowles, N. R. 1995). Moreover, apart from developing mechanisms for own stress tolerance, plant growth promoting rizobacteria (PGPR) can also increase the tolerance to plants, towards abiotic stresses like salinity. Interaction of PGPR with the plant in saline conditions reducing the extent of poor growth and thus helps plants survive and improve the performance in adverse conditions (Dimkpa, C et all 2009)

Basing on this, the current study takes place to investigate the effect of one species of PGPB inoculums on the growth of bean plants (Vicia Faba L.) under saline stress conditions comparing with plants free from (PGPB). And To determine the effect of salinity on some plant growth parameters such as plant height, root height, plant fresh weight (wt.), shoot dry wt., root dry wt., root/shoot ratio and chlorophyll content in the presence or absence of (PGPB) inoculums to assess the role of (PGPB) on improve tolerance of bean to salinity condition as well as reducing the harmful effects induced by salinity stress conditions.

Objectives

General Objectives

To study the effect of PGPB on Faba Bean (*Vicia Faba L.*) under salt stress.

Specific objectives

1.To evaluate the effects of one species of PGPB on bean plants (*Vicia Faba* L.) under salt stress conditions comparing with plants free from PGPB.

2.To determine the effect of salinity on some plant growth parameters (plant height, root height, plant fresh wt., shoot dry wt., root dry wt., root/shoot ratio and chlorophyll content) in the presence or absence of PGPB inoculums to assess the role of PGPB on improve tolerance of bean to salinity condition.

Chapter Two
Literature Review

The review in this study will consider the previous and current studies on the influence of salinity stress on the different growth parameters, yield

and its components and other parameters. Also, will consider the symbiotic association with Faba Bean that may reduce the effect of salinity on the plant.

This review will be classified under the following topics:

2.1. Effect of salinity stress on Growth parameters of Faba Bean plants:

"Salinity has been a threat to agriculture in some parts of the world for over 3000 years; in recent times, the threat has grown" (Tim Flowers, 2006).

Legumes have long been recognized as sensitive or moderately tolerant to salinity (Subbarao and Johansen, 1993). The reductions in growth from high salinity are the consequences of both osmotic stress including a water defect and the effects of excess Na + and Cl- ions on critical biochemical processes (Munns and Tester, 2008).

Due to salinity in soil water, the plant growth inhibited for two reasons. First, it reduces the plant's ability to take up water, and this will leads to slower growth (Nedumaran, S et all., 2013). Second, it may enter the transpiration stream and eventually injure cells in the transpiring leaves, further reducing growth (Nedumaran, S et all., 2013). The salt in the soil solution reduces leaf growth and, to a lesser extent, root growth (Munns, 2002&2003).

Munnes (2002a, 2005) has developed a concept to explain the whole response to salinity which is “two-phase growth response to salinity” (figure1)

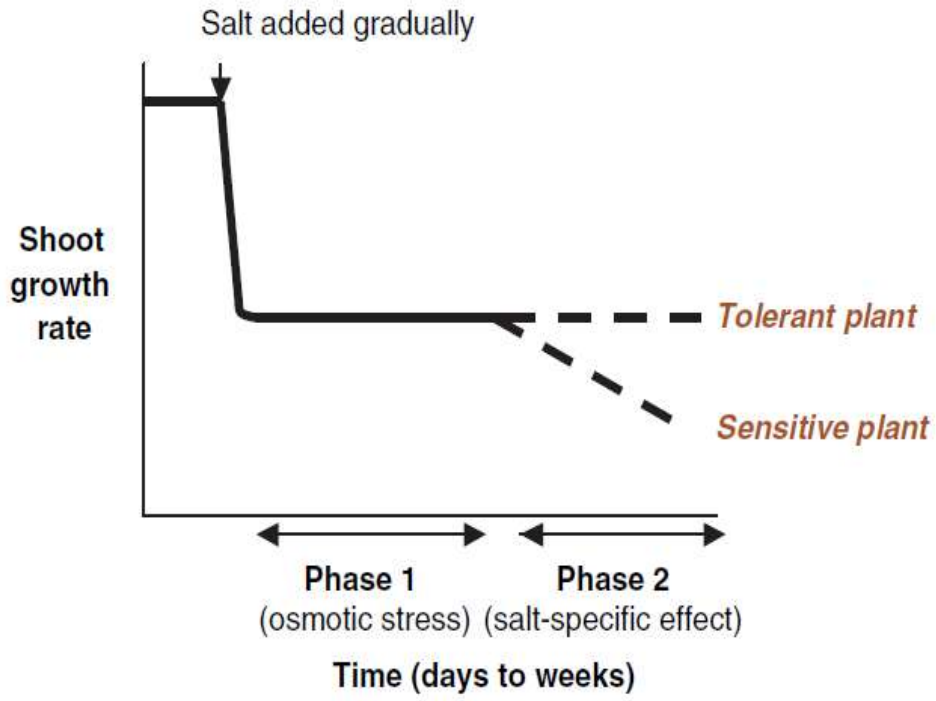

Figure 1: Schematic illustration of two-phase growth response to salinity.

The death of plants or decreasing in productivity can be observed at the whole plant level as an effect of high salinity, during the development of the stress on the plant all the major processes like photosynthesis, energy and lipid metabolism are effected as for as protein synthesis (Parida, A. K., & Das, A. B. 2005).

The earliest response to salinity stress is a reduction in the rate of leaf surface area, the expansion in the leaf surface will stop as the stress continue (Wang and Nil, 2000). Furthermore as a result of accumulation of Na and Cl in the

leaves, this will lead to salt toxicity to the whole plant, and as a result death of leaves occure followed by reduction in photosynthesis, unbalance in the overall carbon balance, the growth of the whole plant will be affected (Munns,2002a).

Rajendran et al., (2009) reported that the early response to the osmotic phase of salt stress could delay leaf appearance, retard leaf expansion, promoting leaf senescence as a response to the large accumulation of toxic ions. Consequently, the responsible for the reduction in growth and yield under salinity stress frequently assumed is the Sodium (Tsai et al., 2004; Hong et al., 2009). Several studies indicated that the high concentration of Chloride is always found in tissues of the plants that grown under salt stress, however the toxicity of excess Chloride levels has been given less attention (Gorham, 1990; Kingsbury and Epstein, 1986).

Magdi T. Abdel Hamid et all., (2010) pointed out that the plant growth of four species of Faba Bean were significantly reduced especially at high concentrations, about 43% of the growth reduced at 100 mM sodium chloride salinity, plant height, leaf number, dry weight per plant, number of tillers are all affected.

Greenway and Munns (1980) stated that the effect of salinity on leaf number and area was greater than on dry weight, the salt accumulation in the shoot due to transpiration stream, which is higher in old leaves causing death to

leaves. Salt stress cause injuries not only due to osmotic and oxidative effects, but also due to toxic and nutrient deficiency effects of salinity.

Gama P.B.S. et al., (2007) studied the effect of salinity stress on five cultivars of common bean, they found a significant differences among the salt levels and cultivars on parameters biomass yield, water relations, ion uptake and shoot dry weight, and consequently both root dry weight and root height were reduced as salinity increased.

Many studies investigated the effect of salt stress on plants growth reported that there is a high connection between plant height decreasing and the increasing in sodium chloride concentration (Mustard and Renault ,2006; Gama et al.,2007;Memon et al.,2010), also , another harmful effect of salt stress on leaf number, this causing decreasing in the number of leaves while salinity concentration increases according to the studies done by Raul et al .,(2003) , Jamil et al., (2005), Gama et al., (2007) and Ha et al., (2008).

Amira M.S & Abdul Qados, (2010) confirmed in their study about the effect of salt stress on bean plants with different concentration levels that the gradual decrease is gradual in salinity level (60, 120, 240 mM) associated with a decrease in leaf number with the increase of salt concentration compared with control plants, these results have been confirmed also by (Karen et al., 2002; Raul et al., 2003).

Leaf area is highly effected by salinity stress, this could be due to the negative effect of salt on photosynthesis, this effect leads to reduction in plant growth, leaf growth, and chlorophyll content (Netondo et al., 2004),

another study revealed decreasing in leaf area with the increasing of NaCl concentration on moth bean plant (*Vigna aconitifolia L*.), this reduction was inversely symmetrical to the concentrations (Mathur et al., 2006).

Likewise sugar cane (*Beta Vulgaris L*.) revealed a significant decrease in leaf area as a response to salt stress using different levels of concentrations (0, 50,100,150mmol) of NaCl (Jamil et al., 2007). The reduction and inhibition of leaf area and elongation under salt stress is also noticed for maize (Cramer, 1992), rice (Yeo et al., 1991), tomato (Tantawy et al., 2009), and in wheat and chickpea (Sheldon et al., 2004).

Mohammad et al., (1998) mentioned that the increasing of salinity is causing a significant reduction in plant height, shoot weight, root height, number of leaves per plant, and root surface area per plant in tomato. Consequently, the increase of sodium chloride cause a significant decrease in shoot, root, and increase in root/shoot ratio and reduction in leaf growth biomass (Meloni et al., 2001).

Lauchli and Epstein, (1990) indicated that the salinity usually reduces shoot growth more than root growth and that the reduction in shoot growth of a plant under salinity stress is commonly expressed by a reduced leaf area and stunted shoots, take in consideration that leaf size depends on both cell division and elongation.

Papp et al., (1983) suggested that cell division which is responsible for leaf initiation was shown to be unaffected by salt stress not compared like as leaf extension which found to be salt sensitive process in sugar beet plant.

Also, this stress can increase sterility and reduce the number of florets per ear, effect the time of flowering and maturity in both wheat and rice (Maas and Poss, 1989) (Khatun et al.1995).

Essa T. A. (2002) revealed that the effect of salinity stress on shoot dry weight of three soybean cultivars was significantly reduced in contrast to the increasing in salinity levels, the dry weight was reduced about 44% as average b/w the three cultivars, however , the dry weight of the roots was not significantly affected. Shoots seemed less resistance to salinity than roots (Noble and Rogers1993, Cordo villa et al.1995).

In the same context, another study done by Ullah S. M. et al.,1993 on osmoregulation and plant-water relation in Faba Beans under salt stress indicated that the shoot dry matter was significantly affected by salt stress, while the salt concentration increase (0, 20, 40, 60mM) the shoot dry matter decreases gradually.

Salwa A. Orabi et al., (2013) reported that the effect of salt stress on Faba Bean when irrigated with 4000 mg/L diluted seawater, the plants revealed reduction in shoot height and shoot dry weight 9.61% - 35.82% respectively compared to control irrigation.

Hameda (2011) mentioned that salinity stress which limiting plant growth and productivity is one of the most important a biotic stress factors. The High concentration of NaCl and Na_2So_4 highly reduced the growth in height of shoot, root and dry weight of all plant parts. The study revealed that the crop growth, dry and green matter components were significantly affected with

increasing water salinity. The green matter production ranged from 81.034 g/pot to 7.306 g/pot as the salinity increased, consequently the dry matter production ranged from 38.58 g/pot to 21.53 g/pot.

Ahmed et al. (2008) mentioned that growth parameters of Faba Bean plants generally affected by salinity stress. Control plants revealed relatively higher degree of shoot height than stressed plants by 45 and 90 days old plants. Moreover, fresh and dry weight were commonly lower in stressed plants than unstressed plants. These results may refer to the effect of salinity stress on the water content of the leaves, as indicated by **(**Hu et al., 2007**)**. Salinity stress may lower the soil water potential. Another explain for the reduction in plant growth Water deficit or osmotic also might cause effect for the plant (Munns, 2002).

2.2. Effect of salinity stress on Yield of Faba Bean plant

Salinity affects all stages of growth and development, as well as yield of plants. Vegetative growth is less effected by salt than yield. The reduction in seed yield may be explained due to the decrease in seed set, which may be attributed to a decrease in the stigmatic surface or respectively because of the viability of pollen or both (Sakr et al., 2004**)**.

Many studies conducted to characterize crop response to salinity stress at various growth stages, Rice is one of the important food crops around the world, it’s considered among the sensitive crops to salinity according to (Maas and Grattan, 1999).

Salwa A. Orabi et al., (2013) reported in here study that the increasing salinity levels in irrigation water reduced the number of seeds/plant by 16.78% and 38.16%, mean pods weight by 21.54% and 38.85 and seed yield by 16.65% and 38.01% for (2000,4000 mg/L) salt treatments, respectively compared to the control treatments .

Many studies revealed the negative effect of salinity to the yield and production stage, In this regard, Mass E. V., (1986) stated that broad bean considered moderately sensitive to salinity, the threshold value for the crop is 1.6 ds/m with 50% reduction in seed yield at 5.6 ds/m. Moreover, De Pascale and Barbieri, (1997) indicated that high levels of salt in soil caused reduction in the mean bod weight by 15%, number of pods/plant by 48% and seed yield of Faba Bean by 67%.

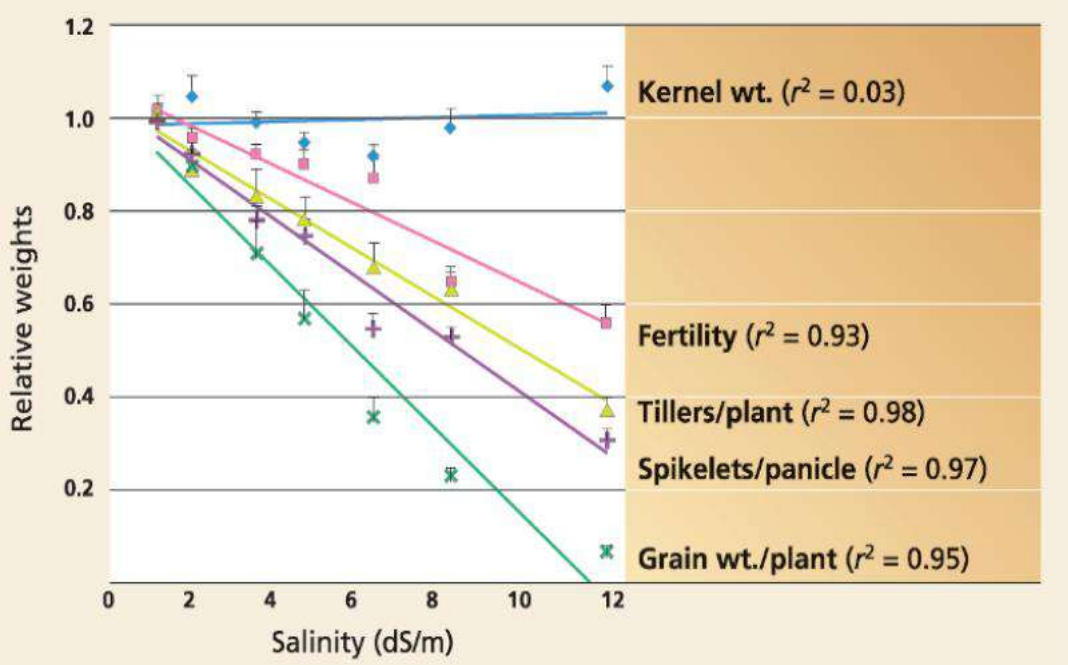

Figure 2: Relation b/w salinity and various yield component of rice *(Oryza sativa* L) (Zeng and Shannon, 2000).

Grattan et al., (2002) reported in his field and green house studies that Salinity had a negative effect on stand establishment and negatively affected a number of yield components and even delayed heading. Consequently, Zeng and Shannon ,(2000) stated that they found linear decreases in several yield components with the increase in salinity including the percent of sterile florets, tiller/plant , spikelet's/panicle which led to large reduction in grain weight/plant at a given salinity (figure 2).

All stages of soybean growth and yield and its components are affected by salt stress. The yield is highly decreased by salt, the highest salinity stress level (9000 mg/L) was the most effective. The negative effect of salinity on grain yield may be due to the reduction on leaf area and number of leaves/plant, causing decrease in the net photosynthetic rate and biomass accumulation and this causing reduction in the supply of carbon assimilate (Sakr and El-Metwally, 2009)**.**

2.3. Effect of salinity stress on Chemical and Mineral content in Faba Bean plant

Marschner, (1995) there is an interaction b/w macro and micro nutrient's in the root medium and within the plant. It is also confirmed that the macronutrient are generally more affected by salt stress than micronutrients (El-Fouly and Salama, 1999). Ions in high concentration like Sodium and Chloride in external solution are taken up at high rates, this may lead to

excessive accumulation in the tissue. Other ions like Potassium and Calcium may be inhibited due to the previous mentioned ions and their transport to shoot through the xylem, leading to a deficiency in the tissue (Hu and Schmidhalter, 2001).

High salt (Sodium Chloride) uptake competes with other nutrient ions, causing deficiency especially in Potassium. The increased treatment of Sodium Chloride induces the increase of both Na^+ and Cl^- and decrease in calcium, potassium, and magnesium levels in number of plants (Khan et al., 1999, 2000; Khan, 2001). The content of Na^+, Ca^{2+} enhanced due to salinity while Cl^- and the ratio of K^+ / Na^+ decreased in *Vicia Faba* (Gadallah, 1999).

Ullah S. M. et al., (1994) revealed about Faba Bean plant grown under salt stress that the concentration of Ca, Mg, P, Na, Cl, PO_4^{3-} in leaves, stems, and shoots were increased significantly in related to the increase in salt levels (0,20,40,60 mM), in the same context K, Fe, and NO_3^- were decreased significantly in related to salt levels in leaves, shoots and stems, also SO_4^- concentration revealed significant decreasing in leaves and significant increase in stems and shoots in related to the different salt levels.

Magdi T. Abdelhamid, (2010) indicated that the effect of salinity stress levels (0, 50,100 mM) were significantly decreased magnesium, calcium, potassium, sulfate and bicarbonate. Consequently, the concentration of sodium, chloride, pH, and electrical conductivity (EC; ds/m) significantly increased.

Essa T. A, (2002) reported that leaf content of calcium and magnesium decreased significantly with the increasing in salinity treatment levels, calcium content decreased by 43 to 49 % in three different cultivars as salinity increased from 0.5 to 8.5 DS/m, magnesium revealed different response with the increasing in salinity levels compared to other minerals, chloride concentration in the leaf was significantly increased with the increasing in soil salinity levels, the increasing of salinity from 6.5 to 8.5 ds/m increased the concentration in leaf by 19.38 to 38% for the different cultivars used in the study . Rengel, (1992) emphasized that the change in calcium homeostasis is main response of the plant to salt stress and salt tolerance of plants related to their maintain calcium and potassium concentration and to avoid sodium toxicity.

Rejili et al. (2007) demonstrated that there is a differences in the accumulation of Na^+ and K^+ in the plant found under salinity stress. The salt sensitivity plants maintained low K^+ content and less K^+/Na^+ ratio compared with the salt tolerant plants. Cuin et al., (2003) reported that the High K^+/Na^+ ratio is more important from maintaining a low concentration of Na^+ for many plant species.

Amira M. S. Abdul Qados (2011) mentioned that carotenoids content was significantly reduced after ten days of treatment with different (NaCl) concentration (0,60,120,240 mM), While the protein content was increased with the same treatments and the same period. The same result registered by (Mustard and Renault, 2006) that a reduction of carotenoid content in

seedling of dogwood (*Cornus sericea* L.) as a reason to salt stress. Also (Chao et al., 1999) noticed an increase in protein content as a response to salt treatment in tomato plant *(Lycopersicon esculentum* L.).

Tester and Davenport, (2003) stated that Leaves are considered weaker than roots to sodium simply due to Na^+ and Cl^- accumulate to higher levels in shoots than roots. Sagi et al., (1997) suggested that there is a restriction in sodium transport from roots to shoots take place, causing minimizing in the accumulation of Na^+ in the leaves. Ashraf and Mc-Neily (1990) noted that in salt sensitive variety of *Brassica* there was higher amount of chloride ions in roots compared with the amount has been founded in shoots.

2.4. Effect of salinity stress on chlorophyll content:

The stressful environment like salinity, drought, and high temperature causing changes in a wide range of biochemical, physiological, and molecular processes in plant. Photosynthesis process considered one of the most fundamental and complex physiological process in all green plants, such stresses severely affecting all photosynthesis phases (Ashraf M. and Harris P. J. C, 2013).

Li et al., (2010) stated that the salt stress causing break down in chlorophyll, this due to the increase of toxic cation, Na^+. Also its been reported in some studies on different crops e.g., sunflower (*Heliantus annus*) a reduction in photosynthetic pigments, such as chlorophyll a and b, in contrast

photosystem II activity significantly inhibited as a response to salt stress (Akram and Ashraf, 2011).

Mehta et al., (2010) stated the donor side in photosystemII was damaged more than the receptor side because of salt stress (0.1-0.5 M NaCl) in wheat. Moreover, the damage in photosystemII was reversible, 100% recovery in the acceptor side and 85% in donor side.

In various studies, the decrease Chlorophyll content due to salt stress is commonly reported, this may be attributed to different reasons, the membrane deterioration is one of them (Mane et aj.,2010; Tantawy et al.,2009). Generally, a reduction in chlorophyll and total carotenoid content in leaves usually happened under salt stress. The oldest leaves start to develop chlorosis and fall as the salt stress period continue on the plant (Hernandez et al., 1995, 1999; Gadallah, 1999; Agastian et al., 2000).

Munnes and Termatt, (1986) mentioned that salt stress causes both short and long term effects on photosynthesis. After a few hours during one or two days of the exposure to salt stress the short-term effect occurs and this response is important, as there is complete cessation of C assimilation within hours. After several days of exposure to salt the long-term takes place and the reduction in C assimilation due to the salt accumulation in leaves occur.

Gama et al (2007) conducted a study on five cultivars of common bean (*phaseolus vulgaris* L.) under salt stress and indicated that photosynthesis assimilation rate, transpiration rate, and stomatal conductance are significantly reduced in contrast to the increasing in salinity levels (0, 50,

100 mM), this could be attributed to stomatal factors, the reduction in photosynthesis has some effects on both stomata and transpiration as the three considered the integral elements of the photosynthetic apparatus of the plant. CO_2 concentration in chloroplast decreases due to the reduction is stomatal conductance. Brugnoli and Laueri (1991) emphasized that reduced photosynthetic C assimilation was attributed to reduced stomatal conductance.

2.5. Effect of salinity stress on Plant growth promoting bacteria (PGPB)

Porcel R. et al., (2010) emphasized that salinity is one of the most severe environmental stress as it reduces crop production of more than 20% of irrigated land worldwide, so it is important to develop salt tolerant crops.

Many ways have been made to develop salt tolerant crops and to reduce the effect of salt stress on growth and yield, chemical amelioration, that involve developing salt- resistant varieties, soil leaching the excess salts to lower soil depths, amelioration of saline soils under leaching and cropping system (Qadir M. et al., 2000).

Therefore, the methods and strategies to diminish the effect of salt stress on plants have received good attention. Recently the biological approach using plant growth promoting rizobacteria (PGPR) inoculation, Arbuscular mycorrhiza fungi (AMF) inoculation, and many species of rhizobacteria was

attempt. In such condition (salt stress) the usage of biological approach may be the appropriate solution to salt stress as using the salt tolerant bacterial inoculants that may prove useful in developing strategies to increase the plant tolerance and enhance plant growth in saline soils (Bacilio M. et al., 2004).

Gray & Smith, (2005) indicated that the soil condition and composition of root secretions play important roles in the type and specificity of those interactions. Tokala et al., (2002) reported that the bacteria in root zone that have been found to have beneficial effects on many plants include species of the genera *Azotobacter, Arthrobacter*, *Azospirillum*, *Bacillus*, *Pseudomonas and Serratia, Enterobacter* as well as *Streptomyces spp.*

Ryan et al., (2009)stated that plants in nature interact with many beneficial micro-organisms, which improve plant stress tolerance. Therefore, Mayak S. (2004) mentioned that salt-tolerant root-colonizing bacteria that have managed to survive and reverse the environmental factors and could greatly help in employing them for their beneficial properties in such environment in which other microorganisms not easily or even hardly survive.

Among such microorganisms, (PGPR) are one of the most studied which can be classified as extracellular existing in spaces b/w cells (Gray & smith, 2005). The mechanism of (PGPR) can be explained into direct and indirect ones. The direct mechanism include nitrogen fixation, producing of plant growth promoting substances (auxin, cytokinins, or gibberellins), soil mineral solubilization, and reduction of ethylene levels, among others. The

indirect mechanism include favoring colonization by other beneficial microorganisms, as Mycorrhizal fungi (Vessey 2003; lugtenberg and kamilova 2009). Many species were used for promoting the growth in salinity sensitive and moderately sensitive crops, such a species mentioned as *B. megaterium, Pseudomonas fluorescens, and Azospirillum spp* (Hesham M., 2005).

Randy Ortiz C., (2008) defined the PGPR as a free living, rhizosphere-inhabiting bacteria that have a positive influence on plant growth and development. Plant growth and bacterial fitness are being increased due to many rhizobacterial species associated with plants. Alstrom S.,(1991) ;Persello-Cartieaux F., (2001) emphasized that diverse genera of microorganisms such as Azospirillum, Pseudomonas, and Bacillus spp have been identified from a wide range of plant species, such as rice, barley, bean and Arabidopsis.

The inoculation of PGPR under osmotic stress conditions have beneficial effect are not only as a biomass growth increasing, but also as an improvement in water status (Nadeem et al. 2007; Kohler et al. 2009). To hold tissue water status under osmotic stress conditions, plants need to achieve a balance between water lost by leaf transpiration and water picked up by root take-up. The impact of PGPR immunization on leaf transpiration has been generally considered with differentiating comes (Rincon et al. 2008; Alguacil et al. 2009; Bashan et al. 2009). Notwithstanding, with respect to how PGPR inoculation influenced root water take-up capacity

remains practically unexplored. Consequently, there is just a single report describing an increase in root water hydraulic conductance (L) in sorghum plants by vaccination with *Azospirillum brasilense* under control and osmotic anxiety conditions (Sarig et al. 1992).

Interaction of PGPR with several crops in saline conditions reduced the extent of poor growth and thus helps plants survive and improve performance in adverse conditions (Dimkpa et al. 2009). Some PGPR may exert a direct stimulation on plant growth and development by providing plants with fixed nitrogen, phytohormones, iron that has been sequestered by bacterial siderophores, and soluble phosphate (Hayat et al. 2010; Rodriguez and Fraga 1999). Others do this indirectly by protecting the plant against soil-borne diseases, most of which are caused by pathogenic fungi (Lugtenberg and Kamilova 2009). Soil-borne pseudomonads have received particular attention because of their catabolic versatility, excellent root-colonizing ability and capacity to produce a wide range of enzymes and metabolites that help the plant withstand varied biotic and abiotic stress conditions (Vessey 2003). Among the PGPR, *B. megaterium* have been supported as effective and temperate bio-inoculant to use in the coordinated supplement and pest control framework. *B. megaterium* is a gram positive, rod molded endospore-shaping microbes. It is considered aerobic, but when necessary it is also capable for growing under anaerobic conditions Aunpad R. et al., (2007); Ausubel et al (1995). *B. megaterium* considered important group of gram-positive microscopic organisms, individuals from this family comprise generous recommendation of the micro flora of free living

saprophytes in soil, marine situations, fresh water and numerous other normal territories Banerjee S et al., (2007); Brophy PF et al.,(1982).

