An-Najah National University

Faculty of Graduate Studies

Effects of Salinity, Nutrients, Heavy Metals and Organic Matters on Growth, Yield and Uptake of Pea in Piped Hydroponics

By

Mohammad Ass'ad Saeed AL Jada

Supervisor

Prof. Dr. Marwan M. Haddad

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This Thesis was defended successfully on 17/12/2014 and approved by:

Defense Committee Members		**Signature**
– Prof. Dr. Marwan Haddad	(Supervisor)	…………………
– Dr. Yamen Hamdan	(External Examiner)	…………………
– Dr. Munqez Shtaya	(Internal Examiner)	…………………

Dedication

- *My parents: Thank you for your unconditional support with my studies. I'm honored to have you as my parents. Thank you for giving me a chance to prove and improve myself through all my walks of life. Please do not ever change. I love you.*
- *My family: Thank you for believing in me; for allowing me to further my studies. Please do not ever doubt my dedication and love for you.*
- *My brothers: Hoping that with this research I have proven to you that there is no mountain higher as long as God is on our side, hoping that you will walk again and be able to fulfill your dreams.*

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I thank God for the completion of this work

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My heartfelt thanks to my mother dear, that supported me by prayer and supplication to God

And my gratitude to my wife and my children, for their patience and encouragement to me…

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For all.…

Thank you

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الإقرار

أنا الموقع أدناه، مقدم الرسالة التي تحمل عنوان:

Effects of Salinity, Nutrients, Heavy Metals and Organic Matters on Growth, Yield and Uptake of Pea in Piped Hydroponics

أقر بأن ما اشتملت عليه هذه الرسالة إنما هي نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وإنّ هذه الرسالة ككل، أو أي جزء منه الميقدم منقبللني لأية درجة أو لقب علمي أو بحثي لدى أية مؤسسة تعليمية أو 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 : محمد اسعد سعيد الجدع : اسم الطالب

Signature: : التوقيع

Date: ١٧/١٢/٢٠١٤ : التاريخ

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List of Acronyms

Cm	Centimeter
Cm^3	Cubic Centimeter
DM	Dry Matter
EC	Electrical Conductivity
F	FAO estimate
FAO	Food Agriculture Organization of The United Nation
FAOSTAT	FAO Statistical Databases
FC	Calculated data
ICARDA	ICARDA International Center for Agricultural Research in the Dry Areas.
IM	FAO data based on imputation methodology
MS	Millisiemens
OD	Official data
OP	Osmotic Pressure
PCBS	Palestinian Central Bureau of Statistics
PHS	Piped Hydroponic System
PWA	Palestinian Water Authority
TDS	Total Dissolved Salts
WUE	Water Use Efficiency

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Abstract

Population growth in Palestine and consequent increased water consumption lead to erosion of arable land and reduction in fresh water suitable for agriculture, so hydroponics may be the most appropriate alternative in these circumstances. The main objective of this research is to study the effect of three salinity levels(750, 1500 and 3750 ppm NaCl) , two levels of micro and macronutrients(Cooper, 1/4 Cooper solution) and of heavy metals(3.26 , 3.2 , and 2 ppm Zn, Cu and Fe, respectively) on growth, yield, and uptake of pea plants grown in piped hydroponic. Six inches plastic (PVC) pipe have been used in closed hydroponics, that contain sites growth, injection tubes, sprayers, drainage tube, as well as 120 liter drums and pumps (1/2 Horse Power). The experiment was divided to six lines that depended on composition of nutrient solutions as mentioned above, each line included five pipes, each pipe contains a four seedlings, and all the pipes in various lines have been raised on a wooden stand about one meter. Then seeds are planted in organic soil for approximately 15 days, placed in a pot or a bin and installed by substrates and transferred to the pipelines of growth chambers that received tap water for one week and replaced with nutrient solutions that are previously prepared and pumps run three times for entirety 1.5 to 2 hours a day.

Experience has shown survival percentage of six lines: 100%, 95%, 90%, 80%, 50% and 70%, respectively. The plants separated and divided into pods, leaves, stems and roots, then physical and chemical measurements conducted on them. It has been observed that the different salt proportion and nutrients and heavy metals affect significantly the quantities of some nutritional elements, and a negative effect on morphological characteristics of plants at high salinity of nutrient solution, that's where the plants under 3750 ppm did not produce pods. The best growth and yield and weight plants were in the Line 1, where fresh weight of pods, leaves, stems and roots were measured (6.53, 1.81, 1.58, 1.60 g), respectively . The least growth, yield and biomass plants were in the Line 5. Fresh biomass weight of pods, leaves, stems and roots (0.00, 0.23, 0.21 and 0.15g/plant), respectively. Stems and roots of plants that grew in Line 6, they had length 20.21, 21.07 cm that more than control . the performance of the plants have dropped under nutrient solution which has deficiency and decreased relative water content with increasing salinity (Ec) between 79.10% and 86.00%, where the relative water content relied directly on the salinity of the solutions, with the exception of the Line 6 was less than expected. Increasing the concentration of sodium chloride in the nutrient solutions that led generally to increase the concentration of sodium and chloride ions in plant parts, and particularly to increase chloride concentration in the roots(largest value 5.16% in Line 5) and sodium in the leaves and stems (largest values 4.90% and 6.11% in Line 5). Concentrations of nitrate and potassium in plants has decreased due to the impact and interact with chloride and sodium ions ,respectively.

Calcium percentage found in Line 2 is greater than Line 1, but in roots decreased (3.76% , 2.63% respectively), in roots of Line 6 more than Line3 (1.74% , 1.57% respectively), the greatest phosphate percentage in whole plants of Line 1 (0.64%). In general, high salinity led to decrease the elements in plant parts, but some elements increased in plant parts such as phosphorus in the roots, and other elements has increased in the leaves or stems, such as magnesium and calcium and phosphate in the pods peas, but nitrate was noted a slight increase in leaves of plants at 1500 ppm NaCl (Line 4) became (0.71%). The largest weight copper and zinc were found at the root of Line 6 (36.05 and 211.58 mg/kg dry plant, respectively). The effect of nutrients on plant peas have been positive, but increased nutrient value that needs the plant does not lead to growth, yield and production more than usual and decreased with increasing salinity, However there are complex interactions between the ions within the plants. The recommendations to the Palestinian community, it is desirable to use PHS because it does not need a large space and fertilizers as well as use water has electrical conductivity about 4 ms/cm, in addition it economically feasible, and recommendations fot researchers; study the effect of salinity on pea plants in hydroponics at different levels of salinity between the extent (1500 - 3750) ppm NaCl, in order to determine the maximum tolerable in peas without affecting the growth and performance of the plant and study the effect of a few types (pairs) of nutrients within different levels of salinity, due to the existence of relationships and complex interactions occur between the ions in nutrient solutions and within the plant tissue.

Chapter one
Introduction

Introduction

1.1. Research background

Pisum sativum, the common pea plant is an important legume grown as a garden or field crop throughout the temperate regions of the world; it is also grown as a cool season crop or hill country crop in the tropics. It ranks third in production among the grain legumes after soybean and beans, Pea is valued primarily for the nutritional quality of its seeds – pea protein is low in sulfur-containing amino acids, cysteine and methionine, but rich in lysine and other essential amino acids (Christou, 1994**)**.

World agriculture is facing a lot of challenges like producing 70% more food for an additional 2.3 billion people by 2050 while at the same time fighting with poverty and hunger, consuming scarce natural resources more efficiently and adapting to climate change (FAO, 2009) . However, the productivity of crops is not increasing in parallel with the food demand. The lower productivity in most of the cases is attributed to various abiotic stresses. Curtailing crop losses due to various environmental stressors is a major area of concern to cope with the increasing food requirements (Shanker and Venkateswarlu, 2011).

The major abiotic stresses like drought, high salinity, cold, and heat negatively influence the survival, biomass production and yield of staple food crops up to 70% (Ahmad et al, 2012); thus, threaten food security in all parts of the world.

Salinity is one of the most brutal environmental factors limiting the productivity of crop plants because most of the crop plants are sensitive to salinity caused by high concentrations of salts in the soil. A considerable amount of land in the world is affected by salinity which is increasing day by day. More than 45 million hectares of irrigated land which account to 20% of total land have been damaged by salt worldwide and 1.5 M ha are taken out of production each year due to high salinity levels in the soil (Pitman and Lauchli, 2002 ; Munns and Tester, 2008).