Adriana M et all., 2010 demonstrated that Inoculated plants were found to show higher root water conductance (L) values under both unstressed and salt stressed conditions. It's been found that these higher L values in the inoculated plants related with higher plasma membrane type two (PIP2) aquaporin quantity in their roots under salt-stressed conditions. Additionally, ZmPIP1;1 protein quantity under salt stressed conditions was higher in immunized leaves than in non-immunized ones. The inoculation with *B. megaterium* also had a significant effect on reducing the salt injury which estimated by quantifying the percentage of necrotic leaf area with inoculated plants compared with non-inoculated. The treatment with salt increased K^+ concentration in non-inoculated plants, both inoculated and non-inoculated exhibited increase in Cl- concentration, Mg^{2+} concentration only increased in inoculated plant. Hesham M. A. El-komy 2005 reported that *B. megaterium* and *Azospirillum lipofreum* inoculated as single or mixed with wheat (*Triticum aestivum L.*), both significantly enhanced phosphorus solubilization and shoot phosphorus content increased in about 37%-53% compared to plants not inoculated used as control. López-Bucio et all, 2007 studied the Effect of *B. megaterium* inoculation on plant growth. The effect of *B. megaterium* inoculation on plant growth for bean (Phaseolus vulgaris) was investigated. The fresh and dry weights of the plants inoculated with *B. megaterium* significantly increased. Interestingly, plant-growth promotion

was related to the increase in lateral-root number and in lateral-root height and modifications in root architecture.

Chapter Three
Materials and Methods

3.1 Plant material

The experiments were carried out in a greenhouse (in order to control irrigation without rainfall), at Jenin in the north of West Bank (Palestine) using (*Vicia Faba* L.) plant.

Picture 1: Jenin City, the location of the experiment

Two varieties were used (Qertase and local); the Qertase have bigger seeds size, more surface area of leaves than local variety, the seeds were obtained from the local market and both are of the types grown in Palestine.

3.2 Preparing and sowing of seed

Intact seeds, which were homogeneous and identical in size and color, and free from wrinkles, were chosen. Two seeds were grown at 17th of Nov 2016 in each plastic pot (20 cm in diameter and 22 cm height), containing 5L of mixed soil from sand and clay 1:1. The seeds were left to grow inside the greenhouse under natural lighting, (26/4) ± 2 C (day/night) and 60%

relative humidity. The experiment design were 2*5*3 split plot including irrigation with four different salinity levels and one with fresh tab water (0, 2, 4, 6 and 8 ds/m NaCl), one inoculation treatments (inoculated with *B. megaterium*) with 3 replicates for each treatment for each Faba Bean variety in lines, with each line comprising of all treatments. The number of plants per pot was decreased to one after 3 weeks , and only homogenous seedlings showing the strongest growth, were selected and left to grow until they were 24 days of age (from the beginning of germination), then treatments of adding started.

The plants were left for 6 days after inoculation and the irrigation continues with fresh water to give the bacteria enough time for adaptation and propagation, Treatment of irrigation with different salinity levels were started after 6 days of inoculation and 30 days age.(picture 2.).

Picture 2: Faba Bean plant, 30 days age.

3.3 Bacteria propagation and inoculation

B. megaterium (ATCC® 14581™) were prepared two week before inoculated to plants. It was activated in 100 ml nutrient broth (Nutrient Broth (BD 234000).Its Incubated for 24-48 h in a rotary shaker, 200 rpm at 30± 2°C. Several subcultures conducted to the bacteria to increase the total colony forming units and the quantity of bacteria. Every culture was diluted to colony forming10^8 units (cfu) /ml.

The number of colony forming units was measured by obtaining the optical density (OD) (1 ml) using spectrophotometer (at 600 nm, Model V530, Jasco Corporation, Japan). The final OD unit (at 600 nm) of 1.0 ml is equivalent to approximately $7x10^8$ CFU.ml-1 used for plant inoculation. Each pot was placed on plastic dish which was spread on soil surface to prevent airborne dispersal of bacteria within the controlled greenhouse.

The bacteria solution added directly to the mixed soil in pots after 24 days of age, 1.5 ml (OD for each 1 ml = 7×10^8 CFU.ml-1) added for each treatment with bacteria, each line from the pots have three replicates with bacteria and three without.

3.4 Treatments with NaCl

After 30 days of plants age, different concentrations of NaCl (0, 2, 4, 6, and 8 ds/M) were used in irrigation. Salt concentrations prepared depending on Rani, B., & Sharma, V. K. (2015) method. Pots were irrigated when needed depending on moisture content in soil, the pots divided to lines depending on

salt concentration, each line comprising one of the concentrations of NaCl. The control plants only received fresh water.

T1: different salinity levels on plants without *B.megaterium*

T2: different salinity levels on plants with *B.megaterium*

T3: control (fresh water) on plants with *B. megaterium*

T4: control (fresh water) on plants without *B.megaterium*

Table 1: The electric conductivity (Ece) and total dissolved solids (TDS) for the water used in the experiment.

Sample	Ece (ds/m)	Tds (ppm)
Frwsh Water	**0.875**	**461**
2 ds/m	**2.59**	**1190**
4 ds/m	**4.63**	**2800**
6 ds/m	**6.22**	**3110**
8 ds/m	**7.65**	**3850**

3.5 Growth Parameters

Growth parameters were taken for the plants at 5th of March 2017 at 108 age, the three replicates taken for each treatment individually, the measurements of each pot were taken as following:

- Number of flowers after 15 days of first flowering.
- Shoot height (cm) using regular meter from the soil surface to the top of the plant.
- Number of main tillers.
- Number of True leaves.
- Shoot fresh weight (g) using Precision balance (Kern 440-46, Germany).
- Shoot dry weight (g) after being dried by oven (P Selecta, Spain) at 70 C for 48 hours.
- Roots fresh weight (g).
- Roots dry weight (g).
- Number of nodules on roots.

3.6 Yield and it`s components

- Number of pods per plant.
- Pods height, width.
- Pods weight.
- Number of seeds per plant.
- Weight of seeds per plant.
- Pods and seeds fresh and dry weight per plant.

3.7 Chlorophyll content

The chlorophyll readings and leaf greenness of the Faba Bean plants were taken in 2 days before harvesting using chlorophyll meter (Chlorophyll Meter SPAD-502Plus, Konica Minolta Sensing, Inc., Japan) , for each plant three readings taken at three locations for each replicate, then the average of the three readings estimated (the upper leaf , middle leaf and lower leaf) were taken.

SPAD units defined by manufacturer as ‘‘1’’ equivalent to very pale green coloration (chlorotic) and ‘‘50’’equivalent to very dark green coloration.

Picture 3.Chlorophyll Meter SPAD-502Plus, Konica Minolta Sensing, Inc., Japan.

3.8 Nutrient element content

At the laboratory of faculty of Agriculture, An Najah National University, Tulkarm, Palestine. Methodology of Motsara, M.R.Guide to laboratory establishment for plant nutrient analysis, Food and Agriculture Organization of the United Nations, 2008 were used In order to determine the nutrient contents of leaves of Faba Bean. Most of the leaves for each plant were collected, all of leaves were oven dried at 70 C for 48 h and ground using an

electric stainless steel mill using a 0.5‑mm sieve and stored in well-stoppered plastic bottles for analysis.

Dry ashing: From each sample, 1 gm were taken using sensitive balance and placed in crucible and heated at 550 C for 3 hours in High Temperature Laboratory Oven (Carbolite LHT 6/30, UK)

to destroy OM, and the ash so obtained can be dissolved in acids to bring the sample into liquid form for estimation.

3.8.1 Nitrogen and protein content

Nitrogen percentage was estimated by Kjeldahl method.

Digestion: 1 gm from each sample placed in pipet, 20 ml H_2SO_4 for digestion, ½ spoon of catalyst (1 kg of Na_2SO_4 with 30 gm of $CuSo_4$), boiling chips to prevent boiling in the samples, the pipets moved and heated at the turbotherm (Gerhardt, Germany) for two rounds (each round: 15 minutes at 80 C, 15 minutes at 90 C and 90 minutes at 100 C). The samples will be digested and gives clear solution.

Distillation: 25 ml of boric acid added to each solution to catch ammonia gas that results from the process. The distillation unit Vapodest (Gerhardt, Germany) starts by adding 70 ml of NaOH & 30 ml of H_2O and take 4 minutes, the color of boric acid changed from purple to green as an indicator for ammonia gas availability.

Titration: titrate the solution with 0.095mM HCL to change the color from green to purple and we read the volume required and use it in the equation. Protein was calculated by multiplying the percentage of total nitrogen by the factor of 6.25 (A.O.A.C., 1980).

$$\%\ of\ N = \frac{(\text{V. of acid used} - \text{V. of Blank}) \times \text{Normality of aci} \times 1.4007}{\text{weight of sample (gm)}}$$

$$\%\ Protein = \%\ \text{Nitrogen x } 6.25$$

Picture 4: Carbolite (ashing samples), Turbotherm (digestion), Vapodest (Distillation).

3.8.2 Sodium, Potassium and Calcium content

Digestion of samples done using 1 gm of ashed samples with 10 ml of HCL mixed together in flask and heated to 90 C at using hotplate. After digestion, completing to 100ml with distilled water. Each sample filtered before using

flamephotometer (Sherwood, UK) Sodium, potassium and calcium were estimated Flame photometrically using Sherwood Flame Photometer 410. The percent were estimated for shoot samples taken for all replicates.

Picture 5: Flamephotometer (Sherwood, UK).

3.8.3 Chloride content

The estimation of chloride in shoot samples were done using volumetric method (A.O.A.C official method 937.09).

$$M\ mole\ of\ Cl\ =\ m\ mole\ of\ AgNO3 - m\ mole\ of\ NH4SCN$$

$$= (V.OF\ AgNO3\ \times\ Normality) - (V.of\ NH4SCN \times Normality)$$

$$Cl\ (ppm)\ =\ M\ mole\ of\ Cl\ \times\ M.W\ of\ Cl\ \times\ dilution\ factor$$

3.8.4 Phosphorus content

Phosphorus percentage were estimated using Spectrophotometric vanadium phosphomolybdate method (Motsara, M. R., & Roy, R. N., 2008). 1 gm of plant sample was taken and digest as per the wet digestion method, and the volume made up to 100 ml, 5 ml of digest in a 50 ml volumetric flask, and 10 ml added of vanadomolybdate reagent. The volume made up with distilled water, and Kept for 30 minutes. A yellow color develops, which is stable for days and is read at 420 nm on spectrophotometer. The observed absorbance, determined the P content from the standard curve.

The relevant calculation is:

$$P\ content\ (\mu g)\ in\ 1\ g\ of\ sample\ =\ C\ \times\ df$$

$$C\ =\ concentration\ of\ P\ (\mu g/ml)\ as\ read\ from\ the\ standard\ curve;$$

$$df\ =\ dilution\ factor, which\ is\ 100\ \times\ 10\ =\ 1\ 000$$

Picture 6: Spectrophotometer, Pharmacia, biotech.

3.9 Soil analysis

12 sample were taken from the soil mix that been used in the pots, dried in the oven at 105 C for 24 hours , then saturation paste were prepared for samples, the volume of water recorded and left 24 hours.

Using vacuum pump to get the extract, ECe and PH meter were used to take the reading from the extract.

Table 2. Soil analysis readings for the soil that used in the experiment.

Sampel	Distelled water added by ml	Ece ds/m	Ph	Weight gm
0 ds/m	53	2.41	8.75	103.4
0 ds/m+B	54	2.22	8.32	99.4
2 ds/m	44	7.71	8.22	88.1
2 ds/m+b	47	5.33	5.93	92.7
4 ds/m	47	5.36	8.24	99.8
4 ds/m+B	43	6.11	8.18	100.3
8 ds/m	64	14.27	7.78	99.2
8 ds/m+B	56	12.82	7.79	111.5

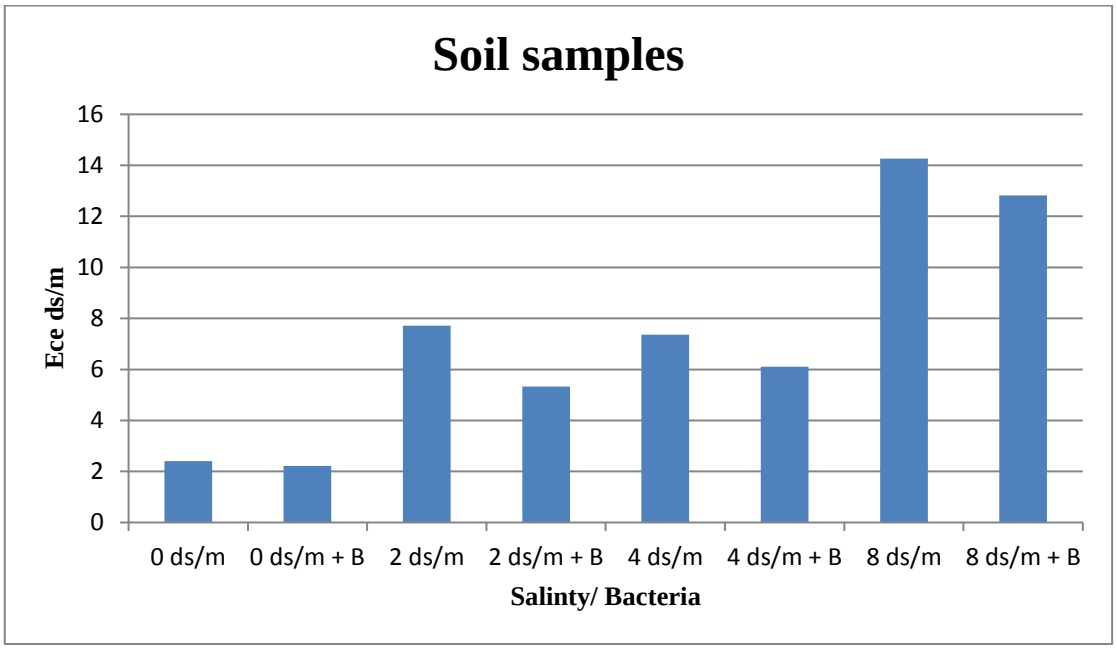

Figure 3: Electrical conductivity of soil samples comparing with and without *B. megaterium*.

3.10 Statistical analysis

To evaluate the difference between inoculated Faba bean and non-inoculated once under saline conditions from the factorial design were subjected to analysis of variance (ANOVA) using the mixed procedure of SAS (SAS Institute 1995). Following ANOVA, treatment means were evaluated with Tukey-Kramer adjusted comparisons of least square means (Kramer, 1956;

Tukey, 1991). We used the PDMIX800 macro to convert pairwise differences between least square means to letter groupings, where means sharing the same letter code are not significantly different (Saxton 1998).

Chapter four

Results

Table 3: Class level Information for the statical Analysis of the results.

Class Level Information		
Class	**Levels**	**Values**
Bacteria	2	(0)Without *B. megaterium*, (1) with *B. megaterium*
salinity	5	(0, 2, 4, 6, 8)ds/m
Variety (var)	2	(1) Local variety (2) Qertase variety
Replicate	3	1 2 3

4.1 The effect of *B. megaterium* inoculation on Number of flowers of Faba Bean plant under different salinity levels.

The number of flowers was effectively affected by the inoculation of Faba Bean *B. megaterium*. The number of flowers of inoculated plants was higher significantly compared with non-inoculated ones. The positive effect of bacteria on number of flower was more evident on variety 1. The highest number of flowers was observed at salinity level 2 with about 23 flowers for variety 1. In addition the interaction between varieties, salinity and bacteria was highly significant as the salinity increase to 8 ds/m the number of flowers for variety 1 was about 16 flowers compared to 4 flowers at the same level of salinity (Table 4) (see list of appendix, table 22-28).

Table 4. The analysis of variance for the effect of *B. megaterium* on number of flowers for Faba Bean.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	38	2.43	0.101
Bacteria	1	38	4.44	0.041
Salinity	4	38	0.05	0.994
Bacteria*salinity	4	38	0.50	0.736
Var	1	38	1.30	0.261
Bacteria*var	1	38	5.01	0.031
salinity*var	4	38	2.65	0.047
Bacteria*salinity*var	4	38	4.99	0.002

Var = Variety 1 (local) and variety 2 (Qertase), bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m.

4.2 The effect of *B. megaterium* inoculation on plant height of Faba Bean plant under different salinity levels

The analysis of variance revealed that salinity and bacteria was significantly influenced plant height of Faba Bean ($P \leq 0.009$). The plants inoculated with *B. megaterium* revealed higher shoots compared with plants not inoculated with *B. megaterium* 60.26 cm and 65.9 cm respectively. The results revealed as salinity increase the plant height decrease however the bacterial inoculation ameliorate the effect of salinity where the maximum height was 72.16 cm at 6 ds/m for inoculated plant compared to 61.3 cm at the same level of salinity without bacterial inoculation. Based on the mean separation the interaction between bacteria x varieties, salinity x varieties and bacteria x salinity x varieties was not significant ($P \leq$ 0.9593, 0.1876 and 0.5686 respectively) (Table 5) (see list of appendix, table 29-35).

Table 5: The analysis of variance for the effect of *B. megaterium* on plant height for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	37	0.79	0.463
Bacteria	1	37	9.00	0.004
Salinity	4	37	3.88	0.009
Bacteria*salinity	4	37	4.66	0.003
Var	1	37	9.19	0.004
Bacteria*var	1	37	0.00	0.959
salinity*var	4	37	1.63	0.187
Bacteria*salinity*var	4	37	0.74	0.568

Var = Variety 1 (local) and variety 2 (Qertase), bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m.

4.3 The effect of *B. megaterium* inoculation on branch number of Faba Bean plant under different salinity levels.

Salinity and bacterial inoculation significantly affected branch number (P ≤0.0220). The interaction between *B. megaterium* x varieties, *B. megaterium* x salinity x varieties significantly number of tillers (P ≤0.0349 and 0.0114 respectively). Average number of branch ranged from 2.7 branch in plants subjected to bacterial inoculation and zero level of salinity to 4.33 branch at 4 ds/m the positive interaction between salinity and *B. megaterium*. Based on LSD variety 1 gives the maximum number of branch (5 branch) in response to *B. megaterium* at salinity level 4ds/m, this indicates the salinity affected both varieties however bacterial treatments ameliorated the inhibitory effect of salinity on branch number especially in the Variety 1 (Table 6) (see list of appendix, table 36-42).

Table 6: The analysis of variance for the effect of *B. megaterium* on branch number for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	37	1.43	0.253
Bacteria	1	37	0.00	0.965
Salinity	4	37	1.73	0.163
Bacteria*salinity	4	37	3.26	0.022
Var	1	37	2.35	0.133
Bacteria*var	1	37	4.80	0.034
salinity*var	4	37	1.22	0.320
Bacteria*salinity*var	4	37	3.77	0.011

Var = Variety 1 (local) and variety 2 (Qertase), bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m

4.4 The effect of *B. megaterium* inoculation on leaves number of Faba Bean plant under different salinity levels

Analysis of variance of number of leaves in both verities revealed that salinity had a highly significant negative effect on this parameter ($P \leq 0.0023$). The treatment effect was significant for both varieties. Inoculation by *B. megaterium* reduces significantly salt stress effect. The response of variety 1 was higher and significantly different than variety 2 with maximum number of leaf 391 compared to 223.33 at the same level of salinity with bacterial inoculation. The *B. megaterium* revealed highly significant differences by increasing the number of leaves compared with the plant without bacteria inoculation. High significant interaction was observed for salinity x varieties and bacteria x salinity x varieties ($P \leq 0.0165$ and 0.0002 respectively). According to the interaction the positive response of *B.*

megaterium is highly pronounced at higher level of salinity (Table 7) (see list of appendix, table 43-49).

Table 7: The analysis of variance for the effect of *B. megaterium* on leaves number for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	37	1.58	0.219
Bacteria	1	37	8.27	0.006
Salinity	4	37	5.09	0.002
Bacteria*salinity	4	37	22.19	<.001
Var	1	37	36.30	<.001
Bacteria*var	1	37	2.16	0.149
salinity*var	4	37	3.48	0.016
Bacteria*salinity*var	4	37	7.54	0.001

Var = Variety 1 (local) and variety 2 (Qertase), bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m

4.5 The effect of *B. megaterium* inoculation on fresh weight of Faba Bean plant under different salinity levels

B. megaterium treatment had significant effect on shoot fresh weight of the two Faba Bean varieties. Shoot fresh weight increased from 85.7667g (with no *B. megaterium* treatment) to 132.73g (with *B. megaterium* treatment) under salt stress (8 ds/m). The highest shoot fresh weight (174.60 g plant-1) was observed in variety 2 with *B. megaterium* treatment under salt stress level 6ds/m and at the same salinity level shoot fresh weight was also observed in this variety (121.9) grown without *B. megaterium* treatment. The response of variety 2 to *B. megaterium* was more positive as the salinity level

increased to 8 ds/m the shoot fresh weight increased from (66.6667g) (with no *B. megaterium* treatment) to 115.73 g(with *B. megaterium* treatment). The interaction between treatments also revealed significant increase in the fresh weight comparing to the plants without *B. megaterium* inoculation (Table 8) (see list of appendix, table 50-56).

Table 8: The analysis of variance for the effect of *B. megaterium* on fresh weight for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	37	0.78	0.467
Bacteria	1	37	13.99	0.001
Salinity	4	37	4.06	0.008
Bacteria*salinity	4	37	4.41	0.005
Var	1	37	4.32	0.044
Bacteria*var	1	37	6.45	0.015
salinity*var	4	37	1.48	0.229
Bacteria *salinity*var	4	37	6.18	0.000

Var = Variety 1 (local) and variety 2 (Qertase), bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m

4.6 The effect of *B. megaterium* inoculation on pods weight of Faba Bean plant under different salinity levels

The statistical analysis revealed that the *B. megaterium* affected the pods number significantly ($P \leq 0.0192$) by increasing the number of pods per plant. The number of pods in the two varieties was also significantly different

(P≤0.0487). Furthermore positive and significant interaction was observed between bacteria x varieties and bacteria x salinity x varieties (P≤ 0.034 and 0.048) respectively. Mean separation revealed that *B. megaterium* treatment contribute the highest number of pods (38.39) compared to plants without *B. megaterium* (29.27). The response of the two varieties based on mean separation revealed that variety 2 gives the highest number of pods 37.6 however in response to bacterial inoculation the number of pods increased from 21.39 to 38.71 for variety 1 (Table 9) (see list of appendix, table 57-63).

Table 9: The analysis of variance for the effect of *B. megaterium* on pods weight for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	34	0.14	0.873
Bacteria	1	34	6.04	0.019
Salinity	4	34	0.90	0.473
Bacteria*salinity	4	34	1.94	0.126
Var	1	34	4.18	0.048
Bacteria*var	1	34	4.88	0.034
salinity*var	4	34	1.75	0.161
Bacteria*salinity*var	4	34	2.68	0.048

Var = Variety 1 (local) and variety 2 (Qertase), bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m

4.7 The effect of *B. megaterium* inoculation on pods height of Faba Bean plant under different salinity levels

The analysis of variance revealed high significant differences ($P \leq 0.001$) for the interaction between variety, bacteria and salinity. Pod height was not affected by bacterial inoculation significantly, however the response to *B. megaterium* significantly affected by salinity treatment. According to our analysis salinity reduce the pod height significantly without bacterial inoculation from 9.598 cm in control plant to 5.366 cm under salinity level 8 ds/m, while the inoculation with *B. megaterium* significantly increase the height of pods at highest salinity levels. The response of the two varieties significantly affected by salinity and bacterial inoculation with highly significant differences in pods height depending on var only also being noticed . For example at the highest salinity level 8 ds/m without and with *B. megaterium* inoculation the pod height was 7.3 cm and 9.03 cm for variety 2 respectively. Furthermore, variety 1 gives the same trend at the same level of salinity 3.43 cm without bacterial inoculation and 5.133 cm with bacterial inoculation (Table 10) (see list of appendix, table 64-70).

Table 10: The analysis of variance for the effect of *B. megaterium* on pods height for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	34	0.80	0.458
Bacteria	1	34	0.33	0.568
Salinity	4	34	1.49	0.225
Bacteria*salinity	4	34	3.21	0.024
Var	1	34	48.59	<.001
Bacteria*var	1	34	4.74	0.036
salinity*var	4	34	2.33	0.075
Bacteria*salinity*var	4	34	9.03	<.001

Var = Variety 1 (local) and variety 2 (Qertase), bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m

4.8 The effect of *B. megaterium* inoculation on pods width of Faba Bean plant under different salinity levels

Pods width was not affected by bacterial inoculation. However salinity significantly reduces the pods width from 0.678 cm at zero salinity level to 0.441 cm at 8 ds/m. Based on mean separation for pods width a significant interaction was observed between bacteria, salinity and varieties. The inoculation with *B. megaterium* in variety 2 at salinity level 4 revealed similar pod width (0.933 cm) as control plant (0.966 cm) and this indicates a positive effect of bacteria on this variety at this level of salinity. Furthermore, the same trend was observed at higher salinity level 6 ds/m for variety 1 (Table 11) (see list of appendix, table 71-77).

Table 11: The analysis of variance for the effect of *B. megaterium* on pods width for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	34	1.15	0.329
Bacteria	1	34	0.06	0.815
Salinity	4	34	3.30	0.021
Bacteria*salinity	4	34	2.44	0.065
Var	1	34	7.59	0.009
Bacteria*var	1	34	2.09	0.157
salinity*var	4	34	1.52	0.218
Bacteria*salinity*var	4	34	2.95	0.034

Var = Variety 1 (local) and variety 2 (Qertase), bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m

4.9 The effect of *B. megaterium* inoculation on seeds number of Faba Bean plant under different salinity levels

The statistical analysis revealed that seeds number increased significantly in the plants that have *B. megaterium* inoculation compared to non-inoculated plants ($P \leq 0.05$). Salinity treatments have no significant difference on seeds number. In addition a significant difference was observed based on the variety type ($P \leq 0.005$). Based on mean separation the highest average number of seeds was 25.4 in plant inoculated with bacteria compared to 20.09 in plant without inoculation. Furthermore Variety 1 produce the highest average number of seeds 26.65 compared to 18.84 for variety 2 (Table 12) (see list of appendix, table 78-84).