In most of the cases, the negative effects of salinity have been attributed to increase in Na^+ and Cl^- ions in different plants hence these ions produce the critical conditions for plant survival by intercepting different plant mechanisms. Although both Na^+ and Cl^- are the major ions which produce many physiological disorders in plants, Cl^- is the most dangerous (Tavakkoli et al, 2010). Salinity at higher levels causes both hyperionic and hyperosmotic stress and can lead to plant demise. The outcome of these effects may cause membrane damage, nutrient imbalance, altered levels of growth regulators, enzymatic inhibition and metabolic dysfunction, including photosynthesis which ultimately leads to plant death (Mahajan and Tuteja, 2005; Hasanuzzaman et al, 2012).

Palestinian population continues to increase; this requires more water consumption, and lead to a steady decline in the potable water, However, Israeli control over water sources, leading to a decrease in the quality and quantity of water used for agriculture.

Water quality is classified according to the total dissolved salts to several classes **Table (1)**.

Table (1) Classification of water quality based on salt concentration:

Water designation	(TDS) (ppm)	EC(ds/m)
Fresh water	<500	<0.6
Slightly brackish	500 – 1000	0.6 – 1.5
Brackish	1000 – 2000	1.5 – 3.0
Moderately saline	2000 – 5000	3.0 – 8.0
Saline	5000 – 10000	8.0 – 15.0
Highly saline	10000 – 35000	15.0 – 45.0

Source: Pitman and Laüchli, 2002 **ds/m: decisiemens per meter**

ppm: parts per million

In general the response of various plants for different salinity levels vary from plant to another, but most of them involved in the low rate of growth, the number of leaves, fresh, dry weight of plants, productivity and plant height, that due to expended high energy for additional osmoregulation and ions uptake (Nawaz et al, 2010) .

Study of abiotic stress is vital, and salt stress requires a modified environment where pea plants grown, and the best way to study the effect of salinity on pea plants were selected piped hydroponics, where it flows nutrient solution through the pipes and goes back to the reservoirs and pumps push solutions to the plants rotary and continuously, through hydroponics, it is possible to control the conditions of the environment that embraces pea plants to live. Where are controlled concentrations of sodium chloride salt and nutrients that are added to the nutrient solution, and control the environmental conditions of pea plants where different levels of salinity and nutrients, where translate these differences on the characteristics of plants such as height, number of leaves, number of pods and root length in addition to the biomass of leaves, stems , roots and pods, not only that, but can identify the impact of salinity and nutrient concentration of elements in different parts of the pea plants .The importance of this study for Palestine, it may be exploited less land area and water quality, such as the utilization of saline water wells, and consumption of less quantity of fertilizers, control the conditions of the growth of plants to get more production of fruits and biomass and even outside of the planting season.

1.2. Objectives:

The main aim of this research to identify the impact of increased salinity, nutrients and heavy metals on pea plants in piped hydroponics, and that by achieving the following objectives:

- Comparison between the attributes of pea plants under different concentrations of salinity and nutrients in terms of the number of pods, leaves and the length of stems and roots.
- Comparison between biomass weight of pea plants under different concentrations of salinity and nutrients.
- Recognize the effects of salinity and concentrations of nutrients in pea plants.
- Describe the impact ions of copper and zinc and iron on the natural properties of the pea plants and concentrations of different elements.

Chapter Two
Literature review

Literature review

2.1. General overview on Pea:

Peas(*Pisum sativum*) from the field crops of the family leguminous (Lazaro, 2006), which is characterized by the high proportion of protein and carbohydrates in seeds (Choudhury, 2007), is also characterized by its ability to fix nitrogen in atmosphere by bacteria root nodules of the genus (Rhizobium) (Rowland et al, 1994), which leads to raise the fertility of the medium cultivated and increase the proportion of nitrogen out. Moreover, dry pea seed is a rich source of protein (19–27%), and is relatively free of anti-nutritional substances (Petterson and Mackintosh, 1994).

The pea plants are grown for use fresh (green pods) or dry seeds, as food for humans and sometimes as animal food.

Pea is one of the most studied plants from genetics point of view and a source of immense variation (Marx, 1977; Choudhury, 2007). The wild pea's flowers have five sepals, five petals (two fused keel petals, two wing petals and a standard petal), ten another (nine fused into a filament tube and one partially free) and a single central carpel (Yaxley, 2001; Tucker, 1989; Ferrandiz et al., 1999). Further, pea is a self-pollinated, annual herb, with weak stem, alternate leaves, leaflets ovate or elliptic and terminal branched tendrils (Duke, 1981; Ghafoor, 2005).