Table 12: The analysis of variance for the effect of *B. megaterium* on seeds number for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	34	0.20	0.821
Bacteria	1	34	4.15	0.049
Salinity	4	34	1.75	0.161
Bacteria*salinity	4	34	0.80	0.533
Var	1	34	9.02	0.005
Bacteria*var	1	34	1.08	0.306
salinity*var	4	34	1.54	0.211
Bacteria*salinity*var	4	34	0.44	0.777

Var = Variety 1 (local) and variety 2 (Qertase), bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m

4.10 The effect of *B. megaterium* inoculation on pods number of Faba Bean plant under different salinity levels.

Pods number was significantly different depending on *B. megaterium* inoculation, the number of pods increased with *B. megaterium* compared with other plants without *B. megaterium* ($P \leq 0.039$). Salinity levels revealed no significant difference on both varieties with or without bacterial inoculation. However, the two varieties revealed highly significant differences ($P \leq 0.001$). Based on mean separation the average number of pods was 11.278 for plants inoculated with bacteria compared to 8.747 in non-inoculated plants. Furthermore variety 1 revealed the highest average number of pods 12.961 while variety 2 produce the lowest number 7.064 (Table 13) (see list of appendix, table 85-91).

Table 13: The analysis of variance for the effect of *B. megaterium* on pods number for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	34	1.82	0.176
Bacteria	1	34	4.60	0.039
Salinity	4	34	1.69	0.174
Bacteria*salinity	4	34	0.36	0.837
Var	1	34	25.16	<.001
Bacteria*var	1	34	0.17	0.686
salinity*var	4	34	2.42	0.067
Bacteria*salinity*var	4	34	1.65	0.183

Bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

4.11 The effect of *B. megaterium* inoculation on seeds fresh weight of Faba Bean plant under different salinity levels

The analysis of variance revealed a significant difference in seed fresh weight in response to variety and salinity interaction. However, bacterial inoculation has no significant effect on seeds fresh weight. Based on mean separation seeds fresh weight was increased from 8.397 g to 10.270 g due to bacterial inoculation. In addition salinity reduces seeds weight from 12.252 g at zero salinity level to 7.146 at 8 ds/m. The interaction between salinity and bacteria revealed that bacteria reduces the effect of salinity on seeds fresh weight compared to non-inoculated plants 11.06 g at 6 ds/m compared to 8.1g at the same salinity level without bacterial inoculation. Varieties have different response to salinity levels for example at 6 ds/m and zero level of

salinity the seeds fresh weight for variety 1 was 14.350 g and 9.118 g compare to 4.816 g and 15.387 for variety 2(Table 14).

Table 14: The analysis of variance for the effect of *B. megaterium* on seeds fresh weight for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	34	0.08	0.925
Bacteria	1	34	1.36	0.252
Salinity	4	34	0.84	0.510
Bacteria*salinity	4	34	0.66	0.621
Var	1	34	0.05	0.829
Bacteria*var	1	34	2.29	0.139
salinity*var	4	34	2.96	0.033
Bacteria*salinity*var	4	34	1.22	0.319

Bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

4.12 The effect of *B. megaterium* inoculation on seeds dry weight of Faba Bean plant under different salinity levels

The analysis of variance revealed no significant effect of salinity and bacterial inoculation in seeds dry weight. However the general trends were seeds dry weight increased in response to bacterial inoculation at various salinity levels. For example at salinity level 8 ds/m for variety 1 inoculated with bacteria seeds dry weight was 1.7 g compared to 0.83 g without bacterial inoculation at the same salinity level (Table 15) (see list of appendix, table 92-98).

Table 15: The analysis of variance for the effect of *B. megaterium* on seeds dry weight for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	33	0.33	0.7192
Bacteria	1	33	3.96	0.0548
Salinity	4	33	0.33	0.8568
Bacteria*salinity	4	33	0.85	0.5015
Var	1	33	0.05	0.8179
Bacteria*var	1	33	0.45	0.5069
salinity*var	4	33	1.37	0.2639
Bacteria*salinity*var	4	33	0.89	0.4798

Bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

4.13 The effect of *B. megaterium* inoculation on shoot dry weight of Faba Bean plant under different salinity levels

B. megaterium and salinity significantly influence shoot dry weight. Based on mean separation higher average shoot dry weight was observed in Faba Bean with bacterial inoculation 16.87 g than without bacterial inoculation 13.28 g. Faba Bean gives the highest shoot dry weight 20.56g and 20.25 g at salinity level 4 and 6 ds/m respectively when inoculated by bacteria compared to non- inoculated bean (Table 16) (see list of appendix, table 99-105).

Table 16: The analysis of variance for the effect of *B. megaterium* on shoot dry weight for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	37	0.72	0.494
Bacteria	1	37	7.64	0.008
Salinity	4	37	1.76	0.157
Bacteria*salinity	4	37	3.22	0.023
Var	1	37	2.62	0.113
Bacteria*var	1	37	1.43	0.240
salinity*var	4	37	0.74	0.569
Bacteria*salinity*var	4	37	2.44	0.064

Bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

4.14 The effect of *B. megaterium* inoculation on nodules number of Faba Bean plant under different salinity levels

Based on the statistical analysis no significant difference was observed with or without bacterial inoculation and even at various salinity levels. However the general output revealed a reduction in nodules number due to salinity and relative increase with bacterial inoculation (Table 17) (see list of appendix, table 106-112).

Table 17: The analysis of variance for the effect of *B. megaterium* on nodules number for two varieties of Faba Bean under four different salinity levels.

type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	24	0.34	0.718
Bacteria	1	24	0.09	0.771
Salinity	4	24	1.72	0.179
Bacteria*salinity	4	24	0.77	0.557
Var	1	24	3.58	0.070
Bacteria*var	1	24	1.97	0.173
salinity*var	4	24	0.13	0.971
Bacteria*salinity*var	4	24	1.05	0.402

Bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

4.15 The effect of *B. megaterium* inoculation on roots fresh weight of Faba Bean plant under different salinity levels

The analysis of variance revealed that salinity and inoculation of *B. megaterium* with the Faba Bean have highly significant effect on roots fresh weight. Mean separation revealed that *B. megaterium* increase the root fresh weight by 30 % compared to plant without bacteria inoculation. Moderate salinity levels 2 and 4 ds/m and bacterial inoculation increase root fresh weight (Table 18) (see list of appendix, table 113-119).

Table 18: The analysis of variance for the effect of *B. megaterium* on roots fresh weight for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	37	0.61	0.548
Bacteria	1	37	18.47	0.001
Salinity	4	37	10.87	<.001
Bacteria*salinity	4	37	11.97	<.001
Var	1	37	0.04	0.833
Bacteria*var	1	37	0.01	0.929
salinity*var	4	37	0.67	0.617
Bacteria*salinity*var	4	37	1.70	0.169

Bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

4.16 The effect of *B. megaterium* inoculation on roots dry weight of Faba Bean plant under different salinity levels

The analysis of variance revealed that dry weight of Faba Bean roots were significantly affected by *B. megaterium* inoculation, the dry weight increased in the plants with *B. megaterium* compared to plants without *B. megaterium* inoculation. Mean separation revealed that moderate salinity 2 and 4 ds/m have a positive effect on root dry weight. In addition, a significant interaction was observed between salinity and bacteria where the roots dry weight increase in the plants inoculated bacteria compared to plants without bacteria at moderate salinity levels 2 and 4 ds/m. Variety 2 revealed higher average root dry weight 6.94 g compared to variety 1 root dry weight 4.75g (Table 19) (see list of appendix, table 120-126).

Table 19: The analysis of variance for the effect of *B. megaterium* on roots dry weight for two varieties of Faba Bean under four different salinity levels.

type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	37	0.72	0.4942
Bacteria	1	37	12.90	0.010
Salinity	4	37	13.53	<.001
Bacteria*salinity	4	37	10.76	<.001
Var	1	37	13.64	0.007
Bacteria*var	1	37	0.54	0.466
salinity*var	4	37	1.75	0.160
Bacteria*salinity*var	4	37	0.91	0.467

Bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

4.17 The effect of *B. megaterium* inoculation on flowering date of Faba Bean plant under different salinity levels

The analysis of variance revealed high significant effect of salinity and bacterial inoculation on flowering data ($P \leq 0.001$). Mean separation revealed that bacterial inoculation and salinity results in early flowering compared to plant without bacterial inoculation 54 days. In addition, variety 1 revealed earlier flowering date 59 days compared to 64.7 days for variety 2. Based on mean separations for the interaction between salinity, variety and bacteria the effect on flowering data was more pronounced as the salinity level increase and in the presence of bacteria (Table 20)(see list of appendix, table 127-133).

Table 20: The analysis of variance for the effect of *B. megaterium* on flowering date for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	37	.	.
Bacteria	1	37	Infty	<.001
Salinity	4	37	Infty	<.001
Bacteria*salinity	4	37	Infty	<.001
Var	1	37	Infty	<.001
Bacteria*var	1	37	Infty	<.001
salinity*var	4	37	Infty	<.001
Bacteria*salinity*var	4	37	.	.

Bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

4.18 The effect of *B. megaterium* inoculation on chlorophyll content of Faba Bean plant under different salinity levels

The analysis of variance revealed that higher levels of salinity significantly reduce the chlorophyll, however *B. megaterium* slightly reduce the effect of salinity. A highly significant difference was observed between the two varieties, where variety 2 has higher chlorophyll content 42.63. Based on mean separation *B. megaterium* positively influenced chlorophyll content for variety 2, in contrast variety 1 revealed opposite response. The overall interactions revealed that variety 2 at salinity level 4 ds/m have the highest chlorophyll content 48.7, while the least content was recorded for variety 1 at salinity level 8ds/m (Table 21)(see list of appendix, table 134-140).

Table 21: The analysis of variance for the effect of *B. megaterium* on chlorophyll content for two varieties of Faba Bean under four different salinity levels.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Replicate	2	38	1.36	0.268
Bacteria	1	38	0.68	0.414
Salinity	4	38	4.83	0.003
Bacteria*salinity	4	38	1.32	0.279
Var	1	38	20.25	<.001
Bacteria*var	1	38	3.97	0.053
salinity*var	4	38	4.23	0.006
Bacteria*salinity*var	4	38	1.09	0.376

Bacteria= *B. megaterium*, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

4.19 The effect of *B. megaterium* inoculation on chloride content in Faba Bean plant under different salinity levels.

Based on the analysis of variance chloride accumulation was higher significantly (347.44 ppm) in variety 1 compared to Variety 2 (269.44 ppm). A liner and significant relationship was also observed between salinity and chloride content as salinity increase the chloride content increase. Bacterial inoculation significantly reduce the effect of salinity as the level of chloride content decrease. For example at 8 ds/m chloride content in inoculated plant was 620.44 PPM compared to 531.79 PPM in non-inoculated plants (Fig. 4) (see list of appendix, figure 12-14).

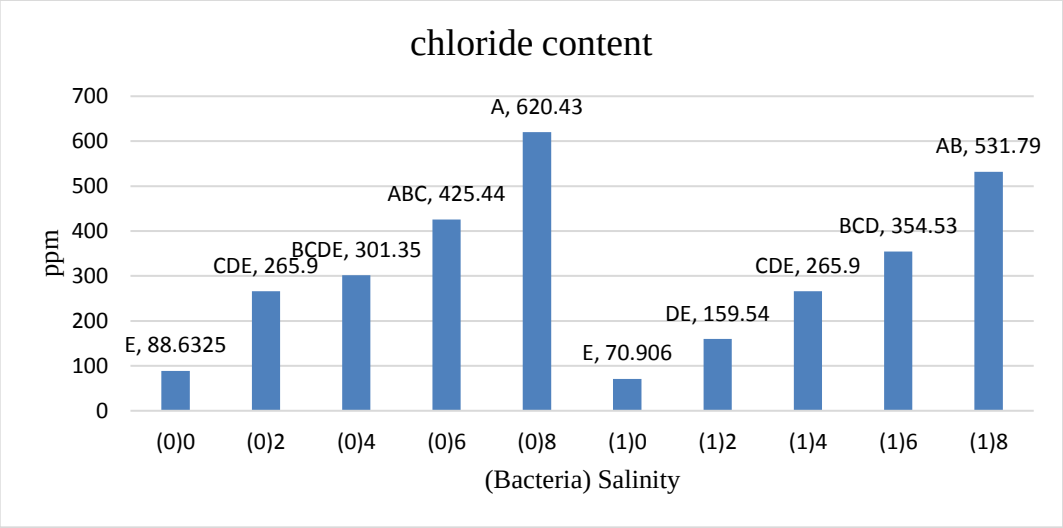

Figure 4: Effect of the interaction between salinity and *B. megaterium* on chloride content of Faba Bean plant .0: without *B. megaterium* 1: with *B. megaterium*, Salinity: (control, 2, 4, 6, 8) ds/m**.**

4.20 The effect of *B. megaterium* inoculation on Sodium content in Faba Bean plant under different salinity levels.

Statistical analysis revealed that variety 2 accumulate significantly higher amount of Sodium (1.97 %) compared to variety 1 (1.93%). In addition the leaves of the two varieties revealed significant reduction in Sodium content when inoculated with bacteria (1.76%) compared to plants without bacterial inoculation (2.14 %), even at different salinity levels the plants with *B. megaterium* inoculation previewed less Na content, that range from 1.12 % at zero level of salinity to 2.58 % at 8ds/m, compared to plants without inoculation that range from 1.5% at zero level of salinity to 2.99 % at 8ds/m. However, the response to salinity per se indicated linear relationship as the salinity increase the Sodium content increase ranged from

1.31 to 2.78 % at zero and 8 ds/m salinity respectively (Fig. 5) (see list of appendix, figure 15-18).

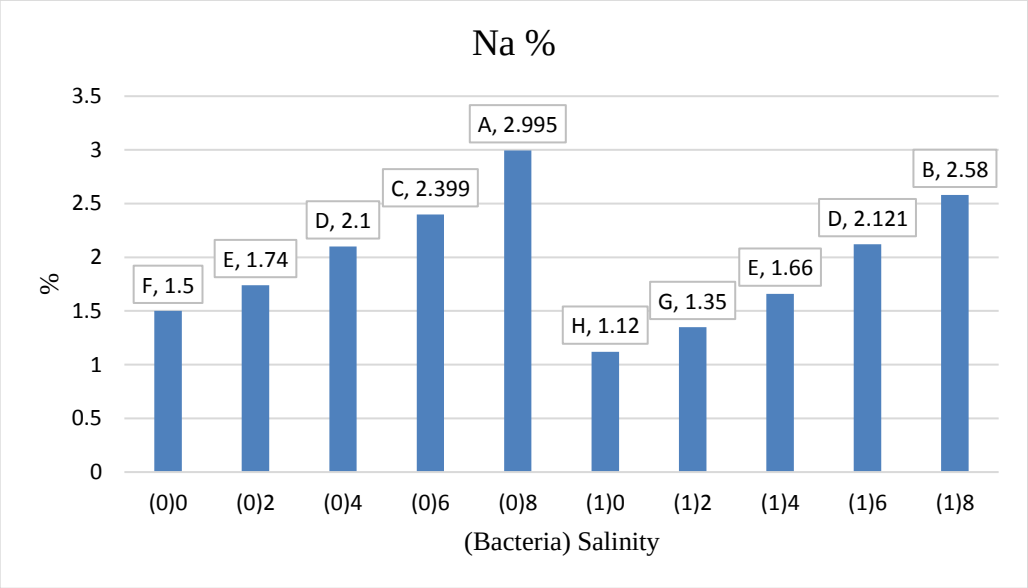

Figure 5: Effect of the interaction between salinity and B. megaterium on Sodium content of Faba Bean.0: without B. megaterium 1: with B. megaterium, Salinity: (control, 2, 4, 6, 8) ds/m.

4.21 The effect of *B. megaterium* inoculation on Potassium content in Faba Bean plant under different salinity levels.

Variety 2 recorded higher significant increase in Potassium content (4.28 %) if compared to Variety 1 (3.13 %). Moreover, Moreover, Faba Bean with bacterial inoculation revealed higher and positive effect on Potassium content (3.81 %) compared to non-inoculated plants (3.60 %). Furthermore, the interaction between salinity X bacteria revealed that bacterial inoculation increased Potassium accumulation 4.50 to 3.12 % at zero to 8 ds/m respectively compared to non-inoculated plant 4.17 to 2.88 % at the same salinity levels. On contrast content of potassium in response to salinity levels presented significant difference in leaves, as salinity level increase potassium

content decrease and ranged between 4.33 % in control to 3.01 % at 8 ds/m (Fig. 6) (see list of appendix, figure 19-20).

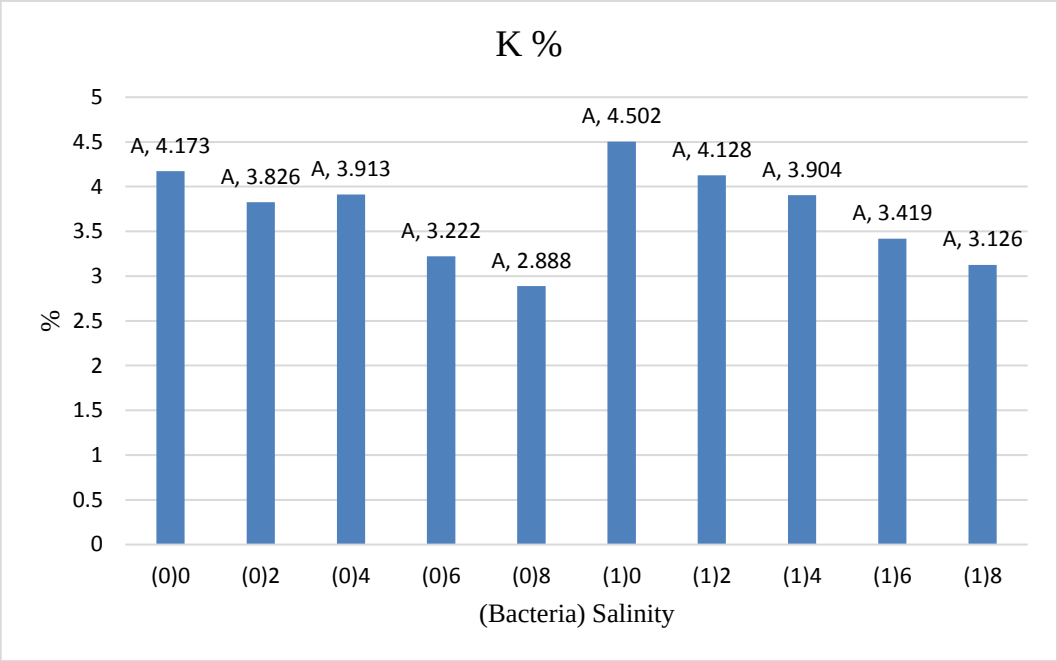

Figure 6: Effect of the interaction between salinity and *B. megaterium* on Potassium content of Faba Bean.0: without *B. megaterium* 1: with *B. megaterium*, Salinity: (control, 2, 4, 6, 8) ds/m.

4.22 The effect of *B. megaterium* inoculation on Calcium content in Faba Bean plant under different salinity levels.

Calcium accumulation in shoots of Faba Bean was significantly higher in Variety 2 (5.72 %) compared to Variety 1 (3.71 %). Generally, with bacterial inoculation, calcium content is significantly increased 4.83 % compared to non-inoculated plant 4.55 %. The presented data graphically illustrated indicated that salinity slightly reduce Calcium content and ranged 4.81 % in control plant to 4.38 % at 8 ds/m. in addition the analysis of variance revealed that salinity and bacterial inoculation interaction have no significant difference on calcium content. However, calcium content slightly increased

at all the salinity levels in the presence of *B. megaterium* inoculation (Fig. 7) (see list of appendix, figure 21-23) .

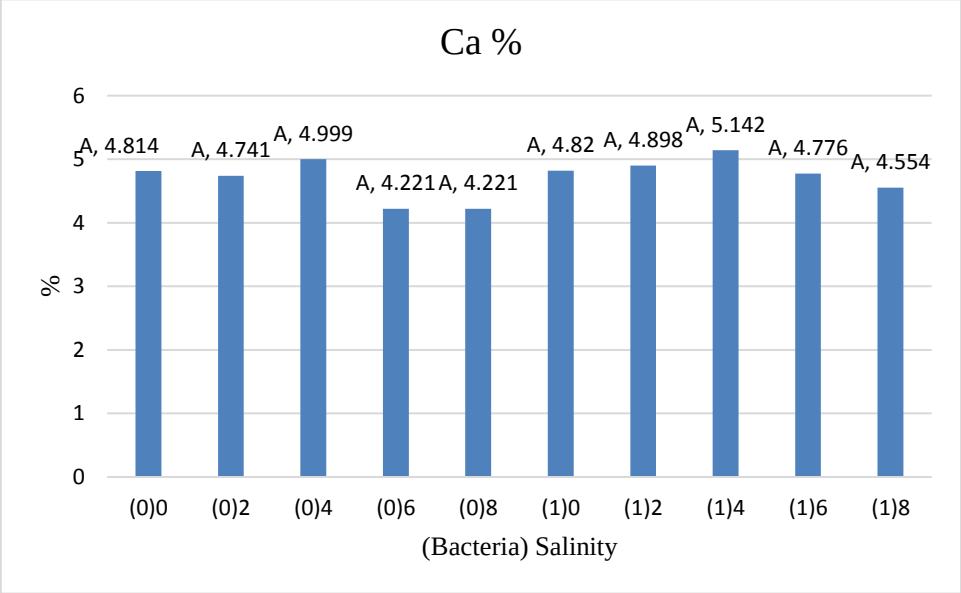

Figure 7: Effect of the interaction between salinity and *B. megaterium* on Calcium content of Faba Bean. 0: without *B. megaterium* 1: with *B. megaterium*, Salinity: (control, 2, 4, 6, 8) ds/m.

4.23 The effect of *B. megaterium* inoculation on Nitrogen content in Faba Bean plant under different salinity levels

The analysis of variance for Nitrogen percentage in seeds, roots and shoots revealed that no significant difference was observed for all the variable; Varieties, salinity, bacterial inoculation and the interaction. However, variety 2 revealed higher nitrogen percentage in seeds (1.44) and in shoots (0.97) compared to variety 1 (1.38, 0.91 respectively). In contrast Variety 1 revealed higher nitrogen percentage in roots (0.64) compared to variety 2 (0.58).

Bacterial inoculation and salinity levels revealed no significant and negative impact on nitrogen percentage for seeds, shoots and roots. On one hand the effect of salinity on Nitrogen percentage was variable but not significant, it seems that salinity reduce nitrogen percentage at 4 and 8 ds/m slightly while bacterial inoculation alleviate salinity effect. On the other hand the effect of salinity level 4 ds/m on nitrogen percentage in shoot and root was positive even with or without bacterial inoculation (Fig. 8) (see list of appendix, figure 24-32).

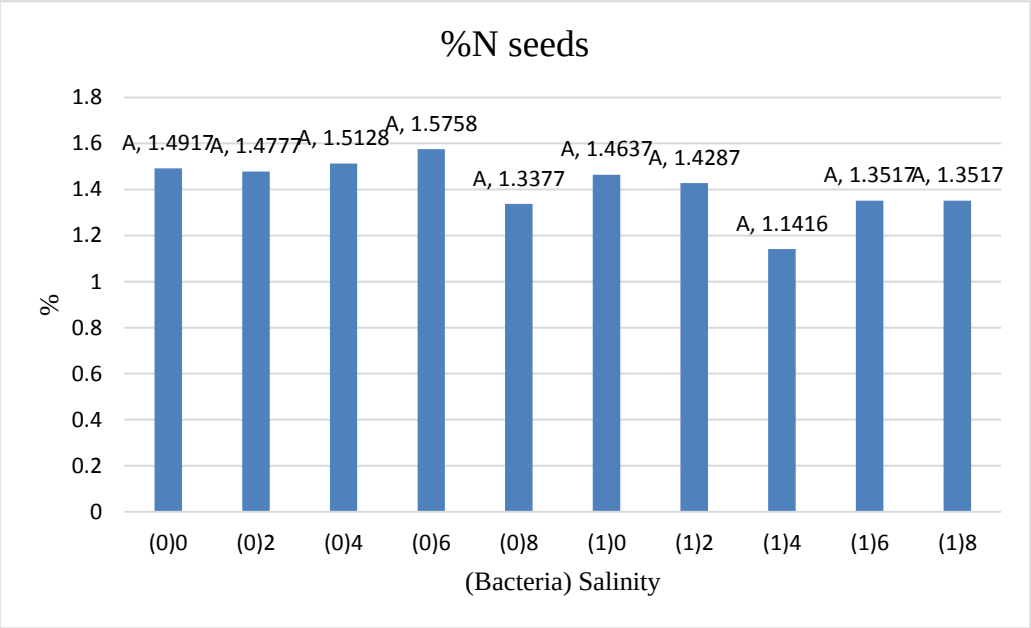

Figure 8: Effect of the interaction between salinity and *B. megaterium* on Nitrogen percent of Faba Bean seeds, 0: without *B. megaterium* 1: with *B. megaterium*, Salinity: (control, 2, 4, 6, 8) ds/m.