2.2. Planting Date :

Pea crop is one of the winter crops that fit with moderate cold weather, and grow from October to mid-November (Tar'an, 2005), and the temperature range suitable for growth (between 10-23°C), with an optimum daily temperature of 17°C, a minimum of 10°C and a maximum of 23°C, where they can get a bumper crop and high quality, the normal growing period is 65 to 100 days for fresh pea, with an additional 20 days for dry peas, even though the growing period is extended under cool conditions. Under irrigation, pea yields 2 to 3 ton/ha shelled fresh pea (70% to 80% moisture), 0.6 and 0.8 ton/ha dry pea (12% moisture) (Tzitzikas, 2005).

The major component of pea seed is a starch, which accounts for up to 50% of the seed dry matter (DM) (Borowska et al. 1996; Wang et al. 1998). Protein and total dietary fiber account for about 24% and 20% DM, respectively, whereas lipids are present in lower amounts (2.5% DM) (Black et al. 1998). However high variation in starch and protein contents were observed frequently, whereas the variations in the other components are usually lower (Borowska et al, 1996).

2.3. Abiotic stresses:

Abiotic stresses remain the greatest constraint to crop production worldwide. It has been projected that more than 50% of yield reduction is the direct result of abiotic stresses (Rodriguez et al, 2005; Acquaah, 2007. The major abiotic stresses like drought, high salinity, cold, and heat negatively influence the survival, biomass production and yield of staple food crops up to 70% (Mantri et al, 2012; Ahmad et al, 2012); hence, threaten the food security worldwide.

2.4. Salinity definition:

The term salinity refers to the amount of dissolved salts that are present in water. Sodium and chloride are the predominant ions in seawater, and the concentrations of magnesium, calcium, and sulfate ions are also substantial. Naturally occurring waters vary in salinity from the almost pure water, devoid of salts, in snowmelt to the saturated solutions in salt lakes.

The quantity and kind of salts present in the groundwater is probably the most important single parameter for evaluating the suitability of water for irrigation. Salinity of irrigation water is usually determined by measuring its electrical conductivity and is the most important parameter in determining the suitability of water for irrigation. The electrical conductivity is expressed as mmho/cm or decisiemens per meter (dS/m). Salinity is expressed also into (TDS) which is the concentration of soluble salts in the water sample in mg/l (FAO, 1985).

There are many studies and researches on the effect of salinity on cultivated plants hydraulically, as different plants vary in their response to salinity.

The effect of salinity on plant reality is very complicated, depending on the type of plant and the duration of exposure to the salinity and type of nutrients (elements and ions) and the stage of growth(Gunes et al, 2000).

The influence of the complex environmental stress resulting from salinity doesn't affect the property osmotic plant only, but it includes toxic effects and unrest in nutrients within the plants. Also disturbing the absorption of ions by the plant and making the proportion of the nutritional elements unstable (Yorgancilar and Gül Yeğin, 2012; Munsuz et al, 2001).

The plants grown in cultural solution aren't absorbing the ions as per their present proportions in the solution; some ions are absorbed more than the others. These ions selection depends on the plant species (Black, C. A. 1970).

The accumulation of toxic ions take a long time, and the effects may be the emergence of a slower pace. Damage grade depends on the time of exposure to toxic substances, and the concentration of toxic ions, the sensitivity of the plant, and finally in the Evapotranspiration from plant(Yurtseven, 2004).

Crop performance may be adversely affected by salinity-induced nutritional disorders. These disorders may result from the effect of salinity on nutrient availability, competitive uptake, transport or partitioning within the plant. For example, salinity reduces phosphate uptake and accumulation in crops grown in soils primarily by reducing phosphate availability but in solution cultures ion imbalances may primarily result from competitive interactions (Grattan and Grieve, 1999).