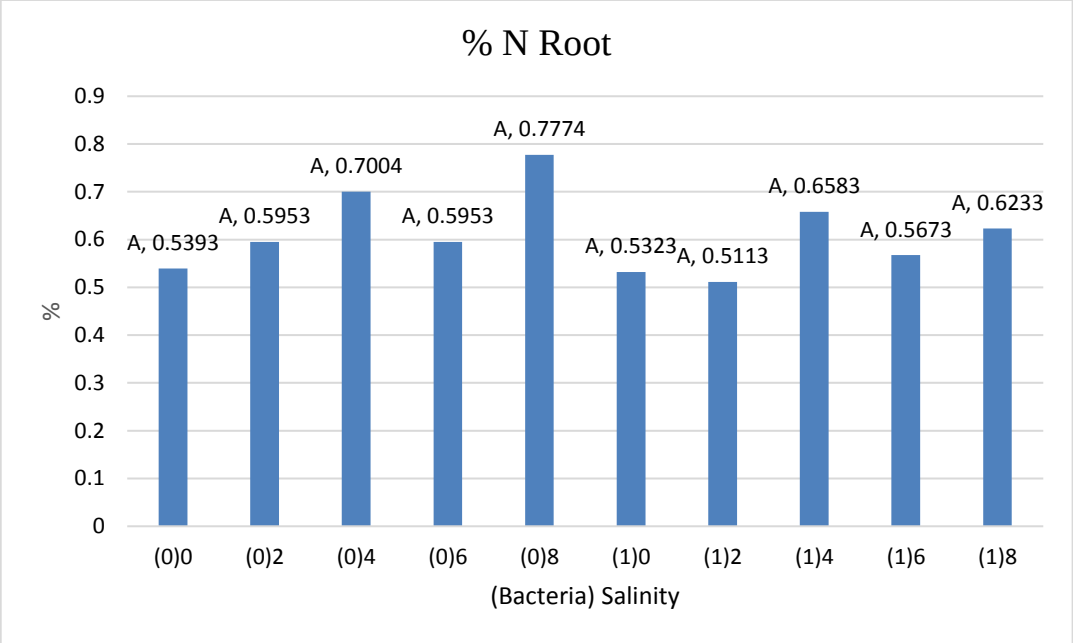

Figure 9: Effect of the interaction between salinity and B. megaterium on Nitrogen percent of Faba Bean roots 0: without B. megaterium 1: with B. megaterium, Salinity: (control, 2, 4, 6, 8) ds/m**.**

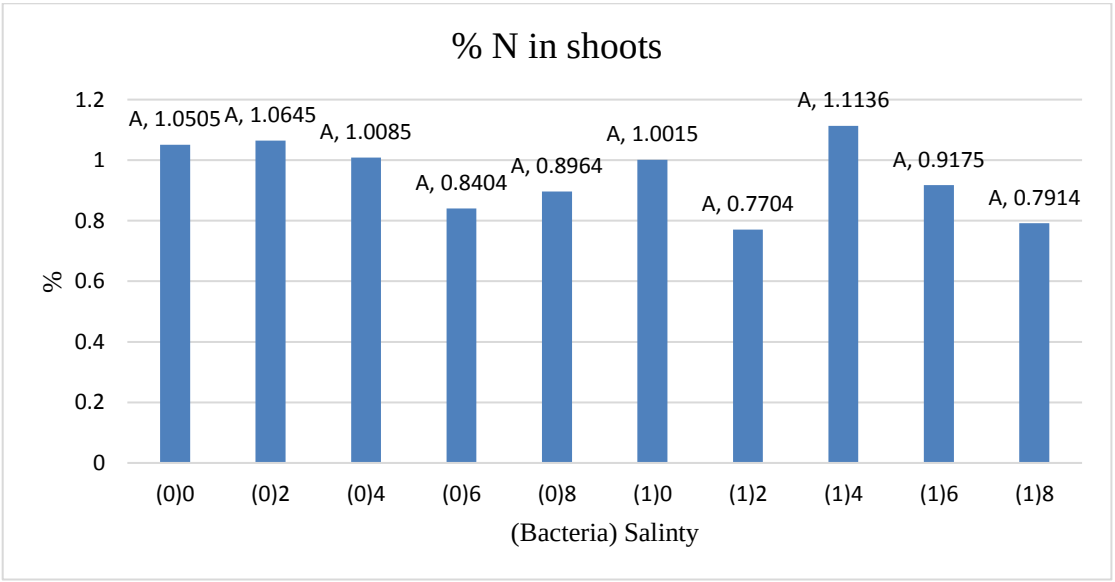

Figure 10: Effect of the interaction between salinity and *B. megaterium* on Nitrogen percent of Faba Bean shoots 0: without *B. megaterium* 1: with *B. megaterium*, Salinity: (control, 2, 4, 6, 8) ds/m.

4.24 The effect of *B. megaterium* inoculation on phosphorus content in Faba Bean plant under different salinity levels.

Statistical analysis revealed that variety 1 accumulate significantly higher amount of phosphorus (0.25 %) compared to variety 2 (0.15 %). In addition the leaves of the two varieties revealed increasing in phosphorus content when inoculated with bacteria (0.23 %) compared to plants without bacterial inoculation (0.18 %), even at different salinity levels the plants with *B. megaterium* inoculation previewed more P content, that range from 0.30 % at zero level of salinity to 0.24 % at 8ds/m, compared to plants without inoculation that range from 0.29 % at zero level of salinity to 0.15 % at 8ds/m. However, the response to salinity per se indicated reverse relationship as the salinity increase the phosphorus content decrease ranged from 4.81 to 4.38 % at zero and 8 ds/m salinity respectively (Fig. 11) (see list of appendix, figure 33-35).

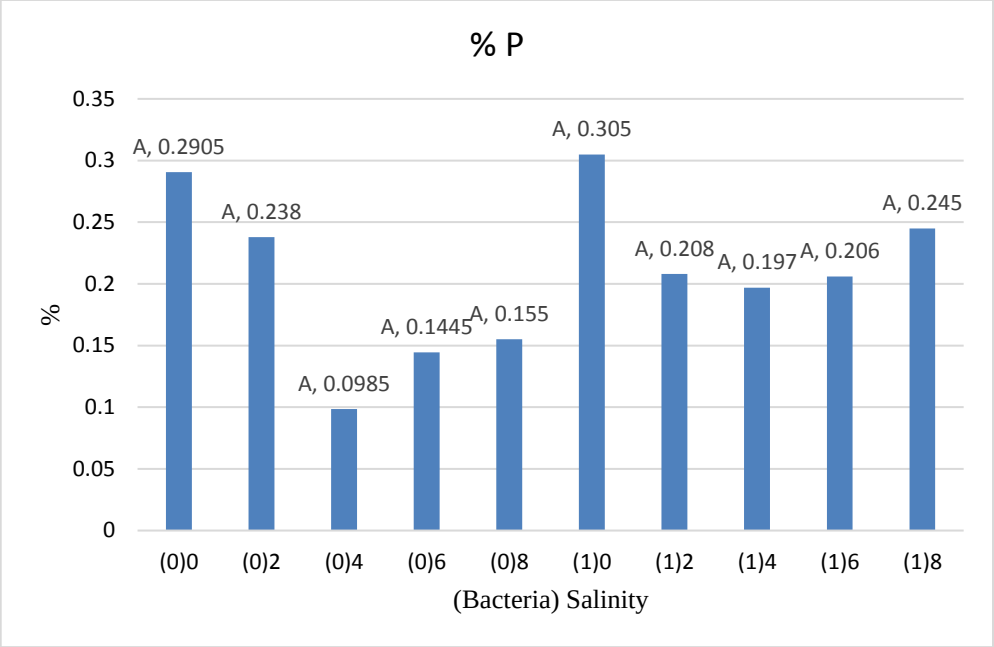

Figure 11: Effect of the interaction between salinity and *B. megaterium* on Phosphorus percent of Faba Bean shoots 0: without *B. megaterium* 1: with *B. megaterium*, Salinity: (control, 2, 4, 6, 8) ds/m

Chapter five
Discussion

5.1 The effect of *B. megaterium* on yield and yield component

Salinization is one of the major environmental constraints limiting crop production (Maggio *et al*. 2011). This phenomenon is particularly expressed in arid and semiarid regions due to high evaporation and low precipitation rates. Paradoxically, irrigation in these extreme environments has led to the accumulation of salts in the uppermost soil layers of arable lands. Thus, to date, large areas of freshwater-irrigated lands have suffered from salt and water build-up in the root zone (Yensen 2006; Rozema and Flowers 2008). This study has shown the effects of inoculation with *B. megaterium* on the performance of two *Vicia faba* varieties. Faba Bean is believed to be an excellent nitrogen fixer due to the genetic potential of symbiotic associates as well as soil and environmental conditions. However, inoculation with different types of plant growth promoter rhizobacteria for increased survival in specific soil types, superior functioning under diverse climates, improved compatibility and competitiveness with other soil microorganisms and higher nitrogen-fixing efficiency have been shown to improve growth and yield components of inoculated legumes (Vessey, 2003).

The analysis of yield components in this study revealed higher response for plant height, number of leaf, number of branch, number of flower, early flowering, pod height, pod width, number of seed, seed weight, fresh and dry weight in plant inoculated with bacteria. Several studies have reported a

positive effect of inoculation leading to a significant improvement in seed yield (Karasu et al. 2009). Although it is a small contribution to crop production.

Salinity reduce the yield and yield component in non-inoculated Faba Bean however the inoculation with *B. megaterium amollerate* the effect of salinity. This could be attributed to the osmatic regulation and high P-solubilizing and mineralizing ability from P-sources, production of growth promoting substances such as auxin (Aditya *et al*., 2009; Akhtar and Siddiqui, 2009). A range of salt-tolerant rhizobacteria (e.g., Rhizobium, Azospirillum, Pseudomonas, Flavobacterium, Arthrobacter, and Bacillus) has so far shown beneficial interactions with plants in stressed environments (Egamberdieva and Islam 2008; Egamberdieva et al. 2011; Adesemoye et al. 2008). The majority of cultivated plant species, especially widely grown horticultural and cereal crops, are susceptible to excessive concentrations of dissolved ions (e.g., ≥30 mM or ≥3.0 dS/m) in the rhizosphere (Ondrasek et al. 2009). For example, the yield of crops such as potato, corn, onion, and bean can be reduced by 50 % when the soil EC is increased to 5.0 dS/m (Horneck et al. 2007).

Earlier reports claim that salinity negatively affects soil bacterial activity by high osmotic strength and toxic effects by salts, but that salt-tolerant bacteria can survive and proliferate in the soil and in the rhizosphere in a harsh environment (Garcia and Hernandez 1996).

Bacterial inoculation significantly reduce the effect of salinity as it revealed increase in the number of flowers in treated Faba Bean. The positive effect on number of flower could be due to significant phytochemical product released by bacteria which it was suggested by several studies to be ACC deaminase enzyme. Ali et al., (2016) proposed that the plants pretreated with ACC deaminase containing bacterial endophytes exhibit higher fresh and dry biomass and a greater number of flowers and buds than the other treatments. The use of PGPB with ACC deaminase activity has the potential to facilitate plant growth on land that is not normally suitable for the majority of crops due to their high salt contents. Our result is also in agreement with Dorothea et al., (2012) when study the effect of *B. megaterium* on *Nicotiana attenuata suggested that it increase the* flowers number. Our results also indicated that different varieties may have variable response as the local Faba Bean revealed higher number of flowers when treated with *B. megaterium.*

Faba Bean in relation to plant height under saline condition revealed increase in height as salinity level increase up to 4 ds/m level. However the bacterial inoculation reduce the effect of salinity and increase the height of plants by 6.7 %. Incubated bacteria had significant on height, this result shown at table 20. The comparison of mean with Tukey-Kramer revealed that the treatments of 2, 4, 6 and 8dS/m resulted increase in 13, 12, 14 and 0.7 percent in comparison to the control. According to interaction between incubation with salinity, it was founded that incubation led to higher induction of plant height 39 % at 8ds/m of salinity (Table 20). Kumar et al (2012) mentioned that Lower salinity (3dsm-1) did not affect the germination, growth and yield

attributing parameters. Higher salinity levels reduced germination, growth and yield attributing parameters. Other results that support what has been shown here, are those by Hamada (1995) with his study on maize Zea mays L., Misra et al. (1997) with their study on rice seedlings Oryza sativaL. vr. Damodar, Dantus et al. (2005) in their study on cowpea, Vigna unguiculata L., and finally by Memon et al.(2010) in their study on Brassica campestris L. where they indicated that the use of low concentrations of sodium chloride led to increases in plants heights, whereas higher concentrations caused shortage. Contrary results were registered as well, including the study done by Mathur et al. (2006) on moth bean Vigna aconitifolia L.,Jamil et al. (2007) on radish plant, Raphanus sativus L., Taffouo et al. (2009) on cowpea Vigna unguiculataL., and Kapoor and Srivastava (2010) on Vigna mungo L. They found that increasing the concentrations of NaCl developed a decline in the heights of the plants

In general, stem elongation when treated with low concentrations of salts may induce osmotic adjustment activity in the plants which may improve growth. On the other hand, the noticed increase in the height of the stem when inoculated with *B. megaterium* and treated with sodium chloride solution, could be due to the positive changes in enzyme activity (that subsequently affects protein synthesis), and growth hormones, both of which can lead to enhancement of the growth.

Results reveal that negative effect of salinity on number of tillers, however the inoculation with *B. megaterium* alleviate the effect of salinity as the

number of tillers reach maximum at 4ds/m in Faba Bean inoculated with bacteria. In addition the results indicated that the positive effect of *B. megaterium* can be seen under saline condition where Qertase at zero level salinity revealed the lowest average branch number 2.0789 compared to 5 tillers at 4 ds/m. Similar results were obtained when combined inoculation of Rhizobium, a phosphate solubilizing *B. megaterium* sub sp. phospaticum strain-PB and a biocontrol fungus Trichoderma spp. revealed increased germination, nutrient uptake, plant height, number of tillers, nodulation, pea yield, and total biomass of chickpea compared to either individual inoculations or an uninoculated control in chickpea as per the studies conducted by Rudresh and coworkers (2005).

The fresh weight and number of leaves of Faba Bean were higher with *B. megaterium*. The highest in fresh shoot weight and leaves number could be due to the effect of inoculants for releasing of growth substances as well as mineralization and solubilization of P-sources (Kumari *et al*., 2009). The effect of *B. megaterium* on increasing the number of flower, bud, leaf area and chlorophyll content indicated that it have ACC deaminase this convulsion based on Ali et al., 2014 who reported that the plants treated with ACC deaminase-containing bacterial isolates exhibited higher fresh and dry biomass, higher chlorophyll content, and a greater number of flowers and buds than the ACC deaminase deficient bacteria and control plants.

Other results that support what has been shown here, are those by Hamada (1995) with his study on maize *Zea mays* L., Misra et al. (1997) with their

study on rice seedlings *Oryza sativa* L. vr. Damodar, Dantus et al. (2005) in their study on cowpea, *Vigna unguiculata* L., and finally by Memon et al. (2010) in their study on *Brassica campestris* L. where they indicated that the use of low concentrations of sodium chloride led to increases in plants heights, whereas higher concentrations caused shortage. Contrary results were registered as well, including the study done by Mathur et al. (2006) on moth bean, Jamil et al. (2007) on radish plant, Taffouo et al. (2009) on cowpea, and Kapoor and Srivastava (2010) on *Vigna mungo* L. They found that increasing the concentrations of NaCl developed a decline in the heights of the plants.

Generally speaking, the elongation of the stem when treated with low concentrations of salts may induce osmotic adjustment activity in the plants which may improve growth. On the other hand, the noticed decrease in the height of the stem, also due to treatment with sodium chloride solution, could be due to the negative effect of this salt on the rate of photosynthesis, the changes in enzyme activity (that subsequently affects protein synthesis), and also the decrease in the level of carbohydrates and growth hormones, both of which can lead to inhibition of the growth (Mazher et al., 2007).

Dobbelaere et al., (2003) suggested that ACC deaminase-containing PGPR can reduce the deleterious effects of environmental stress and can enhance stress tolerance of plants by a variety of mechanisms such as the synthesis of phytohormones, mineral solubilization, nutrient uptake, increased leaf area,

increased chlorophyll and soluble protein content, and antioxidant enzyme activities.

The increase in chlorophyll content at 4ds/m could be attributed to increase in potassium and phosphorus uptake and reduction in sodium accumulation in plant inoculated with *B. megaterium* this result in agreement with several studies on PGPB. Giri and Mukerji, (1999) indicated that inoculated plants accumulated greater amounts of P and K, and decreased the Na uptake by increasing the salinity which helps in chlorophyll synthesis. In contrast the results indicated increase in chlorophyll content in non-inoculated plants to certain level. Our results in agreement with Neelam and Meenu (2009) on various vegetative parameters of tomato plant, i.e. leaf size, number of leaves, number of tillers and number of lateral roots, that revealed rhizobacteria ameliorates treated plants best resisted the toxicity of salinity.

Results presented in Table 32 revealed that higher levels of salinity decrease leaf number throughout the experiment. It was found that the general trend of the treatment reflects a gradual decrease in the number of plant leaves with the increase of salt concentration, compared with the plants of the control experiment, in contrast plant inoculated with bacteria revealed an opposite trends as the salinity increase the number of leaves increase. Furthermore both verities revealed significant positive response to bacterial inoculation, except for the zero level treatment with bacterial inoculation, which did not lead to the increase in the number of leaves on the plants. In this study non-inoculated plant the effect of salinity revealed a notable decrease in leaf area

this could be attributed to increasing the concentrations of sodium chloride, which might be explained as negative effect of salt on photosynthesis which leads to reduction in plant growth, leaf growth, and chlorophyll concentration. Several studies revealed the affection of leaf area negatively by using different concentrations of NaCl (Yilmaz and Kina, 2008).

In addition bacterial inoculation significantly increase Faba Bean shoot fresh and dry weight under saline condition. The maximum fresh weight was 159.27 g at 8 ds/m which significantly exceeds the fresh weight 85.77 at 8 ds/m (table 40). The two varieties revealed positive and response to bacteria however the local bean revealed greater response to bacterial inoculation in fresh weight while the Qertase revealed higher dry weight than local variety. In one hand the interaction between bacteria and varieties revealed 54.96% increase in shoot fresh weight for the local bean compared to -58.86 % reduction for Qertase in control plant. In contrast at 8 ds/m salinity 73.6 and 42.77 % increase in fresh weight for local bean and Qertase respectively when inoculation with bacteria and treated with saline water. In the other hand the dry weight revealed positive increase in local variety by 14.5 % and 33.6% for Qertase at zero level with bacteria while at 8 ds/m salinity 46.7%.

Results agreed with several research in relation to the effect of PGPB under saline condition. Furkan (2016) suggested that the supplementation of the PGP bacterial strains significantly increased the root and shoot height and total fresh weight of the plants. The results obtained from bacterial

application on plant growth indicate that the reduction caused by NaCl was ameliorated with the application the PGP bacterial strains.

In the present work, it was verified that increasing salinity level in water without bacteria inoculation, reduced the pod production, dry biomass of pods, seeds, the number of pods, the numbers of seeds per pod and the weight of seeds and pods, the opposite was true for inoculated plants. Both the local and *Qertase* varieties revealed better performance when inoculated with *B. megaterium.* This results in consensus with Yadegari et al., (2008) on bean (Phaseolus vulgaris); Manaf and Zayed (2015) on cowpea. As a conclusion inoculation of *B. megaterium* increase Faba Bean production under saline condition.

Number of nodules of Faba Bean was not affected by salinity, however slight increase in number of nodules was observed in inoculated plants. This results in agreement with Abdel-Ghaffar (1987) who proposed that Soil salinity or irrigation with saline water EC > 5 mmhos cm^{-1} severely affects plant growth and yield but nodulation in Faba Bean. Other researcher concluded that inoculation of legumes with plant growth-promoting rhizobacteria (PGPR) and rhizobia has been reported to increase the number of nodules compared to those formed by a rhizobial strain alone (Egamberdieva et al., 2013). In contrast other researcher proposed the opposite Yousef and Sprent (1983) revealed that NaCl affected nodulation and they concluded that there may also be effects on infection. The reduction of nodulation in soybean under saline conditions was attributed to shrinkage of the root hairs (Tu, 1981).

It seems that the effect of *B. megaterium* increase Faba Bean root fresh weight 35.99%. This results was previously proposed by Ahmad (2016) using different antioxidant and bioagent in snap bean his study revealed that *S. marcescens* induced the highest increase of fresh and dry weight of shoots followed by *B. megaterium.* This increase could be attributed to plant growth promoter induced by *B. megaterium.* Bacterial secretion of phytohormones can impact root architecture by overproduction of root hairs and lateral roots and subsequently increase nutrient and water uptake, thus contributing to growth (Persello-Cartieaux et al., 2003). Castro et al., (2008) suggested that *B. megaterium* induce cytokinin signinaling and production which might promote plant growth in general and root fresh weight. As a general conclusion the effect of *B. megaterium* on root fresh weight might be correlated to nodulation stability under condition. Furthermore our study reveal that *B. megaterium* reduce soil salinity this funding imply that *B. megaterium* could be used as soil rehabilitation method.

Sahin et al. (2011) studied the effect of microbial application in four different saline-sodic soils with saturated hydraulic conductivity, and treated with plaster. When suspensions of three fungal isolates and two bacterial strains (*Bacillus subtilis* and *B. megaterium*) were mixed with saline-sodic soils. The measurement of the saturated hydraulic conductivity of the soil columns after treatment, indicated that it increased significantly ($P<0.01$) in the saline-sodic soils after application of the microorganisms. The data suggest that the microorganisms tested could have the potential to help improve water circulation through saline soils.

In relation to flowering periods our results revealed that salinity slightly reduce the days to flowering in non-inoculated plants, in contrast *Vicia Faba* inoculated with *B. megaterium* revealed early flowering by 19 % at 6 ds/m which combined with highest nodule formation 5, pod weight 38.7 g, seed number 27.8, pod number 11.66, seed fresh weight 11.06g and dry weight 1.85g. In Palestine early production considered very important as the price of Faba Bean is more profit for farmer. As a results the *B. megaterium* inoculation with Faba Bean might improve farmer income. The results supported by several research, Maas (1986) suggested that soil salinity delays and also reduces flowering and yield of crop plants. However plant that revealed early flowering and decrease production of florets considered tolerant to salinity (Munns 2002).

In addition salinity boost ethylene production which considered stress hormone (Blumwald 2000). The production of ethylene severely affect plant production and growth as a results any factor reduce the ethylene production will reduce the effect of salinity on plant. PGPB that produce ACC deaminase which hydrolysis ACC results in reduction of ethylene production and enhance the survival of stressed plant and facilitate the formation of longer roots (Tank and Saraf 2010). Several studies demonstrated that the treatment with PGPB increase resistance to diseases, root and shoot growth, total biomass, seed weight, early flowering and fruit yield, etc., (van Loon et al., 1998; Ramamoorthy et al., 2001). Early flowering due to PGPB is supported by observation of early flowering of other plants due to inoculation

with Azospirillum has been recorded previously (Okon, 1985; Wani, 1990; El-Nagger and Mohamaud, 1994; Kumar et al., 1995).

5.2 Effect of salinity and *B. megaterium* on chemical composition

Initially, soil salinity represses plant growth through osmotic stress, which is then followed by ion toxicity (Rahnama et al., 2010; James et al., 2011). During initial phases, the water absorption capacity of the root system decreases and water loss from leaves is accelerated due to osmotic stress, and therefore salinity stress is also considered hyperosmotic stress (Munns, 2005). Osmotic stress at the initial stage causes various physiological changes, such as interruption of membranes, nutrient imbalance, impaired ability to detoxify reactive oxygen species (ROS), differences in antioxidant enzymes, and decreased photosynthetic activity (Munns and Tester, 2008; Pang et al., 2010). One of the most damaging effects is accumulation of Na^+ and Cl^- ions in tissues of plants exposed to soils with high NaCl concentrations. Higher Na^+ blocks K^+ uptake, results in lower productivity and may even lead to cell death (Ahmad and Umar, 2011; James et al., 2011).

Soil salinity imposes ion toxicity, osmotic stress, nutrient (N, Ca, K, P, Fe, Zn) deficiency and oxidative stress on plants, and thus limits water uptake from soil. Soil salinity significantly reduces plant phosphorus (P) uptake because phosphate ions precipitate with Ca ions (Bano and Fatima, 2009). Some elements, such as sodium, chloride, and boron, have specific toxic effects on plants. Excessive accumulation of sodium in cell walls can rapidly lead to osmotic stress and cell death (Munns, 2002). Plants sensitive to these

elements may be affected at relatively low salt concentrations if the soil contains enough of the toxic element. Because many salts are also plant nutrients, high salt levels in the soil can upset the nutrient balance in the plant or interfere with the uptake of some nutrients (Blaylock et al., 1994).

In the present work Sodium and Chloride concentration in the leaves increased along with the increased salinity level of irrigation water. However Faba Bean inoculated with *B. megaterium* have lower the concentration by 18.75% for chloride content and 17.73% for Sodium content. Since the accumulation of chlorides influence several physiological process such as the reduction of chlorophyll content in our study could be attributed to the higher Cl− accumulation. Potassium and Calcium content increased by 5% in plants treated with *B. megaterium* compared to non-inoculated plants. However this reduction in non-inoculated plant might be due to the replacement of potassium by sodium. Zhu (2002) suggested that ion toxicity is the result of replacement of K^+ by Na^+ in biochemical reactions, and Na^+ and Cl^- induced conformational changes in proteins. For several enzymes, K^+ acts as cofactor and cannot be substituted by Na^+. Excess Na^+ ion concentration affects low-affinity potassium uptake system because of the similar chemical nature of Na^+ and K^+ ions thereby, inhibiting K^+ uptake by the roots. Plants activate high-affinity K^+ transporters (HKT) to increase the uptake of K^+ ions over Na^+ ions and K^+ concentration relative to Na^+ in cytoplasm increases salinity tolerance (Rodriguez-Navarro and Rubio, 2006). High K^+ concentration is also required for binding tRNA to ribosomes and thus protein synthesis. Tank and Saraf (2010) revealed that PGPRs

which are able to solubilize phosphate, produce phytohormones and siderophores in salt condition promote growth of tomato plants under 2% NaCl stress. Recent results show that PGPRs can increase uptake of potassium, magnesium and calcium and decrease sodium uptake. According to Tavakkoli et al. (2010), plants grown in the presence of high NaCl concentrations accumulate both Na+ and Cl− simultaneously, although the effects of the two ions may differ. High Cl− concentrations reduce the photosynthetic capacity and quantum yield due to chlorophyll degradation and impaired photosystem II efficiency. High Na+ interferes with K+ and Ca2+ nutrition, affecting stomatal regulation and decreasing photosynthesis and growth.

Several researcher proposed that in salt-affected soils, excessive buildup of sodium and chloride ions in the rhizosphere leads to severe nutritional imbalances in plants due to strong interference of these ions with other essential mineral elements such as potassium, calcium, nitrogen, phosphorus, magnesium, iron, manganese, copper, and zinc (Hasegawa et al. 2000; Karimi et al.2005; Turan et al. 2010). In the current research the nitrogen content was not affect greatly with salinity, it seems that roots and seeds accumulate more nitrogen as salinity increase compared to shoot in non-inoculated plants. However plants inoculated with bacteria revealed higher nitrogen percentage in shoot. This might be justified by the ability of *B. megaterium* to facilitate nutrients uptake and assimilation.

Phosphate solubilization ability of *B. megaterium* was reported by several researcher (Han and Supanjani, 2006). In the present work phosphorus accumulation in plant inoculated with *B. megaterium* was 25% greater than non-inoculated plant. The increase in total P percentage mainly due to efficient solubilization of insoluble soil-P by *B. megaterium. Similar increase in P uptake, when inoculated with B. megaterium along with MRP has been reported in cereals (Sundara Rao and Sinha, 1963 and Subba Rao, 1980) and in cowpea (Bajpai and Sundara Rao, 1971 and Nagaraju et al., 1995;* Sridhar et al., 2004*).*

As a conclusion the inoculation of B. megaterium could be used as a biofertilzer in a saline soil with insoluble phosphours and low potassium availability.

Conclusion

Faba Bean plant and most of legumes plants is highly effected by the salinity in soil or even in irrigation water, using microorganisms species like *B. megaterium* revealed positive effects on the stressed plants to reduce the negative effect of salinity.

Several main points arise from this study:

- *B. megaterium* has significant effect in alleviating salinity stress on growth parameters (plant height increased 9%, number of leaves increased 10 %, fresh weight of shoot increased 21%, and fresh weight of roots 36%).
- *B. megaterium* increase bean production significantly even under high level of salinity (seeds number 21% and pods number 29%).
- The inoculation with *B. megaterium* significantly increased flowers number (27 %) and reduced the period required for flowering (from 66 days to 55 days), good indicator for early yield.
- The accumulation of Na and Cl in plant tissue significantly reduced.
- The bacteria improved plant absorption for K, P, N and Ca was higher in plant inoculated with bacteria under high salinity level.
- Bacteria have a positive effect in reducing soil salinity (15 %).

Recommendation

Based on the results of this study, the researcher came up with the following recommendations;

- *B. megaterium* bacteria can be used in bean as bio fertilizer, and then testing it on other crops.
- Use *B. megaterium* in saline soil (recommended salinity level around 6-8 ds/m).
- For early production and higher prices use of bacteria inoculation is highly recommended.

- Testing *B. megaterium* on different plants species at different/ higher salinity levels.
- Testing *B. megaterium* with different species of PGPB.

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Appendix

Table 22. Mean separation for the number of flowers based on the effect of *B. megaterium* inoculation. Effect= Bacteria Method = Turkey (P<.05)

Bacteria	**Estimate**	**Standard Error**	**Letter Group**
0	**11.633**	**1.074**	**B**
1	**14.833**	**1.074**	**A**

0= without bacteria, 1= with bacteria

Table 23. Mean separation for the number of flowers based on the effect salinity. Effect= Salinity Method=Turkey (P<.05)

Salinity	**Estimate**	**Standard Error**	**Letter Group**
0	13.000	1.698	A
2	13.750	1.698	A
4	13.416	1.698	A
6	12.750	1.698	A
8	13.250	1.698	A

Salinity = (0, 2, 4, 6, 8) ds/m

Table 24. Mean separation for the number of flowers based on the effect of Bacteria interaction with salinity. Effect= Bacteria*Salinity Method=turkey (P<.05)

Bacteria	**salinity**	**Estimate**	**Standard Error**	**Letter Group**
0	0	10.833	2.402	A
0	2	11.000	2.402	A
0	4	11.166	2.402	A
0	6	11.666	2.402	A
0	8	13.500	2.402	A
1	0	15.166	2.402	A
1	2	16.500	2.402	A
1	4	15.666	2.402	A
1	6	13.833	2.402	A
1	8	13.000	2.402	A

0= without bacteria, 1= with bacteria, Salinity= (0, 2, 4, 6, 8) ds/m

Table 25. .Mean separation for the number of flowers based on the effect of two Faba Bean varieties .Effect = var Method=Tukey (P<.05)

Var	Estimate	Standard Error	Letter Group
1	12.3667	1.0744	A
2	14.1000	1.0744	A

Variety 1 (local) and variety 2 (Qertase)

Table 26. Mean separation for the number of flowers based on the interaction of the two Faba Bean varieties with bacterial inoculation .Effect=Bacteria*var Method=Tukey (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	9.0667	1.5194	B
0	2	14.2000	1.5194	AB
1	1	15.6667	1.5194	A
1	2	14.0000	1.5194	AB

Bacteria= B. megaterium, Variety 1 (local) and variety 2 (Qertase).

Table 27. Mean separation for the number of flowers based on the interaction of salinity and two Faba Bean varieties. Effect=salinity*var Method=Tukey (P<.05)

Salinity	var	Estimate	Standard Error	Letter Group
0	1	12.6667	2.4024	A
0	2	13.3333	2.4024	A
2	1	9.6667	2.4024	A
2	2	17.8333	2.4024	A
4	1	12.8333	2.4024	A
4	2	14.0000	2.4024	A
6	1	16.0000	2.4024	A
6	2	9.5000	2.4024	A
8	1	10.6667	2.4024	A
8	2	15.8333	2.4024	A

Salinity = (0, 2ds/m, 4ds/m, 6ds/m, 8ds/m), Var = Variety 1 (local) and variety 2 (Qertase),

Table 28. Mean separation for the number of flowers based on the interaction of the two varieties of Faba Bean with bacterial inoculation and the four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey (P<.05)

Bacteria	Salinity	var	Estimate	Standard Error	Letter Group
0	0	1	5.6667	3.3975	AB
0	0	2	16.0000	3.3975	AB
0	2	1	10.0000	3.3975	AB
0	2	2	12.0000	3.3975	AB
0	4	1	10.3333	3.3975	AB
0	4	2	12.0000	3.3975	AB
0	6	1	14.6667	3.3975	AB
0	6	2	8.6667	3.3975	AB
0	8	1	4.6667	3.3975	B
0	8	2	22.3333	3.3975	AB
1	0	1	19.6667	3.3975	AB
1	0	2	10.6667	3.3975	AB
1	2	1	9.3333	3.3975	AB
1	2	2	23.6667	3.3975	A
1	4	1	15.3333	3.3975	AB
1	4	2	16.0000	3.3975	AB
1	6	1	17.3333	3.3975	AB
1	6	2	10.3333	3.3975	AB
1	8	1	16.6667	3.3975	AB
1	8	2	9.3333	3.3975	AB

Var= Variety1 Qertase and variety 2 local, bacteria= *B. megaterium*, 0= without bacteria, 1= *with B. megaterium, salinity=0, 2ds/m, 4ds/m, 6ds/m, 8ds/m.*

Table 29. The analysis of variance for the effect of *B. megaterium* on plant height for two varieties of Faba Bean under four different salinity levels.

Bacteria	Estimate	Standard Error	Letter Group
0	60.2667	1.3113	B
1	65.9035	1.3454	A

Table 30. Mean separation for the plant height based on the effect salinity .Effect=salinity Method=Tukey-Kramer (P<.05) Set=2

Salinity	Estimate	Standard Error	Letter Group
0	58.3421	2.2056	A
2	66.0000	2.0734	A
4	65.5833	2.0734	A
6	66.7500	2.0734	A
8	58.7500	2.0734	A

Salinity = (0, 2, 4, 6, 8) ds/m

Table 31. Mean separation for the plant height based on the effect of Bacteria inoculation interaction with salinity Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	Salinity	Estimate	Standard Error	Letter Group
0	0	62.8333	2.9323	ABC
0	2	63.0000	2.9323	ABC
0	4	63.3333	2.9323	ABC
0	6	61.3333	2.9323	ABC
0	8	50.8333	2.9323	C
1	0	53.8509	3.2956	BC
1	2	69.0000	2.9323	A
1	4	67.8333	2.9323	AB
1	6	72.1667	2.9323	A
1	8	66.6667	2.9323	AB

Salinity = (0, 2, 4, 6, 8) ds/m 0= without bacteria, 1= with bacteria

Table 32. Mean separation for the plant height based on the effect of two varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

var	Estimate	Standard Error	Letter Group
1	65.9333	1.3113	A
2	60.2368	1.3454	B

Var = Variety 1 (local) and variety 2 (Qertase)

Table 33. Mean separation for the plant height based on the interaction of the two varieties of Faba Bean with bacterial inoculation Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	63.0667	1.8545	AB
0	2	57.4667	1.8545	B
1	1	68.8000	1.8545	A
1	2	63.0070	1.9497	AB

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase)

Table 34. Mean separation for the plant height based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

salinity	var	Estimate	Standard Error	Letter Group
0	1	58.5000	2.9323	AB
0	2	58.1842	3.2956	AB
2	1	72.0000	2.9323	A
2	2	60.0000	2.9323	AB
4	1	65.5000	2.9323	AB
4	2	65.6667	2.9323	AB
6	1	70.6667	2.9323	A
6	2	62.8333	2.9323	AB
8	1	63.0000	2.9323	AB
8	2	54.5000	2.9323	B

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 35.Mean separation for the plant height based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	salinity	var	Estimate	Standard Error	Letter Group
0	0	1	61.3333	4.1468	AB
0	0	2	64.3333	4.1468	AB
0	2	1	69.6667	4.1468	AB
0	2	2	56.3333	4.1468	AB
0	4	1	62.6667	4.1468	AB
0	4	2	64.0000	4.1468	AB
0	6	1	68.0000	4.1468	AB
0	6	2	54.6667	4.1468	AB
0	8	1	53.6667	4.1468	AB
0	8	2	48.0000	4.1468	B
1	0	1	55.6667	4.1468	AB
1	0	2	52.0351	5.1232	AB
1	2	1	74.3333	4.1468	A
1	2	2	63.6667	4.1468	AB
1	4	1	68.3333	4.1468	AB
1	4	2	67.3333	4.1468	AB
1	6	1	73.3333	4.1468	A
1	6	2	71.0000	4.1468	A
1	8	1	72.3333	4.1468	A
1	8	2	61.0000	4.1468	AB

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase).

Table 36. Mean separation for the branch number based on the effect of *B. megaterium* inoculation. Effect=Bacteria Method=Tukey-Kramer (P<.05)

Bacteria	Estimate	Standard Error	Letter Group
0	3.6000	0.1250	A
1	3.6079	0.1282	A

0= without bacteria, 1= with bacteria

Table 37. Mean separation for the branch number based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05)

Salinity	Estimate	Standard Error	Letter Group
0	3.2697	0.2102	A
2	3.5000	0.1976	A
4	4.0000	0.1976	A
6	3.6667	0.1976	A
8	3.5833	0.1976	A

Salinity = (0, 2, 4, 6, 8) ds/m

Table 38. Mean separation for the branch number based on the effect of Bacteria inoculation interaction with *salinity*. Effect=Bacteria*salinity Method=Tukey-*Kramer (*P<.05)

Bacteria	salinity	Estimate	Standard Error	Letter Group
0	0	3.8333	0.2794	AB
0	2	3.1667	0.2794	AB
0	4	3.6667	0.2794	AB
0	6	3.6667	0.2794	AB
0	8	3.6667	0.2794	AB
1	0	2.7061	0.3140	B
1	2	3.8333	0.2794	AB
1	4	4.3333	0.2794	A
1	6	3.6667	0.2794	AB
1	8	3.5000	0.2794	AB

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 39. Mean separation for the branch number based on the effect of varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

var	Estimate	Standard Error	Letter Group
1	3.4667	0.1250	A
2	3.7412	0.1282	A

Var = Variety 1 (local) and variety 2 (Qertase)

Table 40. Mean separation for the branch number based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	3.2667	0.1767	A
0	2	3.9333	0.1767	A
1	1	3.6667	0.1767	A
1	2	3.5491	0.1858	A

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase)

Table 41. Mean separation for branch number based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

salinity	var	Estimate	Standard Error	Letter Group
0	1	3.3333	0.2794	A
0	2	3.2061	0.3140	A
2	1	3.1667	0.2794	A
2	2	3.8333	0.2794	A
4	1	4.0000	0.2794	A
4	2	4.0000	0.2794	A
6	1	3.6667	0.2794	A
6	2	3.6667	0.2794	A
8	1	3.1667	0.2794	A
8	2	4.0000	0.2794	A

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 42. Mean separation for the branch number based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels.
Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	salinity	Var	Estimate	Standard Error	Letter Group
0	0	1	3.3333	0.3951	AB
0	0	2	4.3333	0.3951	AB
0	2	1	3.0000	0.3951	AB
0	2	2	3.3333	0.3951	AB
0	4	1	3.0000	0.3951	AB
0	4	2	4.3333	0.3951	AB
0	6	1	3.6667	0.3951	AB
0	6	2	3.6667	0.3951	AB
0	8	1	3.3333	0.3951	AB
0	8	2	4.0000	0.3951	AB
1	0	1	3.3333	0.3951	AB
1	0	2	2.0789	0.4882	B
1	2	1	3.3333	0.3951	AB
1	2	2	4.3333	0.3951	AB
1	4	1	5.0000	0.3951	A
1	4	2	3.6667	0.3951	AB
1	6	1	3.6667	0.3951	AB
1	6	2	3.6667	0.3951	AB
1	8	1	3.0000	0.3951	AB
1	8	2	4.0000	0.3951	AB

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase

Table 43. Mean separation for leaves number based on the effect of *B. megaterium* inoculation.
Effect=Bacteria Method=Tukey-Kramer (P<.05).

Bacteria	Estimate	Standard Error	Letter Group
0	219.20	5.3740	B
1	241.35	5.5136	A

0= without bacteria, 1= with bacteria

Table 44. Mean separation for the leaves number based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05) Set=2

salinity	Estimate	Standard Error	Letter Group
0	205.28	9.0388	B
2	228.42	8.4971	AB
4	257.00	8.4971	A
6	240.42	8.4971	AB
8	220.25	8.4971	B

Salinity = (0, 2, 4, 6, 8) ds/m

Table 45. Mean separation for the leaves number based on the effect of Bacteria inoculation interaction with salinity. Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	salinity	Estimate	Standard Error	Letter Group
0	0	264.67	12.0167	AB
0	2	214.50	12.0167	BCD
0	4	206.83	12.0167	CD
0	6	221.83	12.0167	BCD
0	8	188.17	12.0167	DE
1	0	145.90	13.5056	E
1	2	242.33	12.0167	BCD
1	4	307.17	12.0167	A
1	6	259.00	12.0167	ABC
1	8	252.33	12.0167	ABC

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 46. Mean separation for the leaves number based on the effect of two varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

Var	Estimate	Standard Error	Letter Group
1	253.47	5.3740	A
2	207.08	5.5136	B

Var = Variety 1 (local) and variety 2 (Qertase)

Table 47. Mean separation for the leaves number based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	236.73	7.6000	B
0	2	201.67	7.6000	C
1	1	270.20	7.6000	A
1	2	212.49	7.9900	BC

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase)

Table 48. Mean separation for the leaves number based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

Salinity	Var	Estimate	Standard Error	Letter Group
0	1	213.50	12.0167	C
0	2	197.07	13.5056	C
2	1	241.33	12.0167	BC
2	2	215.50	12.0167	C
4	1	300.50	12.0167	A
4	2	213.50	12.0167	C
6	1	277.83	12.0167	AB
6	2	203.00	12.0167	C
8	1	234.17	12.0167	BC
8	2	206.33	12.0167	C

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 49. Mean separation for the leaves number based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	Salinity	var	Estimate	Standard Error	Letter Group
0	0	1	282.00	16.9942	BC

0	0	2	247.33	16.9942	BCDE
0	2	1	245.00	16.9942	BCDE
0	2	2	184.00	16.9942	DEF
0	4	1	210.00	16.9942	CDEF
0	4	2	203.67	16.9942	CDEF
0	6	1	241.00	16.9942	BCDE
0	6	2	202.67	16.9942	CDEF
0	8	1	205.67	16.9942	CDEF
0	8	2	170.67	16.9942	EF
1	0	1	145.00	16.9942	F
1	0	2	146.80	20.9953	EF
1	2	1	237.67	16.9942	BCDE
1	2	2	247.00	16.9942	BCDE
1	4	1	391.00	16.9942	A
1	4	2	223.33	16.9942	BCDEF
1	6	1	314.67	16.9942	AB
1	6	2	203.33	16.9942	CDEF
1	8	1	262.67	16.9942	BCD
1	8	2	242.00	16.9942	BCDE

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 50. Mean separation for the fresh weight based on the effect of *B. megaterium* inoculation. Effect=Bacteria Method=Tukey-Kramer (P<.05).

Bacteria	**Estimate**	**Standard Error**	**Letter Group**
0	116.54	4.6130	B
1	141.26	4.7328	A

0= without bacteria, 1= with bacteria

Table 51. Mean separation for the fresh weight based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05) Set=2

Salinity	Estimate	Standard Error	Letter Group
0	121.87	7.7588	AB
2	128.37	7.2938	AB
4	136.88	7.2938	AB
6	148.12	7.2938	A
8	109.25	7.2938	B

Salinity = (0, 2, 4, 6, 8) ds/m

Table 52. Mean separation for the fresh weight based on the effect of Bacteria inoculation interaction with salinity. Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	salinity	Estimate	Standard Error	Letter Group
0	0	137.53	10.3150	ABC
0	2	112.73	10.3150	BCD
0	4	114.50	10.3150	BCD
0	6	132.18	10.3150	ABCD
0	8	85.7667	10.3150	D
1	0	106.21	11.5930	CD
1	2	144.02	10.3150	ABC
1	4	159.27	10.3150	AB
1	6	164.07	10.3150	A
1	8	132.73	10.3150	ABCD

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 53. Mean separation for the fresh weight based on the effect of varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

Var	Estimate	Standard Error	Letter Group
1	122.04	4.6130	B
2	135.77	4.7328	A

Var = Variety 1 (local) and variety 2 (Qertase)

Table 54. Mean separation for the fresh weight based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	101.29	6.5238	B
0	2	131.80	6.5238	A
1	1	142.79	6.5238	A
1	2	139.73	6.8585	A

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase)

Table 55. Mean separation for the fresh weight based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

Salinity	Var	Estimate	Standard Error	Letter Group
0	1	111.17	10.3150	AB
0	2	132.58	11.5930	AB
2	1	118.72	10.3150	AB
2	2	138.03	10.3150	AB
4	1	141.10	10.3150	A
4	2	132.67	10.3150	AB
6	1	148.00	10.3150	A
6	2	148.25	10.3150	A
8	1	91.2000	10.3150	B
8	2	127.30	10.3150	AB

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 56. Mean separation for the fresh weight based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	Salinity	var	Estimate	Standard Error	Letter Group
0	0	1	87.2000	14.5876	CD
0	0	2	187.87	14.5876	A
0	2	1	101.40	14.5876	BCD
0	2	2	124.07	14.5876	ABCD
0	4	1	108.70	14.5876	BCD

0	4	2	120.30	14.5876	ABCD
0	6	1	142.47	14.5876	ABCD
0	6	2	121.90	14.5876	ABCD
0	8	1	66.6667	14.5876	D
0	8	2	104.87	14.5876	BCD
1	0	1	135.13	14.5876	ABCD
1	0	2	77.2912	18.0221	CD
1	2	1	136.03	14.5876	ABCD
1	2	2	152.00	14.5876	ABC
1	4	1	173.50	14.5876	AB
1	4	2	145.03	14.5876	ABCD
1	6	1	153.53	14.5876	ABC
1	6	2	174.60	14.5876	AB
1	8	1	115.73	14.5876	ABCD
1	8	2	149.73	14.5876	ABC

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 57. Mean separation for the pods weight based on the effect of *B. megaterium* inoculation. Effect=Bacteria Method=Tukey-Kramer (P<.05).

Bacteria	**Estimate**	**Standard Error**	**Letter Group**
0	29.2703	2.7452	B
1	38.3934	2.5004	A

0= without bacteria, 1= with bacteria

Table 58. Mean separation for the pods weight based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05)

salinity	**Estimate**	**Standard Error**	**Letter Group**
0	41.4701	4.9831	A
2	32.1917	3.8531	A
4	33.7475	4.0996	A
6	31.4500	3.8531	A
8	30.3000	3.8531	A

Salinity = (0, 2, 4, 6, 8) ds/m

Table 59. Mean separation for the pods weight based on the effect of Bacteria inoculation interaction with salinity. Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	salinity	Estimate	Standard Error	Letter Group
0	0	47.6568	7.8096	A
0	2	28.3000	5.4491	A
0	4	26.1449	6.1265	A
0	6	24.1333	5.4491	A
0	8	20.1167	5.4491	A
1	0	35.2835	6.1265	A
1	2	36.0833	5.4491	A
1	4	41.3500	5.4491	A
1	6	38.7667	5.4491	A
1	8	40.4833	5.4491	A

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 60. Mean separation for the pods weight based on the effect of two varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

Var	Estimate	Standard Error	Letter Group
1	30.0514	2.6815	B
2	37.6123	2.5590	A

Var = Variety 1 (local) and variety 2 (Qertase)

Table 61. Mean separation for the pods weight based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	21.3894	4.1091	B
0	2	37.1513	3.6238	A
1	1	38.7133	3.4463	A
1	2	38.0734	3.6238	A

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase)

Table 62. Mean separation for the pods weight based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05).

Salinity	var	Estimate	Standard Error	Letter Group
0	1	32.9068	7.8096	A
0	2	50.0335	6.1265	A
2	1	24.6167	5.4491	A
2	2	39.7667	5.4491	A
4	1	31.1000	5.4491	A
4	2	36.3949	6.1265	A
6	1	36.2667	5.4491	A
6	2	26.6333	5.4491	A
8	1	25.3667	5.4491	A
8	2	35.2333	5.4491	A

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 63.Mean separation for the pods weight based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	salinity	var	Estimate	Standard Error	Letter Group
0	0	1	23.5468	13.5859	AB
0	0	2	71.7667	7.7062	A
0	2	1	18.4000	7.7062	B
0	2	2	38.2000	7.7062	AB
0	4	1	28.8667	7.7062	B
0	4	2	23.4231	9.5264	B
0	6	1	25.8333	7.7062	B
0	6	2	22.4333	7.7062	B
0	8	1	10.3000	7.7062	B

0	8	2	29.9333	7.7062	B
1	0	1	42.2667	7.7062	AB
1	0	2	28.3003	9.5264	AB
1	2	1	30.8333	7.7062	AB
1	2	2	41.3333	7.7062	AB
1	4	1	33.3333	7.7062	AB
1	4	2	49.3667	7.7062	AB
1	6	1	46.7000	7.7062	AB
1	6	2	30.8333	7.7062	AB
1	8	1	40.4333	7.7062	AB
1	8	2	40.5333	7.7062	AB

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 64. Mean separation for the pods height based on the effect of *B. megaterium* inoculation. Effect=Bacteria Method=Tukey-Kramer (P<.05)

Bacteria	**Estimate**	**Standard Error**	**Letter Group**
0	6.8141	0.3548	A
1	7.0905	0.3232	A

0= without bacteria, 1= with bacteria

Table 65. Mean separation for the pods height based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05) Set=2

salinity	**Estimate**	**Standard Error**	**Letter Group**
0	8.1006	0.6441	A
2	6.9417	0.4980	A
4	7.0025	0.5299	A
6	6.4917	0.4980	A
8	6.2250	0.4980	A

Salinity = (0, 2, 4, 6, 8) ds/m

Table 66. Mean separation for the pods height based on the effect of Bacteria inoculation interaction with salinity. Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	salinity	Estimate	Standard Error	Letter Group
0	0	9.5986	1.0094	A
0	2	6.8167	0.7043	AB
0	4	5.7717	0.7919	AB
0	6	6.5167	0.7043	AB
0	8	5.3667	0.7043	B
1	0	6.6026	0.7919	AB
1	2	7.0667	0.7043	AB
1	4	8.2333	0.7043	AB
1	6	6.4667	0.7043	AB
1	8	7.0833	0.7043	AB

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 67. Mean separation for the pods height based on the effect of two varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

Var	Estimate	Standard Error	Letter Group
1	5.2864	0.3466	B
2	8.6182	0.3308	A

Var = Variety 1 (local) and variety 2 (Qertase)

Table 68. Mean separation for the pods height based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	4.6261	0.5311	B
0	2	9.0020	0.4684	A
1	1	5.9467	0.4454	B
1	2	8.2344	0.4684	A

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase)

Table 69. Mean separation for the pods height based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

Salinity	var	Estimate	Standard Error	Letter Group
0	1	6.7820	1.0094	AB
0	2	9.4193	0.7919	A
2	1	4.6333	0.7043	B
2	2	9.2500	0.7043	A
4	1	4.7167	0.7043	B
4	2	9.2884	0.7919	A
6	1	6.0167	0.7043	AB
6	2	6.9667	0.7043	AB
8	1	4.2833	0.7043	B
8	2	8.1667	0.7043	A

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 70. Mean separation for the pods height based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels

Bacteria	Salinity	var	Estimate	Standard Error	Letter Group
0	0	1	4.6973	1.7560	BCD
0	0	2	14.5000	0.9960	A
0	2	1	4.2333	0.9960	CD
0	2	2	9.4000	0.9960	ABC
0	4	1	4.8333	0.9960	CD
0	4	2	6.7100	1.2313	BCD
0	6	1	5.9333	0.9960	CD
0	6	2	7.1000	0.9960	BCD
0	8	1	3.4333	0.9960	D
0	8	2	7.3000	0.9960	BCD

1	0	1	8.8667	0.9960	BC
1	0	2	4.3386	1.2313	CD
1	2	1	5.0333	0.9960	CD
1	2	2	9.1000	0.9960	BC
1	4	1	4.6000	0.9960	CD
1	4	2	11.8667	0.9960	AB
1	6	1	6.1000	0.9960	CD
1	6	2	6.8333	0.9960	BCD
1	8	1	5.1333	0.9960	CD
1	8	2	9.0333	0.9960	BC

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 71. Mean separation for the pods width based on the effect of *B. megaterium* inoculation. Effect=Bacteria Method=Tukey-Kramer (P<.05).

Bacteria	Estimate	Standard Error	Letter Group
0	0.5721	0.03339	A
1	0.5827	0.03042	A

0= without bacteria, 1= with bacteria

Table 72. Mean separation for the pods width based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05) Set=2

Salinity	Estimate	Standard Error	Letter Group
0	0.6786	0.06061	A
2	0.5417	0.04687	AB
4	0.6417	0.04987	A
6	0.5833	0.04687	AB
8	0.4417	0.04687	B

Salinity = (0, 2, 4, 6, 8) ds/m

Table 73. Mean separation for the pods width based on the effect of Bacteria inoculation interaction with salinity. Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	salinity	Estimate	Standard Error	Letter Group
0	0	0.8270	0.09500	A
0	2	0.4833	0.06628	AB

0	4	0.6001	0.07452	AB
0	6	0.5167	0.06628	AB
0	8	0.4333	0.06628	B
1	0	0.5301	0.07452	AB
1	2	0.6000	0.06628	AB
1	4	0.6833	0.06628	AB
1	6	0.6500	0.06628	AB
1	8	0.4500	0.06628	AB

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 74. Mean separation for the pods width based on the effect of two varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

Var	Estimate	Standard Error	Letter Group
1	0.5154	0.03262	B
2	0.6394	0.03113	A

Var = Variety 1 (local) and variety 2 (Qertase)

Table 75. Mean separation for the pods width based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	0.4775	0.04998	B
0	2	0.6667	0.04408	A
1	1	0.5533	0.04192	AB
1	2	0.6120	0.04408	AB

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase),

Table 76. Mean separation for the pods width based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

Salinity	var	Estimate	Standard Error	Letter Group
0	1	0.6604	0.09500	AB
0	2	0.6968	0.07452	AB
2	1	0.4667	0.06628	AB

2	2	0.6167	0.06628	AB
4	1	0.4833	0.06628	AB
4	2	0.8001	0.07452	A
6	1	0.5833	0.06628	AB
6	2	0.5833	0.06628	AB
8	1	0.3833	0.06628	B
8	2	0.5000	0.06628	AB

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

Table 77. Mean separation for the pods width based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	**salinity**	**var**	**Estimate**	**Standard Error**	**Letter Group**
0	0	1	0.6874	0.1653	ABC
0	0	2	0.9667	0.09374	A
0	2	1	0.4333	0.09374	BC
0	2	2	0.5333	0.09374	ABC
0	4	1	0.5333	0.09374	ABC
0	4	2	0.6668	0.1159	ABC
0	6	1	0.4333	0.09374	BC
0	6	2	0.6000	0.09374	ABC
0	8	1	0.3000	0.09374	C
0	8	2	0.5667	0.09374	ABC
1	0	1	0.6333	0.09374	ABC
1	0	2	0.4268	0.1159	ABC
1	2	1	0.5000	0.09374	ABC
1	2	2	0.7000	0.09374	ABC
1	4	1	0.4333	0.09374	BC
1	4	2	0.9333	0.09374	AB
1	6	1	0.7333	0.09374	ABC
1	6	2	0.5667	0.09374	ABC

1	8	1	0.4667	0.09374	ABC
1	8	2	0.4333	0.09374	BC

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m
, Var = Variety 1 (local) and variety 2 (Qertase),

Table 78. Mean separation for the seeds number based on the effect of *B. megaterium* inoculation. Effect=Bacteria Method=Tukey-Kramer (P<.05)

Bacteria	Estimate	Standard Error	Letter Group
0	20.0918	1.9309	B
1	25.4073	1.7588	A

0= without bacteria, 1= with bacteria

Table 79. Mean separation for the seeds number based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05) Set=2

salinity	Estimate	Standard Error	Letter Group
0	23.1557	3.5051	A
2	20.8333	2.7102	A
4	27.1754	2.8836	A
6	24.9167	2.7102	A
8	17.6667	2.7102	A

Salinity = (0, 2, 4, 6, 8) ds/m

Table 80. Mean separation for the seeds number based on the effect of Bacteria inoculation interaction with salinity. Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	salinity	Estimate	Standard Error	Letter Group
0	0	25.4414	5.4932	A
0	2	16.8333	3.8328	A
0	4	23.8508	4.3093	A
0	6	22.0000	3.8328	A
0	8	12.3333	3.8328	A
1	0	20.8699	4.3093	A
1	2	24.8333	3.8328	A
1	4	30.5000	3.8328	A

1	6	27.8333	3.8328	A
1	8	23.0000	3.8328	A

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 81. Mean separation for the seeds number based on the effect of two varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

var	Estimate	Standard Error	Letter Group
1	26.6550	1.8861	A
2	18.8441	1.8000	B

Var = Variety 1 (local) and variety 2 (Qertase),

Table 82. Mean separation for the seeds number based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	22.6432	2.8903	AB
0	2	17.5403	2.5489	B
1	1	30.6667	2.4241	A
1	2	20.1480	2.5489	B

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase),

Table 83. Mean separation for the seeds number based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

salinity	var	Estimate	Standard Error	Letter Group
0	1	24.1081	5.4932	AB
0	2	22.2032	4.3093	AB
2	1	25.3333	3.8328	AB
2	2	16.3333	3.8328	B
4	1	35.5000	3.8328	A
4	2	18.8508	4.3093	AB
6	1	31.0000	3.8328	AB
6	2	18.8333	3.8328	AB
8	1	17.3333	3.8328	AB
8	2	18.0000	3.8328	AB

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

Table 84. Mean separation for the seeds number based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	salinity	var	Estimate	Standard Error	Letter Group
0	0	1	28.5495	9.5561	AB
0	0	2	22.3333	5.4204	AB
0	2	1	19.0000	5.4204	AB
0	2	2	14.6667	5.4204	AB
0	4	1	29.0000	5.4204	AB
0	4	2	18.7017	6.7007	AB
0	6	1	27.3333	5.4204	AB
0	6	2	16.6667	5.4204	AB
0	8	1	9.3333	5.4204	B
0	8	2	15.3333	5.4204	AB
1	0	1	19.6667	5.4204	AB
1	0	2	22.0731	6.7007	AB
1	2	1	31.6667	5.4204	AB
1	2	2	18.0000	5.4204	AB
1	4	1	42.0000	5.4204	A
1	4	2	19.0000	5.4204	AB
1	6	1	34.6667	5.4204	AB
1	6	2	21.0000	5.4204	AB
1	8	1	25.3333	5.4204	AB
1	8	2	20.6667	5.4204	AB

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

Table 85. Mean separation for the pods number based on the effect of *B. megaterium* inoculation. Effect=Bacteria Method=Tukey-Kramer (P<.05).

Bacteria	Estimate	Standard Error	Letter Group
0	8.7471	0.8728	B
1	11.2782	0.7950	A

0= without bacteria, 1= with bacteria

Table 86. Mean separation for the pods number based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05)

salinity	Estimate	Standard Error	Letter Group
0	10.0986	1.5843	A
2	9.2500	1.2250	A
4	12.0478	1.3034	A
6	10.9167	1.2250	A
8	7.7500	1.2250	A

Salinity = (0, 2, 4, 6, 8) ds/m

Table 87. Mean separation for the pods number based on the effect of Bacteria inoculation interaction with salinity. Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	salinity	Estimate	Standard Error	Letter Group
0	0	9.3063	2.4829	A
0	2	7.0000	1.7324	A
0	4	11.4290	1.9478	A
0	6	10.1667	1.7324	A
0	8	5.8333	1.7324	A
1	0	10.8909	1.9478	A
1	2	11.5000	1.7324	A
1	4	12.6667	1.7324	A
1	6	11.6667	1.7324	A
1	8	9.6667	1.7324	A

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 88. Mean separation for the pods number based on the effect of varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

Var	Estimate	Standard Error	Letter Group
1	12.9613	0.8525	A
2	7.0640	0.8136	B

Var = Variety 1 (local) and variety 2 (Qertase),

Table 89. Mean separation for the pods number based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	11.4559	1.3064	AB
0	2	6.0382	1.1521	C
1	1	14.4667	1.0957	A
1	2	8.0897	1.1521	BC

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase),

Table 90. Mean separation for the pods number based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

salinity	Var	Estimate	Standard Error	Letter Group
0	1	10.8063	2.4829	ABC
0	2	9.3909	1.9478	ABC
2	1	12.5000	1.7324	ABC
2	2	6.0000	1.7324	C
4	1	17.8333	1.7324	A
4	2	6.2623	1.9478	BC
6	1	14.8333	1.7324	AB
6	2	7.0000	1.7324	BC
8	1	8.8333	1.7324	BC
8	2	6.6667	1.7324	BC

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 91. Mean separation for the pods number based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	salinity	var	Estimate	Standard Error	Letter Group
0	0	1	12.6126	4.3194	AB
0	0	2	6.0000	2.4500	B
0	2	1	8.6667	2.4500	AB
0	2	2	5.3333	2.4500	B
0	4	1	15.3333	2.4500	AB
0	4	2	7.5246	3.0287	AB
0	6	1	14.6667	2.4500	AB
0	6	2	5.6667	2.4500	B
0	8	1	6.0000	2.4500	B
0	8	2	5.6667	2.4500	B
1	0	1	9.0000	2.4500	AB
1	0	2	12.7817	3.0287	AB
1	2	1	16.3333	2.4500	AB
1	2	2	6.6667	2.4500	B
1	4	1	20.3333	2.4500	A
1	4	2	5.0000	2.4500	B
1	6	1	15.0000	2.4500	AB
1	6	2	8.3333	2.4500	AB
1	8	1	11.6667	2.4500	AB
1	8	2	7.6667	2.4500	AB

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

Table 92. Mean separation for the seeds dry weight based on the effect of *B. megaterium* inoculation. Effect=Bacteria Method=Tukey-Kramer (P<.05).

Bacteria	Estimate	Standard Error	Letter Group
0	1.2120	0.1554	A
1	1.6275	0.1394	A

0= without bacteria, 1= with bacteria

Table 93. Mean separation for the seeds dry weight based on the effect salinity. Effect=salinity

Method=Tukey-Kramer (P<.05) Set=2

salinity	Estimate	Standard Error	Letter Group
0	1.5882	0.2779	A
2	1.4027	0.2285	A
4	1.3161	0.2285	A
6	1.5250	0.2147	A
8	1.2667	0.2147	A

Salinity = (0, 2, 4, 6, 8) ds/m

Table 94. Mean separation for the seeds dry weight based on the effect of Bacteria inoculation interaction with salinity. Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	Salinity	Estimate	Standard Error	Letter Group
0	0	1.5890	0.4356	A
0	2	1.4388	0.3415	A
0	4	1.0155	0.3415	A
0	6	1.2000	0.3037	A
0	8	0.8167	0.3037	A
1	0	1.5874	0.3415	A
1	2	1.3667	0.3037	A
1	4	1.6167	0.3037	A
1	6	1.8500	0.3037	A
1	8	1.7167	0.3037	A

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 95. Mean separation for the seeds dry weight based on the effect of two varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

Var	Estimate	Standard Error	Letter Group
1	1.3956	0.1520	A
2	1.4439	0.1426	A

Var = Variety 1 (local) and variety 2 (Qertase)

Table 96. Mean separation for the seeds dry weight based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	1.1178	0.2357	A
0	2	1.3062	0.2020	A
1	1	1.6733	0.1921	A
1	2	1.5816	0.2020	A

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase),

Table 97. Mean separation for the seeds dry weight based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

Salinity	Var	Estimate	Standard Error	Letter Group
0	1	1.3724	0.4356	A
0	2	1.8040	0.3415	A
2	1	1.1555	0.3415	A
2	2	1.6500	0.3037	A
4	1	1.2500	0.3037	A
4	2	1.3821	0.3415	A
6	1	1.9333	0.3037	A
6	2	1.1167	0.3037	A
8	1	1.2667	0.3037	A
8	2	1.2667	0.3037	A

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

Table 98. Mean separation for the seeds dry weight based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	salinity	var	Estimate	Standard Error	Letter Group
0	0	1	0.9781	0.7579	A
0	0	2	2.2000	0.4295	A
0	2	1	1.1110	0.5310	A
0	2	2	1.7667	0.4295	A
0	4	1	1.2000	0.4295	A
0	4	2	0.8310	0.5310	A
0	6	1	1.4667	0.4295	A
0	6	2	0.9333	0.4295	A
0	8	1	0.8333	0.4295	A
0	8	2	0.8000	0.4295	A
1	0	1	1.7667	0.4295	A
1	0	2	1.4081	0.5310	A
1	2	1	1.2000	0.4295	A
1	2	2	1.5333	0.4295	A
1	4	1	1.3000	0.4295	A
1	4	2	1.9333	0.4295	A
1	6	1	2.4000	0.4295	A
1	6	2	1.3000	0.4295	A
1	8	1	1.7000	0.4295	A
1	8	2	1.7333	0.4295	A

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

Table 99. Mean separation for the shoot dry weight based on the effect of *B. megaterium* inoculation. Effect=Bacteria Method=Tukey-Kramer (P<.05)

Bacteria	Estimate	Standard Error	Letter Group
0	13.2867	0.9062	B
1	16.8762	0.9297	A

0= without bacteria, 1= with bacteria

Table 100. Mean separation for the shoot dry weight based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05) Set=2

salinity	Estimate	Standard Error	Letter Group
0	13.4906	1.5241	A
2	15.3417	1.4328	A
4	17.0083	1.4328	A
6	16.8167	1.4328	A
8	12.7500	1.4328	A

Salinity = (0, 2, 4, 6, 8) ds/m

Table 101. Mean separation for the shoot dry weight based on the effect of Bacteria inoculation interaction with salinity. Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	salinity	Estimate	Standard Error	Letter Group
0	0	16.4167	2.0262	AB
0	2	12.6500	2.0262	AB
0	4	13.4500	2.0262	AB
0	6	13.3833	2.0262	AB
0	8	10.5333	2.0262	B
1	0	10.5645	2.2773	AB
1	2	18.0333	2.0262	AB
1	4	20.5667	2.0262	A
1	6	20.2500	2.0262	A
1	8	14.9667	2.0262	AB

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 102. Mean separation for the shoot dry weight based on the effect of two varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

var	Estimate	Standard Error	Letter Group
1	14.0300	0.9062	A
2	16.1329	0.9297	A

Var = Variety 1 (local) and variety 2 (Qertase)

Table 103. Mean separation for the shoot dry weight based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	11.4600	1.2815	B
0	2	15.1133	1.2815	AB
1	1	16.6000	1.2815	A
1	2	17.1525	1.3473	A

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase)

Table 104. Mean separation for the shoot dry weight based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

salinity	var	Estimate	Standard Error	Letter Group
0	1	13.5833	2.0262	A
0	2	13.3978	2.2773	A
2	1	14.8500	2.0262	A
2	2	15.8333	2.0262	A
4	1	16.9167	2.0262	A
4	2	17.1000	2.0262	A
6	1	14.1500	2.0262	A
6	2	19.4833	2.0262	A
8	1	10.6500	2.0262	A
8	2	14.8500	2.0262	A

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

Table 105. Mean separation for the shoot dry weight based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	salinity	var	Estimate	Standard Error	Letter Group
0	0	1	12.6667	2.8655	AB
0	0	2	20.1667	2.8655	AB
0	2	1	12.2000	2.8655	AB
0	2	2	13.1000	2.8655	AB
0	4	1	11.0667	2.8655	AB
0	4	2	15.8333	2.8655	AB
0	6	1	12.7333	2.8655	AB
0	6	2	14.0333	2.8655	AB
0	8	1	8.6333	2.8655	B
0	8	2	12.4333	2.8655	AB
1	0	1	14.5000	2.8655	AB
1	0	2	6.6289	3.5402	B
1	2	1	17.5000	2.8655	AB
1	2	2	18.5667	2.8655	AB
1	4	1	22.7667	2.8655	AB
1	4	2	18.3667	2.8655	AB
1	6	1	15.5667	2.8655	AB
1	6	2	24.9333	2.8655	A
1	8	1	12.6667	2.8655	AB
1	8	2	17.2667	2.8655	AB

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 106. Mean separation for the nodules number based on the effect of *B. megaterium* inoculation. Effect=Bacteria Method=Tukey-Kramer (P<.05)

Bacteria	Estimate	Standard Error	Letter Group
0	3.3522	0.4333	A
1	3.5373	0.4596	A

0= without bacteria, 1= with bacteria

Table 107. Mean separation for the nodules number based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05) Set=2

salinity	Estimate	Standard Error	Letter Group
0	3.0151	0.8003	A
2	3.1200	0.6288	A
4	3.8839	0.7004	A
6	4.7855	0.6987	A
8	2.4194	0.6995	A

Salinity = (0, 2, 4, 6, 8) ds/m

Table 108. Mean separation for the nodules number based on the effect of Bacteria inoculation interaction with salinity. Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	salinity	Estimate	Standard Error	Letter Group
0	0	4.0078	0.9415	A
0	2	3.1667	0.8348	A
0	4	3.2656	1.0518	A
0	6	4.2400	0.9406	A
0	8	2.0811	1.0283	A
1	0	2.0223	1.2867	A
1	2	3.0733	0.9406	A
1	4	4.5023	0.9398	A
1	6	5.3311	1.0283	A
1	8	2.7578	0.9415	A

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 109. Mean separation for the nodules number based on the effect of two varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

var	Estimate	Standard Error	Letter Group
1	2.8516	0.4345	A
2	4.0380	0.4556	A

Var = Variety 1 (local) and variety 2 (Qertase)

Table 110. Mean separation for the nodules number based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	3.2062	0.5867	A
0	2	3.4982	0.6309	A
1	1	2.4969	0.6485	A
1	2	4.5778	0.6593	A

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase),

Table 111. Mean separation for the nodules number based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

salinity	var	Estimate	Standard Error	Letter Group
0	1	2.1689	0.9398	A
0	2	3.8612	1.2928	A
2	1	2.9066	0.9406	A
2	2	3.3333	0.8348	A
4	1	3.1767	1.0291	A
4	2	4.5911	0.9415	A
6	1	4.2400	0.9406	A
6	2	5.3311	1.0283	A
8	1	1.7656	1.0518	A
8	2	3.0733	0.9406	A

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 112. Mean separation for the nodules number based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	salinity	var	Estimate	Standard Error	Letter Group
0	0	1	3.0000	1.1806	A
0	0	2	5.0156	1.4668	A
0	2	1	3.6667	1.1806	A
0	2	2	2.6667	1.1806	A
0	4	1	4.0156	1.4668	A
0	4	2	2.5156	1.4668	A
0	6	1	3.3333	1.1806	A
0	6	2	5.1466	1.4647	A
0	8	1	2.0156	1.4668	A
0	8	2	2.1466	1.4647	A
1	0	1	1.3379	1.4625	A
1	0	2	2.7068	2.0976	A
1	2	1	2.1466	1.4647	A
1	2	2	4.0000	1.1806	A
1	4	1	2.3379	1.4625	A
1	4	2	6.6667	1.1806	A
1	6	1	5.1466	1.4647	A
1	6	2	5.5156	1.4668	A
1	8	1	1.5156	1.4668	A
1	8	2	4.0000	1.1806	A

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 113. The analysis of variance for the effect of *B. megaterium* on roots fresh weight for two varieties of Faba Bean under four different salinity levels.

Bacteria	Estimate	Standard Error	Letter Group
0	29.9400	1.7504	B
1	40.7165	1.7958	A

0= without bacteria, 1= with bacteria

Table 114. Mean separation for the roots fresh weight based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05) Set=2

salinity	Estimate	Standard Error	Letter Group
0	33.7996	2.9440	BC
2	45.7417	2.7676	A
4	42.9250	2.7676	AB
6	30.9000	2.7676	C
8	23.2750	2.7676	C

Salinity = (0, 2, 4, 6, 8) ds/m

Table 115. Mean separation for the roots fresh weight based on the effect of Bacteria inoculation interaction with salinity. Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	salinity	Estimate	Standard Error	Letter Group
0	0	46.2000	3.9139	AB
0	2	34.8000	3.9139	BC
0	4	35.0333	3.9139	BC
0	6	21.9833	3.9139	CD
0	8	11.6833	3.9139	D
1	0	21.3991	4.3989	CD
1	2	56.6833	3.9139	A
1	4	50.8167	3.9139	AB
1	6	39.8167	3.9139	ABC
1	8	34.8667	3.9139	BC

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 116. Mean separation for the roots fresh weight based on the effect of two varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

var	Estimate	Standard Error	Letter Group
1	35.0633	1.7504	A
2	35.5932	1.7958	A

Var = Variety 1 (local) and variety 2 (Qertase)

Table 117. Mean separation for the roots fresh weight based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	29.7867	2.4754	B
0	2	30.0933	2.4754	B
1	1	40.3400	2.4754	A
1	2	41.0930	2.6024	A

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase)

Table 118. Mean separation for the roots fresh weight based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

salinity	var	Estimate	Standard Error	Letter Group
0	1	36.1000	3.9139	ABCD
0	2	31.4991	4.3989	ABCD
2	1	44.9167	3.9139	AB
2	2	46.5667	3.9139	A
4	1	43.5500	3.9139	AB
4	2	42.3000	3.9139	ABC
6	1	27.0167	3.9139	BCD
6	2	34.7833	3.9139	ABCD
8	1	23.7333	3.9139	CD
8	2	22.8167	3.9139	D

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 119. Mean separation for the roots fresh weight based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	salinity	var	Estimate	Standard Error	Letter Group
0	0	1	46.2000	5.5352	ABC
0	0	2	46.2000	5.5352	ABC
0	2	1	35.4333	5.5352	ABCDE
0	2	2	34.1667	5.5352	ABCDE
0	4	1	40.8667	5.5352	ABCD
0	4	2	29.2000	5.5352	ABCDE
0	6	1	13.8333	5.5352	DE
0	6	2	30.1333	5.5352	ABCDE
0	8	1	12.6000	5.5352	DE
0	8	2	10.7667	5.5352	E
1	0	1	26.0000	5.5352	BCDE
1	0	2	16.7982	6.8384	CDE
1	2	1	54.4000	5.5352	AB
1	2	2	58.9667	5.5352	A
1	4	1	46.2333	5.5352	ABC
1	4	2	55.4000	5.5352	AB
1	6	1	40.2000	5.5352	ABCDE
1	6	2	39.4333	5.5352	ABCDE
1	8	1	34.8667	5.5352	ABCDE
1	8	2	34.8667	5.5352	ABCDE

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

Table 120. Mean separation for the roots dry weight based on the effect of *B. megaterium* inoculation. Effect=Bacteria Method=Tukey-Kramer (P<.05).

Bacteria	Estimate	Standard Error	Letter Group
0	4.7833	0.4138	B
1	6.9125	0.4245	A

0= without bacteria, 1= with bacteria

Table 121. Mean separation for the roots dry weight based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05) Set=2

salinity	Estimate	Standard Error	Letter Group
0	5.1314	0.6960	BC
2	7.6500	0.6542	AB
4	8.9667	0.6542	A
6	4.4167	0.6542	C
8	3.0750	0.6542	C

Salinity = (0, 2, 4, 6, 8) ds/m

Table 122. Mean separation for the roots dry weight based on the effect of Bacteria inoculation interaction with salinity. Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	Salinity	Estimate	Standard Error	Letter Group
0	0	7.5833	0.9252	BC
0	2	5.4167	0.9252	CD
0	4	5.4833	0.9252	BCD
0	6	3.7833	0.9252	CD
0	8	1.6500	0.9252	D
1	0	2.6794	1.0399	D
1	2	9.8833	0.9252	AB
1	4	12.4500	0.9252	A
1	6	5.0500	0.9252	CD
1	8	4.5000	0.9252	CD

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 123. Mean separation for the roots dry weight based on the effect of two varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

var	Estimate	Standard Error	Letter Group
1	4.7533	0.4138	B
2	6.9425	0.4245	A

Var = Variety 1 (local) and variety 2 (Qertase)

Table 124. Mean separation for the roots dry weight based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	Var	Estimate	Standard Error	Letter Group
0	1	3.9067	0.5852	B
0	2	5.6600	0.5852	B
1	1	5.6000	0.5852	B
1	2	8.2251	0.6152	A

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase)

Table 125. Mean separation for the roots dry weight based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

salinity	Var	Estimate	Standard Error	Letter Group
0	1	5.3667	0.9252	BCD
0	2	4.8961	1.0399	BCD
2	1	6.0167	0.9252	BCD
2	2	9.2833	0.9252	AB
4	1	7.0167	0.9252	ABC
4	2	10.9167	0.9252	A
6	1	2.9000	0.9252	CD
6	2	5.9333	0.9252	BCD
8	1	2.4667	0.9252	D
8	2	3.6833	0.9252	CD

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 126. Mean separation for the roots dry weight based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	salinity	var	Estimate	Standard Error	Letter Group
0	0	1	8.0000	1.3085	ABCD
0	0	2	7.1667	1.3085	ABCD
0	2	1	4.7667	1.3085	CD
0	2	2	6.0667	1.3085	BCD
0	4	1	3.2667	1.3085	D
0	4	2	7.7000	1.3085	ABCD
0	6	1	1.7667	1.3085	D
0	6	2	5.8000	1.3085	BCD
0	8	1	1.7333	1.3085	D
0	8	2	1.5667	1.3085	D
1	0	1	2.7333	1.3085	D
1	0	2	2.6254	1.6166	D
1	2	1	7.2667	1.3085	ABCD
1	2	2	12.5000	1.3085	AB
1	4	1	10.7667	1.3085	ABC
1	4	2	14.1333	1.3085	A
1	6	1	4.0333	1.3085	CD
1	6	2	6.0667	1.3085	BCD
1	8	1	3.2000	1.3085	D
1	8	2	5.8000	1.3085	BCD

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

Table 127. Mean separation for the flowering date based on the effect of B. *megaterium* inoculation. Effect=Bacteria Method=Tukey-Kramer (P<.05)

Bacteria	Estimate	Standard Error	Letter Group
0	66.8000	0	A
1	57.0000	0	B

0= without bacteria, 1= with bacteria

Table 128. Mean separation for the flowering date based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05) Set=2

salinity	Estimate	Standard Error	Letter Group
0	66.7500	0	A
2	62.5000	0	B
4	61.2500	0	C
6	60.7500	0	D
8	58.2500	0	E

Salinity = (0, 2, 4, 6, 8) ds/m

Table 129. Mean separation for the flowering date based on the effect of Bacteria inoculation interaction with salinity Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05).

Bacteria	salinity	Estimate	Standard Error	Letter Group
0	0	69.5000	0	A
0	2	68.5000	0	B
0	4	67.0000	0	C
0	6	67.0000	0	C
0	8	62.0000	0	E
1	0	64.0000	0	D
1	2	56.5000	0	F
1	4	55.5000	0	G
1	6	54.5000	0	H
1	8	54.5000	0	H

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 130. Mean separation for the flowering date based on the effect of two varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05).

var	Estimate	Standard Error	Letter Group
1	59.1000	0	B
2	64.7000	0	A

Var = Variety 1 (local) and variety 2 (Qertase)

Table 131. Mean separation for the flowering date based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	65.6000	0	B
0	2	68.0000	0	A
1	1	52.6000	0	D
1	2	61.4000	0	C

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase)

Table 132. Mean separation for the flowering date based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

salinity	var	Estimate	Standard Error	Letter Group
0	1	61.5000	0	E
0	2	72.0000	0	A
2	1	60.0000	0	F
2	2	65.0000	0	B
4	1	58.5000	0	H
4	2	64.0000	0	C
6	1	58.0000	0	I
6	2	63.5000	0	D
8	1	57.5000	0	J
8	2	59.0000	0	G

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

Table 133. Mean separation for the flowering date based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	salinity	var	Estimate	Standard Error	Letter Group
0	0	1	67.0000	0	D
0	0	2	72.0000	0	A
0	2	1	67.0000	0	D
0	2	2	70.0000	0	B
0	4	1	65.0000	0	E
0	4	2	69.0000	0	C
0	6	1	65.0000	0	E
0	6	2	69.0000	0	C
0	8	1	64.0000	0	F
0	8	2	60.0000	0	G
1	0	1	56.0000	0	J
1	0	2	72.0000	0	A
1	2	1	53.0000	0	K
1	2	2	60.0000	0	G
1	4	1	52.0000	0	L
1	4	2	59.0000	0	H
1	6	1	51.0000	0	M
1	6	2	58.0000	0	I
1	8	1	51.0000	0	M
1	8	2	58.0000	0	I

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

Table 134.Mean separation for the chlorophyll content based on the effect of B. *megaterium* inoculation. Effect=Bacteria Method=Tukey-Kramer (P<.05).

Bacteria	Estimate	Standard Error	Letter Group
0	66.8000	0	A
1	57.0000	0	B

0= without bacteria, 1= with bacteria

Table 135. Mean separation for the chlorophyll content based on the effect salinity. Effect=salinity Method=Tukey-Kramer (P<.05) Set=2

Salinity	Estimate	Standard Error	Letter Group
0	42.2333	1.2514	A
2	42.4417	1.2514	A
4	41.1417	1.2514	A
6	38.8083	1.2514	AB
8	35.9167	1.2514	B

Salinity = (0, 2, 4, 6, 8) ds/m

Table 136. Mean separation for the chlorophyll content based on the effect of Bacteria inoculation interaction with salinity. Effect=Bacteria*salinity Method=Tukey-Kramer (P<.05)

Bacteria	Salinity	Estimate	Standard Error	Letter Group
0	0	43.8500	1.7698	A
0	2	43.7333	1.7698	A
0	4	39.1500	1.7698	AB
0	6	39.2500	1.7698	AB
0	8	36.8667	1.7698	AB
1	0	40.6167	1.7698	AB
1	2	41.1500	1.7698	AB
1	4	43.1333	1.7698	AB
1	6	38.3667	1.7698	AB
1	8	34.9667	1.7698	B

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m

Table 137. Mean separation for the chlorophyll content based on the effect of two varieties of Faba Bean .Effect=var Method=Tukey-Kramer (P<.05)

Var	Estimate	Standard Error	Letter Group
1	**37.5900**	**0.7915**	**B**
2	**42.6267**	**0.7915**	**A**

Var = Variety 1 (local) and variety 2 (Qertase)

Table 138. Mean separation for the chlorophyll content based on the interaction of the two varieties of Faba Bean with bacterial inoculation .Effect=Bacteria*var Method=Tukey-Kramer (P<.05)

Bacteria	var	Estimate	Standard Error	Letter Group
0	1	39.1667	1.1193	AB
0	2	41.9733	1.1193	A
1	1	36.0133	1.1193	B
1	2	43.2800	1.1193	A

0= without bacteria, 1= with bacteria, Var = Variety 1 (local) and variety 2 (Qertase),

Table 139. Mean separation for the chlorophyll content based on the interaction of four different salinity levels and two varieties of Faba Bean. Effect=salinity*var Method=Tukey-Kramer (P<.05)

salinity	var	Estimate	Standard Error	Letter Group
0	1	41.2333	1.7698	A
0	2	43.2333	1.7698	A
2	1	42.4667	1.7698	A
2	2	42.4167	1.7698	A
4	1	37.0333	1.7698	AB
4	2	45.2500	1.7698	A
6	1	37.5167	1.7698	AB
6	2	40.1000	1.7698	A
8	1	29.7000	1.7698	B
8	2	42.1333	1.7698	A

Salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase)

Table 140. Mean separation for the chlorophyll content based on the interaction of the two varieties of Faba Bean with bacterial inoculation and four different salinity levels. Effect=Bacteria*salinity*var Method=Tukey-Kramer (P<.05)

Bacteria	Salinity	Var	Estimate	Standard Error	Letter Group
0	0	1	43.0333	2.5029	ABC
0	0	2	44.6667	2.5029	AB
0	2	1	44.8667	2.5029	AB
0	2	2	42.6000	2.5029	ABC
0	4	1	36.5333	2.5029	ABCD
0	4	2	41.7667	2.5029	ABCD
0	6	1	41.0333	2.5029	ABCD
0	6	2	37.4667	2.5029	ABCD
0	8	1	30.3667	2.5029	CD
0	8	2	43.3667	2.5029	ABC
1	0	1	39.4333	2.5029	ABCD
1	0	2	41.8000	2.5029	ABCD
1	2	1	40.0667	2.5029	ABCD
1	2	2	42.2333	2.5029	ABCD
1	4	1	37.5333	2.5029	ABCD
1	4	2	48.7333	2.5029	A
1	6	1	34.0000	2.5029	BCD
1	6	2	42.7333	2.5029	ABC
1	8	1	29.0333	2.5029	D
1	8	2	40.9000	2.5029	ABCD

0= without bacteria, 1= with bacteria, salinity = (0, 2, 4, 6, 8) ds/m, Var = Variety 1 (local) and variety 2 (Qertase),

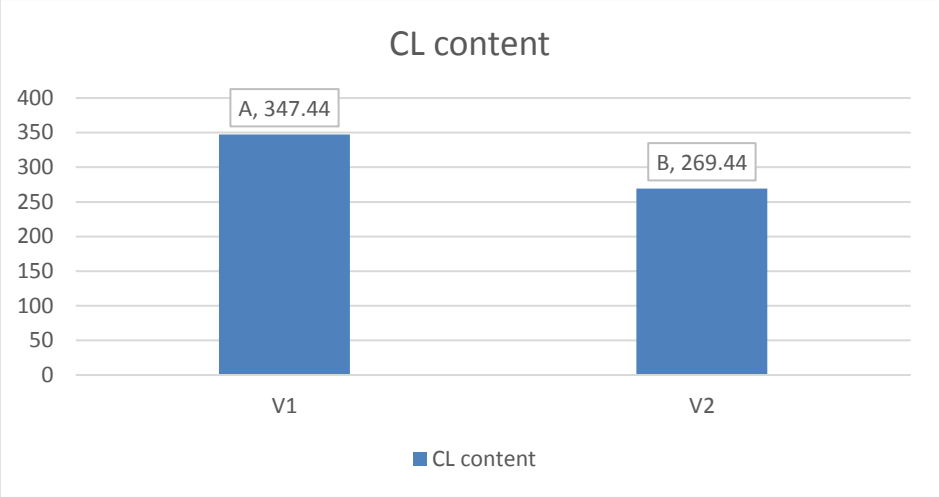


Figure 12. Chloride content of two Faba Bean varieties as a response to salinity and *B. megaterium* .V1 : local variety V2 : Qertase variety

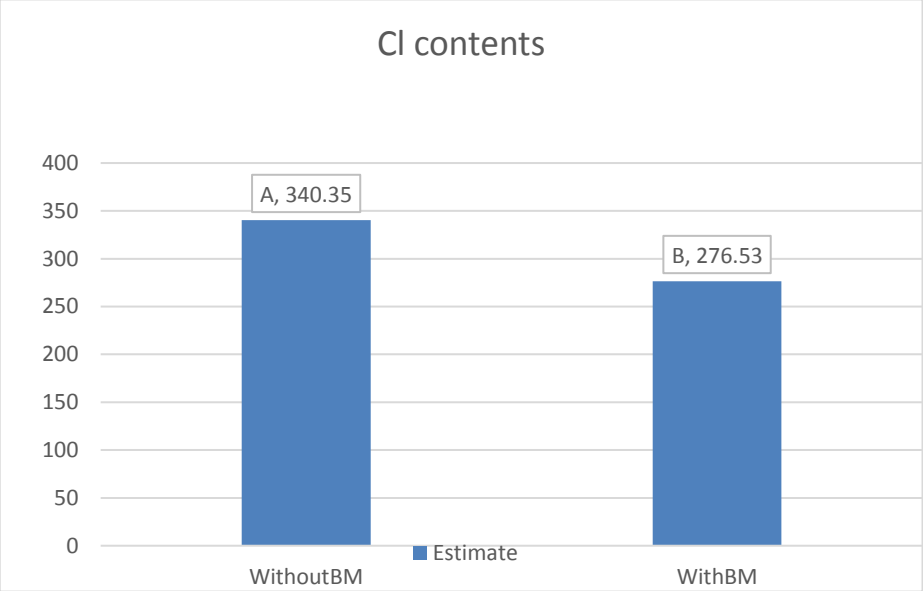


Figure 13. The effect of *B. megaterium* inoculation on Cl content of Faba Bean leaves.

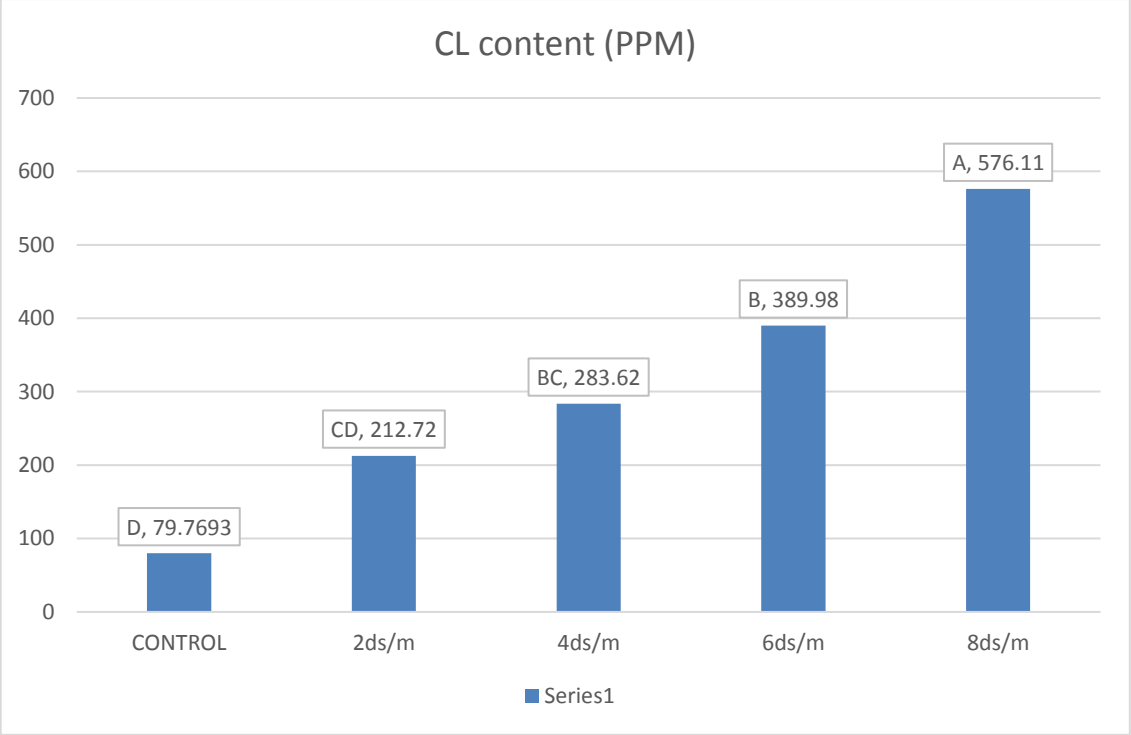


Figure 14. Chloride content in Faba Bean varieties as a response to four different salinity level. Salinity: (control, 2, 4, 6, 8) ds/m

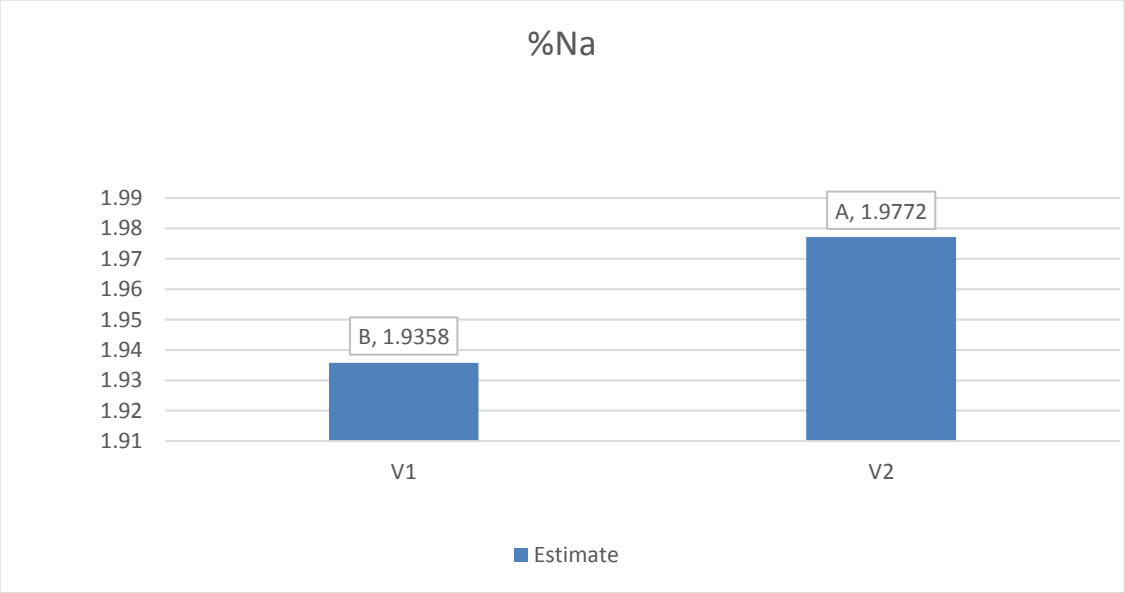


Figure 15. Sodium content of two Faba Bean varieties as a response to salinity and *B. megaterium* V1: local variety V2 : Qertase variety

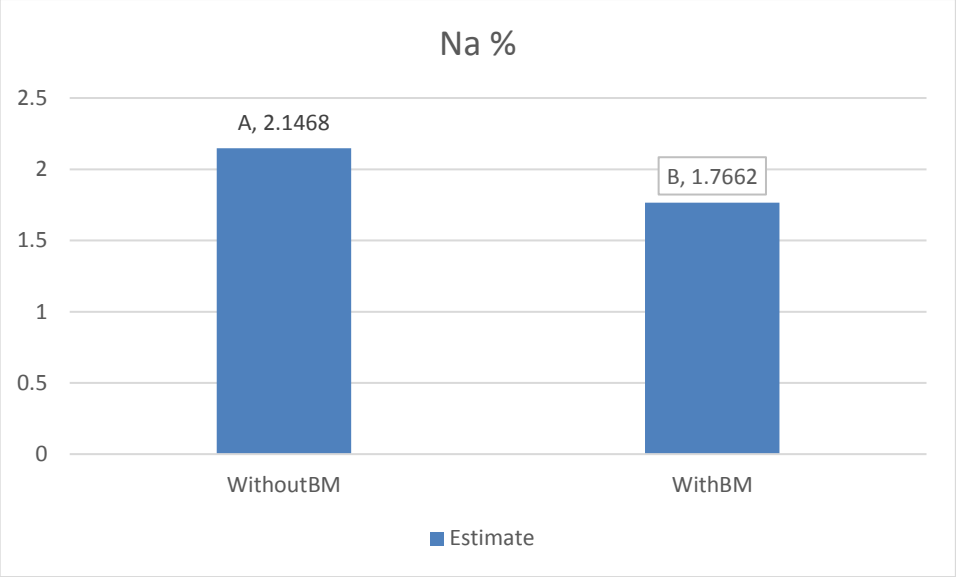
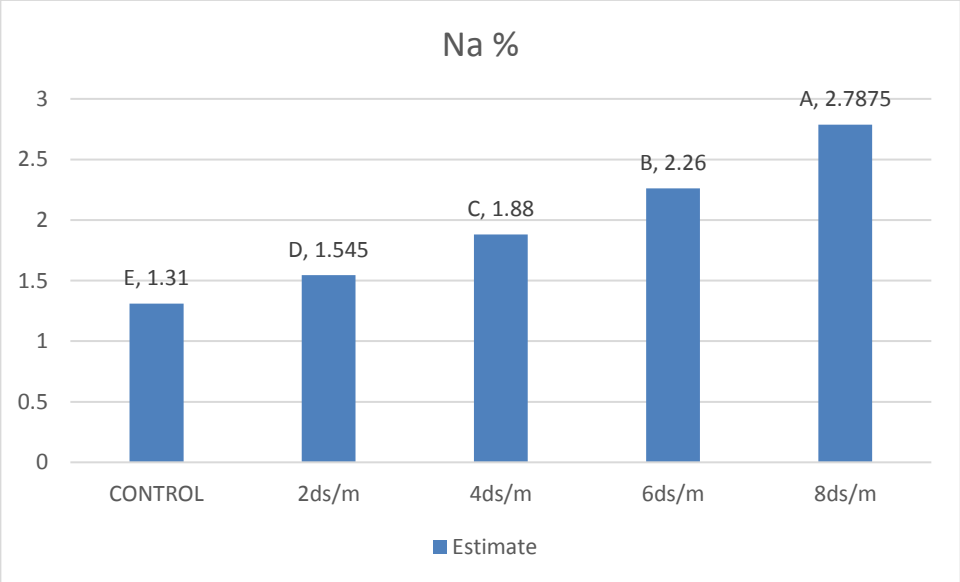


Figure 16. The effect of *B. megaterium* inoculation on Na content of Faba Bean leaves.

Figure 17. Sodium content in Faba Bean varieties as a response to different salinity level. Salinity : (control , 2 , 4 , 6 , 8) ds/m



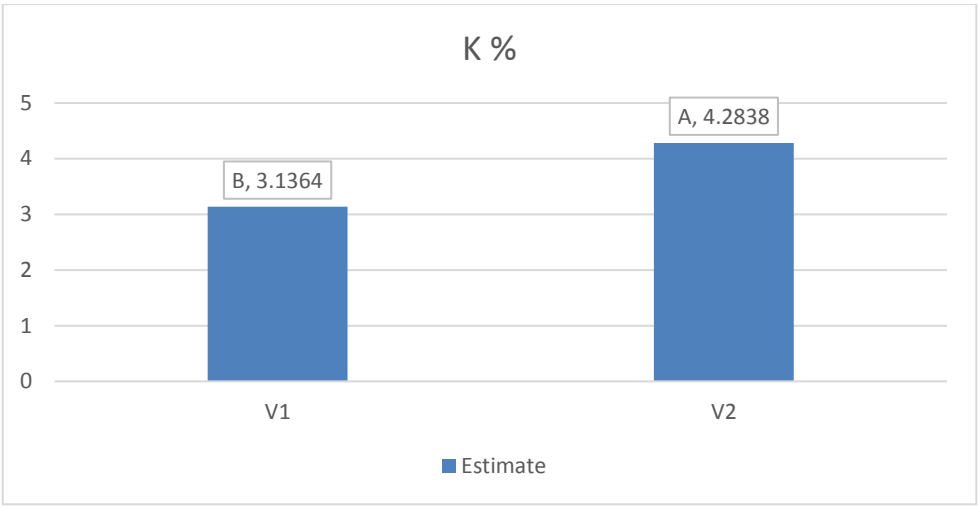


Figure 6. Potassium content of two Faba Bean varieties as a response to salinity and *B. megaterium*.V1: local variety V2 : Qertase variety

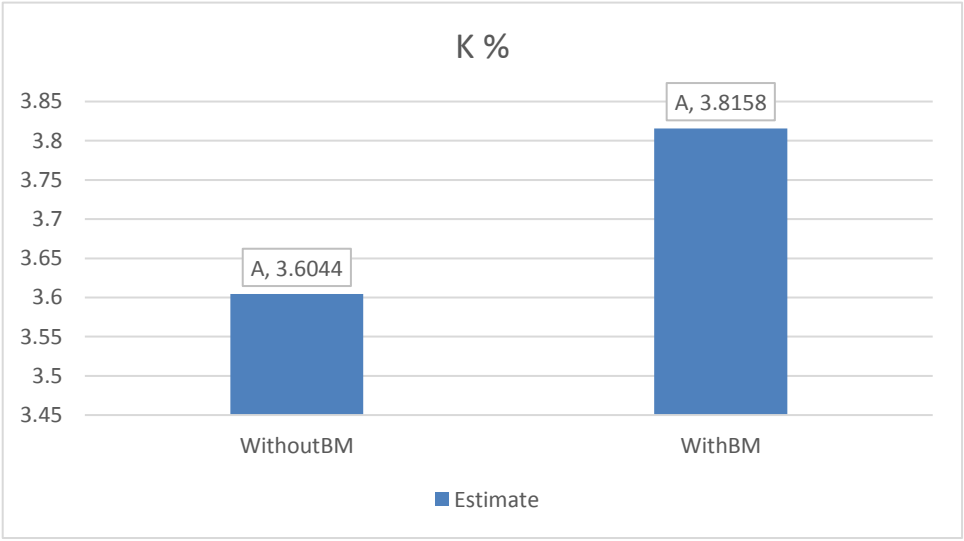


Figure 18. The effect of *B. megaterium* inoculation on K content of Faba Bean leaves.

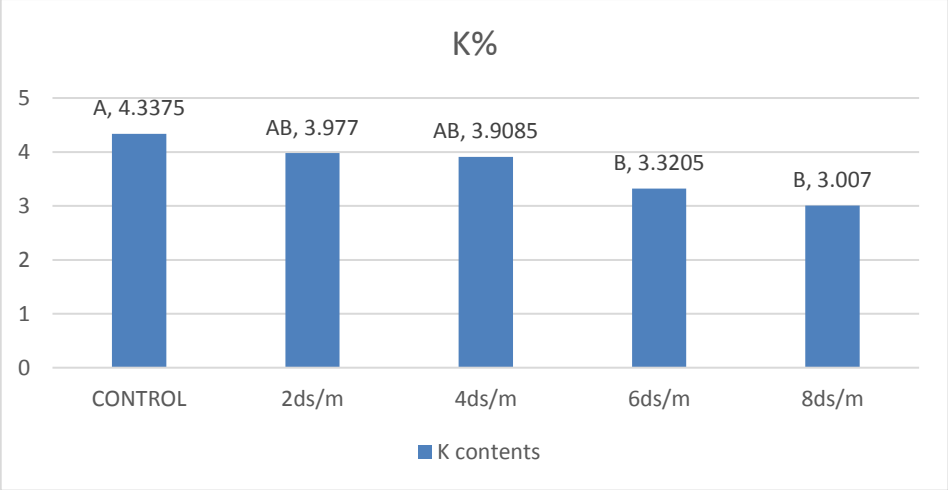


Figure 19. Potassium content in Faba Bean varieties as a response to different salinity level. Salinity : (control , 2 , 4 , 6 , 8) ds/m

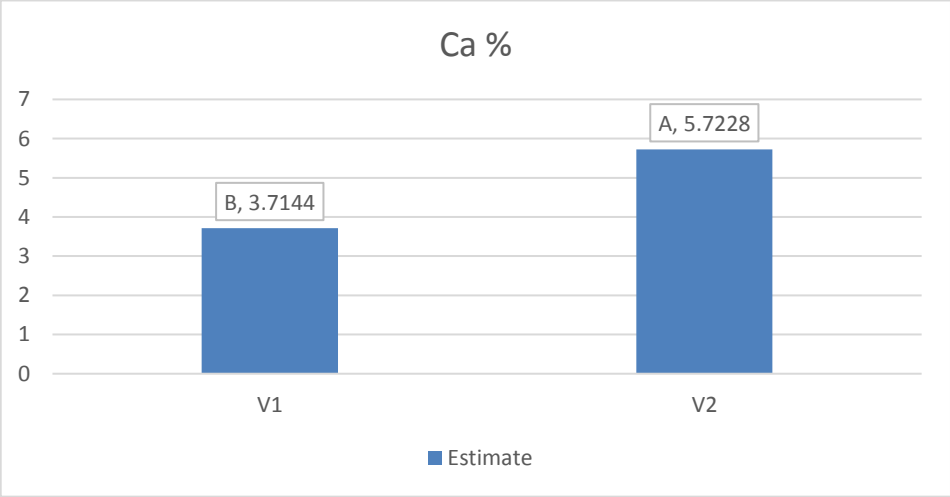


Figure 20. Calcium content of two Faba Bean varieties as a response to salinity and *B. megaterium*, V1: local variety V2 : Qertase variety

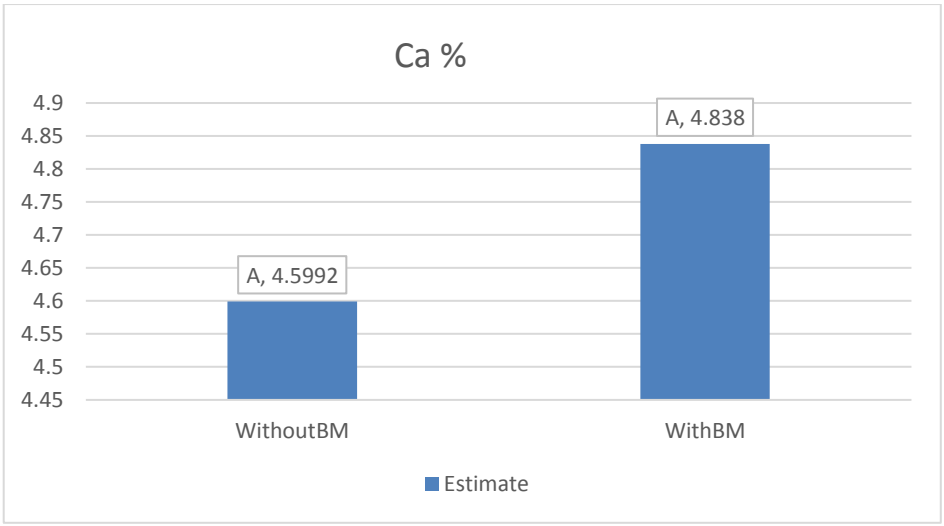


Figure 21. The effect of *B. megaterium* inoculation on Ca content of Faba Bean leaves.

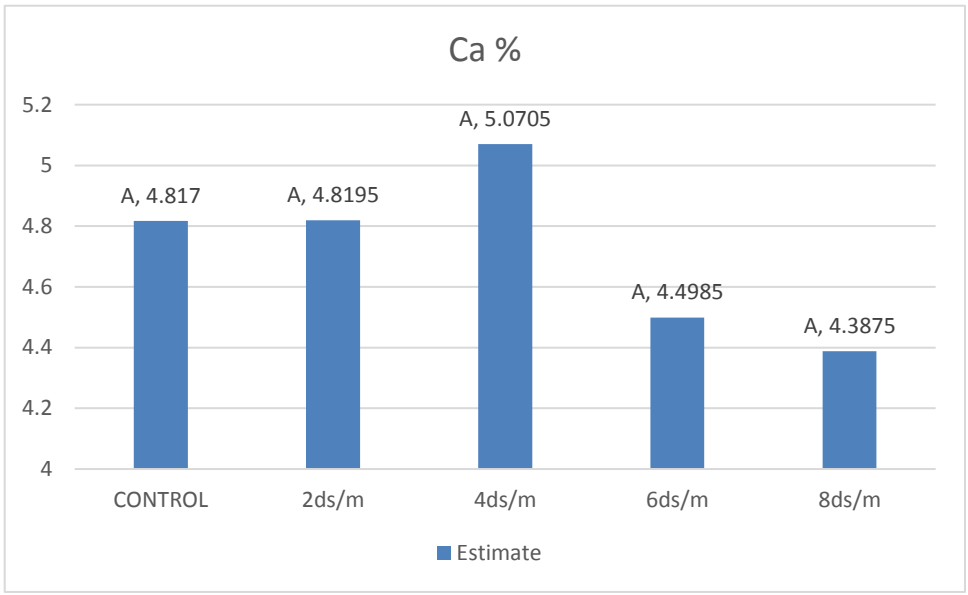


Figure 22. Calcium content in Faba Bean varieties as a response to different salinity level. Salinity: (control, 2, 4, 6, 8) ds/m

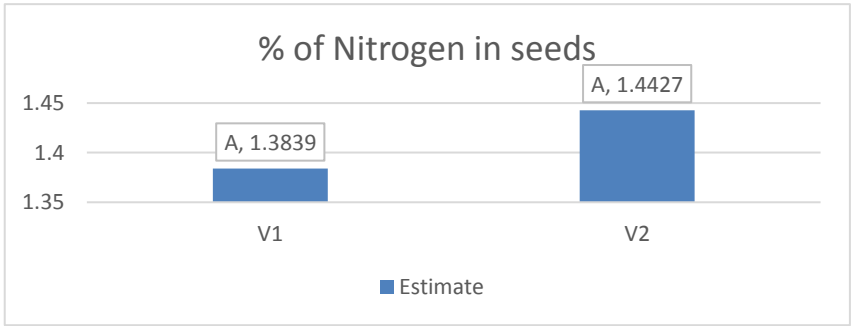


Figure 23. Nitrogen percent in seeds of two varieties of Faba Bean as a response to salinity and *B. megaterium* V1 : local variety V2 : Qertase variety

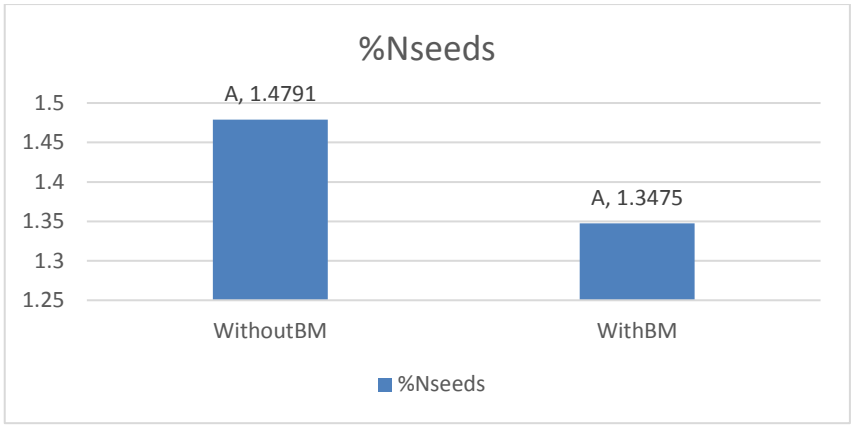


Figure 24. The effect of *B. megaterium* inoculation on N percent of Faba Bean seeds

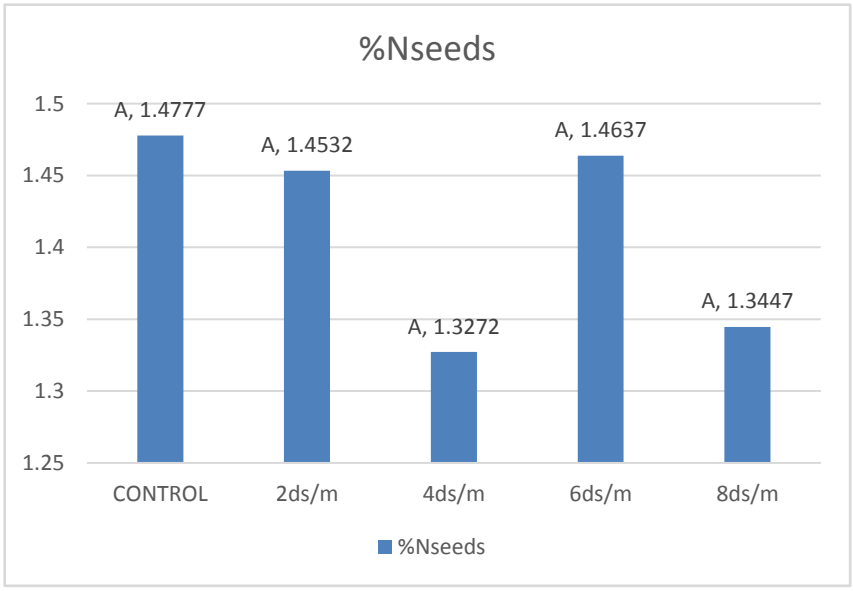


Figure 25. Nitrogen percent in Faba Bean seeds as a response to different salinity level. Salinity: (control, 2, 4, 6, 8) ds/m

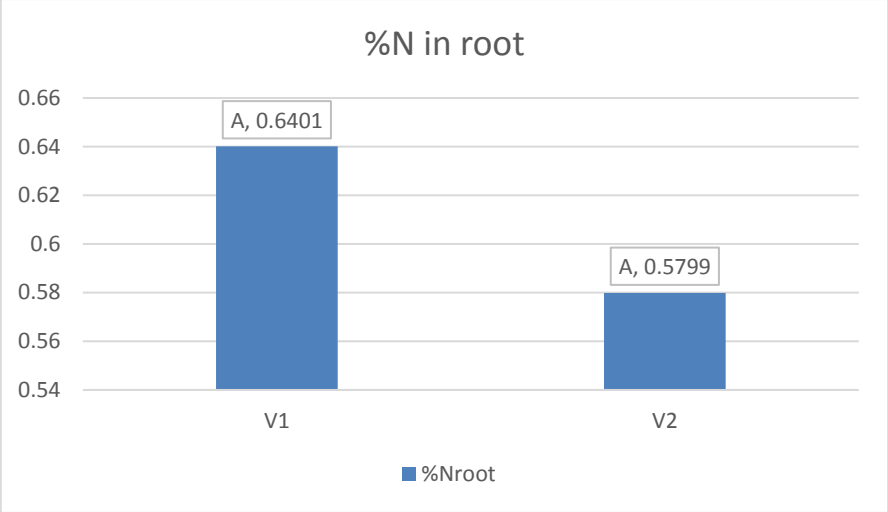


Figure 26. Nitrogen percent in roots of two Faba Bean varieties as a response to salinity and *B. megaterium* V1 : local variety V2 : Qertase variety

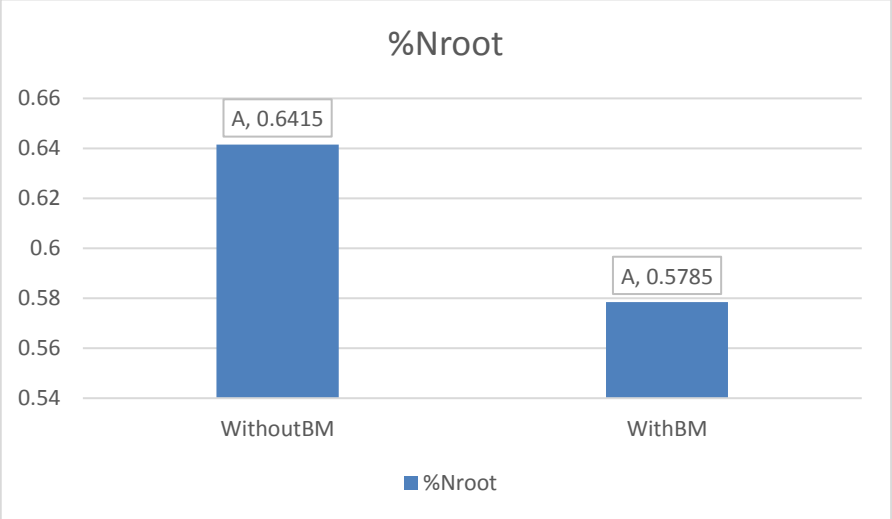


Figure 27. The effect of *B. megaterium* inoculation on N percent of Faba Bean roots.

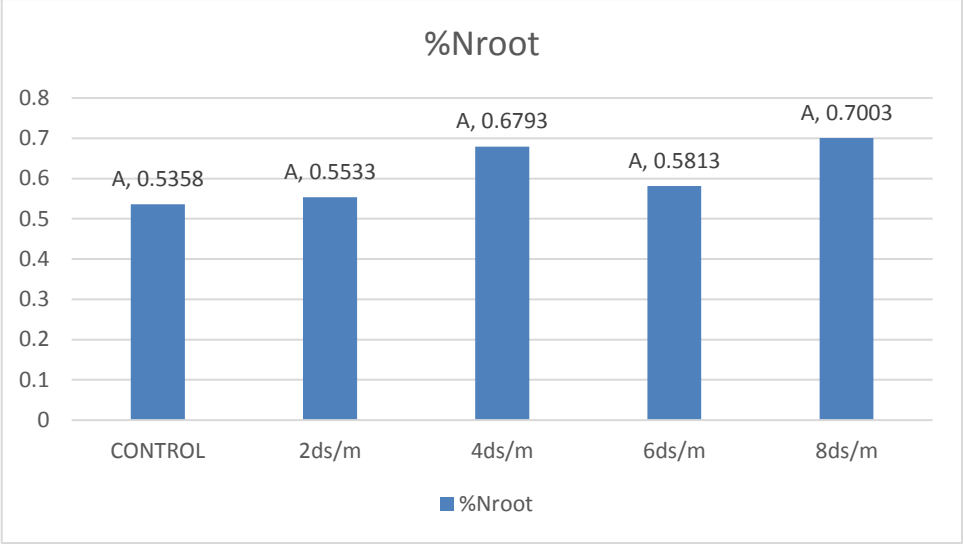


Figure 28. Nitrogen percent in Faba Bean roots as a response to different salinity level Salinity: (control, 2, 4, 6, and 8) ds/m

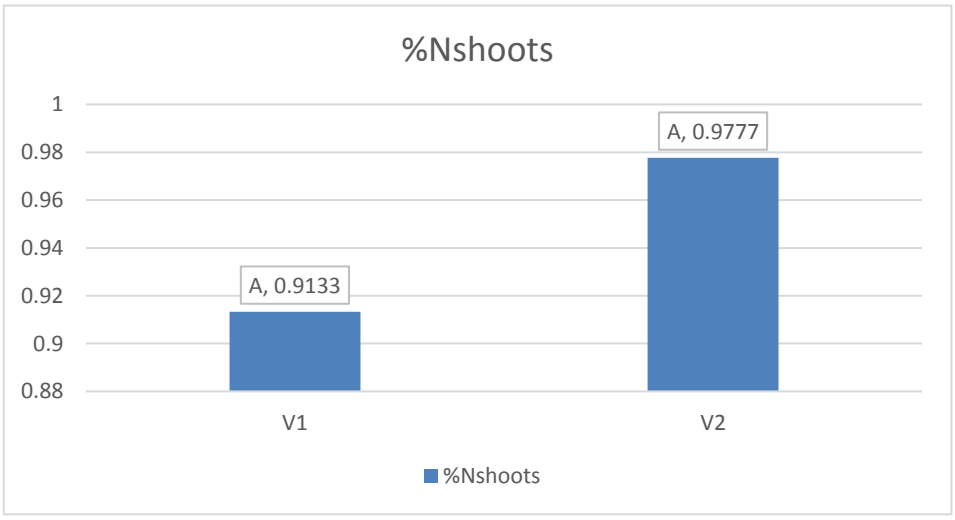


Figure 29. Nitrogen percent in shoots of two Faba Bean varieties as a response to salinity and *B. megaterium*, V1 : local variety V2 : Qertase variety

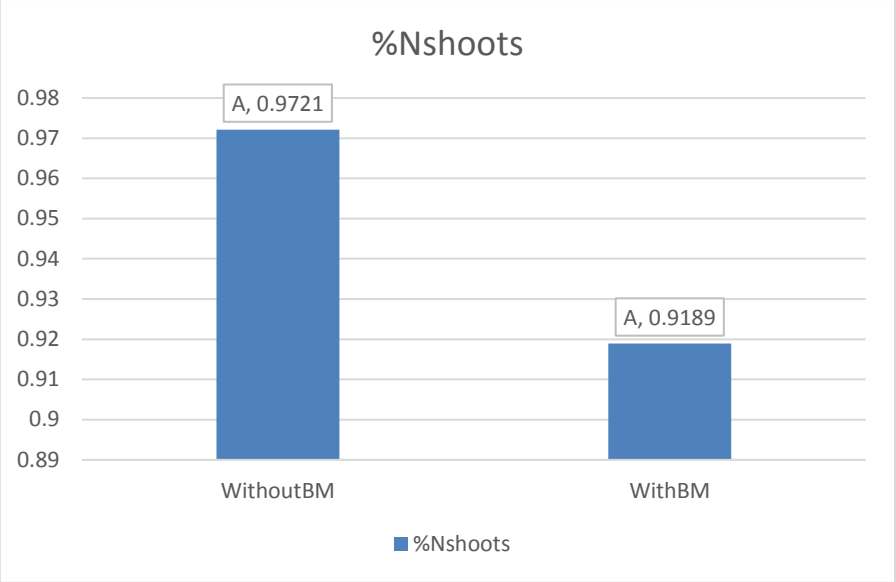


Figure 30. The effect of *B. megaterium* inoculation on N percent of Faba Bean shoots.

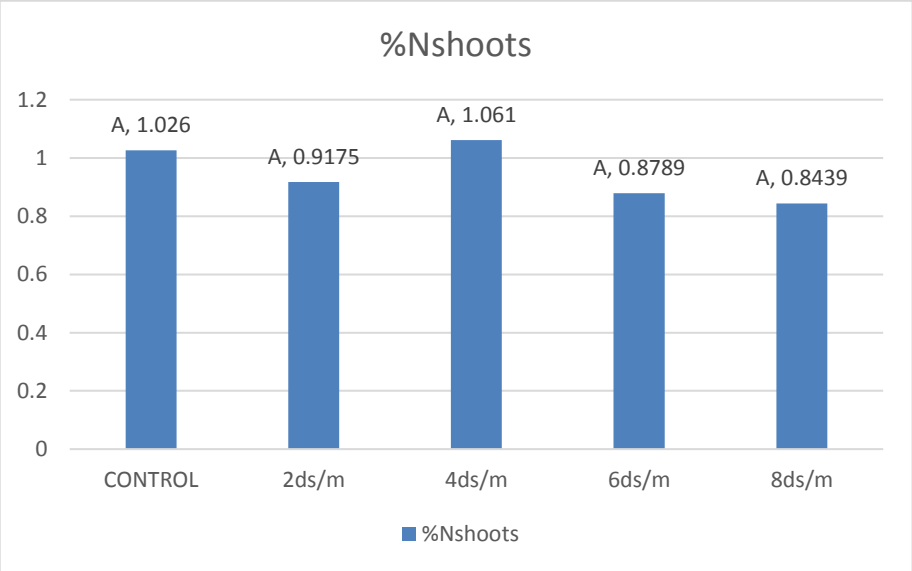


Figure 31. Nitrogen percent in Faba Bean shoots as a response to different salinity level. Salinity: (control, 2, 4, 6, 8) ds/m

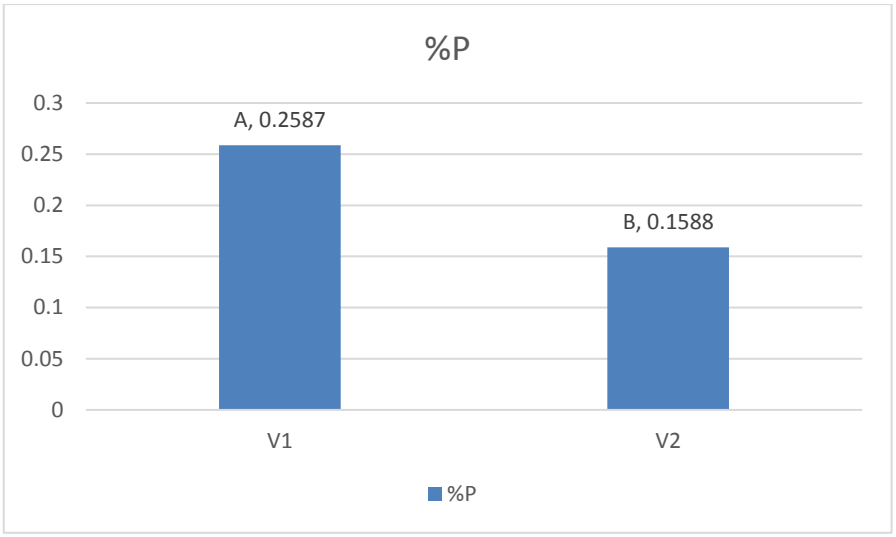


Figure 32. Phosphorus percent in shoots of two Faba Bean varieties as a response to salinity and *B. megaterium* V1 : local variety V2 : Qertase variety

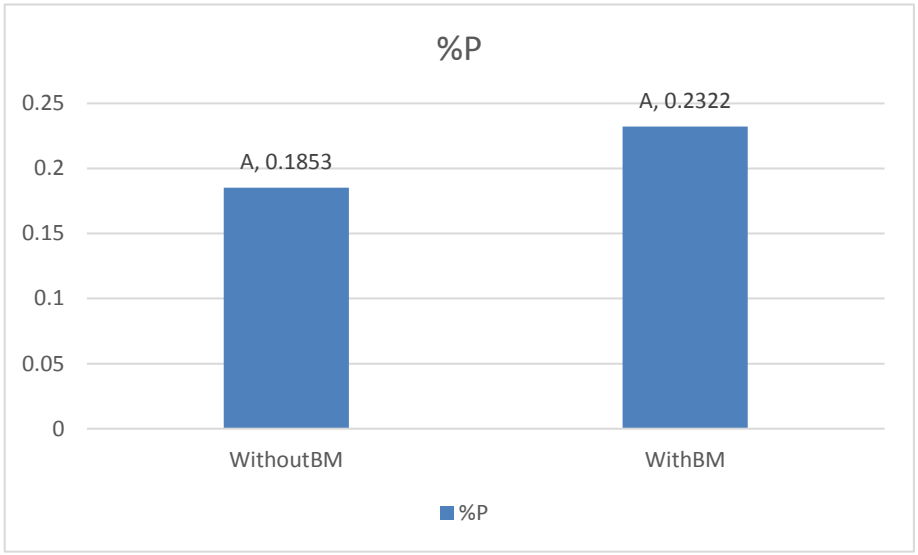


Figure 33. The effect of *B. megaterium* inoculation on P percent of Faba Bean shoots.

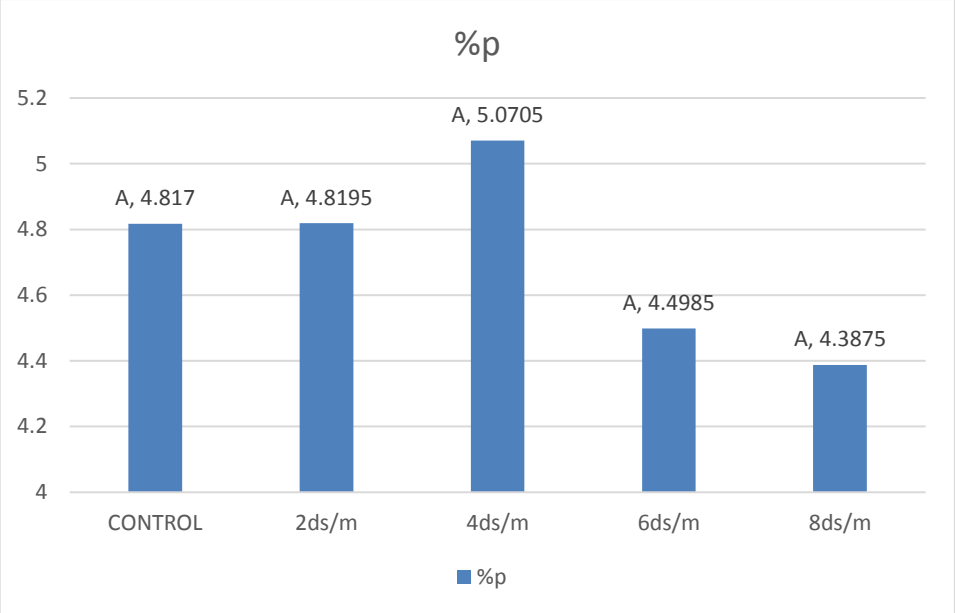


Figure 34. Phosphorus percent in Faba Bean shoots as a response to different salinity level. Salinity: (control, 2, 4, 6, 8) ds/m

جامعة النجاح الوطنية

كلية الدراسات العليا

تعزيز النمو والتخفيف من الاثار الضارة الناجمة عن الاجهاد الملحي في نبات الفول باستخدام البكتيريا المحفزة للنمو PGPB

اعداد

علي فايز علي شيخ ابراهيم

اشراف

د. هبة معين فارس

قدمت هذه الأطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في تخصص إنتاج نباتي بكلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس- فلسطين.

2018

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الملخص

الدراسة الحالية اجريت لتقييم الاثر الناتج عن استخدام المحلول الملحي بدرجات مختلفة على نبات الفول(الصنفين القرطاسي والمحلي) بوجود او عدم وجود بكتيريا *B. megaterium*. تم اجراء التجربة على صنفين من الفول تحت تأثير درجات مختلفة من الملوحة (0, 2, 4, 6, 8 ds/m) بوجود البكتيريا وعدمه في دفيئة بلاستيكية في مدينة جنين، الضفة الغربية، فلسطين في فصل الشتاء 2017/2016.

الأوعية تم ريها بتراكيز مختلفة من محلول كلورايد الصوديم، كل تركيز ملحي فيه مكرر من البكتيريا ومكرر لا يحتوي على البكتيريا. اظهرت نتائج دراسة الاجهاد الملحي على النباتات التي لا تحتوي على البكتيريا تناقص في مقاييس النمو (طول الساق، عدد الاوراق، الوزن الرطب والجاف، كتلة الجذور...)، كمية الانتاج، كذلك زاد تركيز كلورايد الصوديوم في الاوراق مع تناقص في امتصاص عناصر كيميائية اخرى تعد مهمة للنبات كأثر سلبي للاجهاد الملحي.

البكتيريا المحفزة للنمو (PGPB) قادرة على تحسين نمو النبات، تطوره، والتأقلم مع الاجهاد على الرغم ان الية عمل البكتيريا لا تزال غير واضحة. اضافة بكتيريا *B. megaterium* تخفف وتزيل الاثر الناتج عن كلورايد الصوديوم وتحسن النمو والانتاج كما هو واضح من الدراسة الحالية. اضافة بكتيريا *B. megaterium* (ATCC® 14581™) يؤدي الى زيادة طول النبات، عدد الاوراق، عدد الازهار، كتلة النبات، الازهار والانتاج المبكر، تحسين محتوى الكلوروفيل، زيادة المجموع الجذري، التخفيف من تراكم كلورايد الصوديوم في الاوراق، زيادة في امتصاص البوتاسيوم،

الكالسيوم والفسفور. النباتات التي زرعت وتم اضافة البكتيريا عليها اظهرت قدرة عالية على تحمل الاجهاد الملحي مقارنة مع النباتات التي لم تضف اليها البكتيريا.

في هذه الدراسة، وجد ان اضافة البكتيريا ادى الى زيادة في طول النباتات حوالي 39% على درجة ملوحة 8 ds/m، الزيادة في طول النبات التي تم ملاحظتها يمكن تفسيرها نتيجة لتغيير ايجابي في نشاط هرمونات النمو النباتية. أعلى وزن للنباتات غير المجففة او الرطبة كان 159.27 غم على تركيز ملوحة 8 ds/m في النباتات التي تم اضافة البكتيريا اليها مقارنة مع النباتات التي لم يضف اليها بكتيريا حيث كان الوزن الرطب 85.77 غم عند 8 ds/m. تأثير البكتيريا ايضا أدى الى زيادة في وزن الجذور الرطب بحاولي 35 %. بالنسبة للعلاقة مع فترة الازهار، نتائج الدراسة اظهرت ان تأثير الاجهاد الملحي أدى الى تقليل بسيط في الفترة اللازمة للأزهار في النباتات التي لم يضف اليها البكتيريا، بينما اظهرت النباتات التي اضيف اليها البكتيريا ازهار مبكر بنسبة 19% على تركيز 6 ds/m والذي ترافق مع اعلى تكوين للعقد (5)، ووزن القرون 38.7 غم، وعدد البذور 27.8، وعدد القرون 11.66، والوزن غير الجاف للبذور 11.06 غم والوزن الجاف 1.85 غم. محتوى البوتاسيوم والكالسيوم ازداد بنسبة 5% في النباتات المضاف اليها البكتيريا مقارنة مع النباتات الاخرى.

العديد من الدراسات السابقة أظهرت أن الملوحة تؤثر بشكل سلبي على نشاط بكتيريا التربة والضغط الاسموزي بالإضافة الى التأثير الملحي السمي، ولكن بكتيريا *B. megaterium*، تستطيع الصمود في التربة وفي البيئات والظروف القاسية. الدراسة اظهرت ان ملوحة التربة يمكن تخفيفها باستخدام مثل هذا النوع من البكتيريا مع النباتات المزروعة، حيث تناقصت ملوحة التربة المستخدمة في الاوعية بنسبة 10% مقارنة مع التربة التي زرع فيها النباتات اللتي لم يضف اليها بكتيريا *B. megaterium*.