2.5. Electrical conductivity of nutrient solution:

The total ionic concentration of a nutrient solution determines the growth, development and production of plants (Steiner, 1961). The total amount of ions of dissolved salts in the nutrient solution exerts a force called osmotic pressure (OP), which is a colligative property of the nutrient solutions and it clearly depends on the amount of dissolved solutes (Landowne, 2006). Also, the terms solute potential or osmotic potential are widely used in nutrient solution, which represent the effect of dissolved solutes on water potential; solutes reduce the free energy of water by diluting the water (Taiz and Zeiger, 1998). Thus, the terms osmotic pressure and osmotic potential can be used interchangeably, still important considering the units that are used, commonly atm, bar and MPa (Sandoval et al, 2007). An indirect way to estimate the osmotic pressure of the nutrient solution is the electrical conductivity (EC), an index of salt concentration that defines the total amount of salts in a solution. Hence, EC of the nutrient solution is a good indicator of the amount of available ions to the plants in the root zone (Nemali and van Iersel, 2004). Estimation of the osmotic pressure of a nutrient solution from EC can be done by using the following empirical relations (Sandoval et al, 2007):

OP (atm) = 0.36 X EC (in dS m^{-1} at 25 ^{o}C)

OP (bar) = □ 0.36 X EC (in dS m^{-1} at 25 ^{o}C)

OP (MPa) = OP (bars) X 0.1

The ions associated with EC are Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, H^{+}, NO_3^{-}, SO_4^{2}, Cl^{-}, HCO_3^{-}, OH^{-} (United States Department of Agriculture [USDA], 2001). The supply of micronutrients, namely Fe, Cu, Zn, Mn, B, Mo, and Ni, are very small in ratio to the others elements (macronutrients), so it has no significant effect on EC (Sonneveld and Voogt, 2009). The ideal EC is specific for each crop and depends on environmental conditions (Sonneveld and Voogt, 2009); however, the EC values for hydroponic systems range from 1.5 to 2.5 ds m^{-1} or 4 dS m^{-1}(Ayers and Westcot, 1994). Higher EC hinders nutrient uptake by increasing osmotic pressure, whereas lower EC may severely affect plant health and yield (Samarakoon et al, 2006). The decrease in water uptake is strongly and linearly correlated to EC.

2.6. Effect of excess salinity on water regime:

The main cause of reducing plant growth in the presence of salt can be impairment of water regime. Increasing the salt concentration in the nutrient solution that increases the osmotic pressure of the nutrient solution and plants cannot uptake the water as easily as in the case of relatively non saline solution. Therefore, as the concentration of salt i.e. solution EC increases, water becomes less accessible to plants, even if water is available(AL-Jobori and AL-Hadithy, 2014); (Ayers & Westcot, 1994).

Osmotic pressure depends on the number of particles contained in the solution and the temperature, physiological stress symptoms appear it due to lack of water flowing to the plants. In saline solutions, despite the fact that water can exist physically, it becomes inaccessible to plants and the phenomenon is known as physiological drought (Ayers and Westcott, 1994).

The first effects of solution salinity, especially when the plants classified as sensitive and moderate sensitive, can be attributed to the increase of osmotic value of the nutrient solution (Munns and Termaat, 1986). With the increasing salinity of nutrient solution, uptake of water through the root system becomes more difficult which leads to decreased evapotranspiration and yield. There are several reasons why evapotranspiration decreases with increase in the salinity of nutrient solution. Due to decreased accessibility of water to the root system, root growth is reduced which leads to a reduction in the total absorption area for water uptake. At the same time, total leaf area e.g. transpiration surface is reduced. As one of the mechanisms by which plants protect their cells from harmful effect of high concentration of salts is dilution, then increasing of water retention in the tissues of the plant further reduces transpiration. These factors reduce the efficiency of water usage and ultimately result in reduction of vegetable growth and yield.

The period of growth and vegetation is shortened, water regime of plants is disrupted and the uptake and distribution of essential elements in both semi-controlled and field conditions is altered (Maksimović et al, 2008, Maksimović et al, 2010). At very low water potential, the uptake of water and maintenance of turgor pressure in the tissues becomes very difficult. Water potential of leaves of plants well provided with water ranges from -0.2 to about -0.6 MPa, but the leaves of plants in arid regions can have significantly lower values, from -0.2 to 5 MPa even in extreme conditions (Taiz and Zeiger, 2006). Since the uptake of water is spontaneous process, the water potential of root cells must be more negative than potential of nutrient solution. If, due to increased salt concentration, the difference between water potential of nutrient solution and of root cells differs very slightly, plants may adapt osmotically by accumulation of so-called compatible osmolites in their cells. In that way, water potential of plant cells is kept more negative in relation to the nutrient solution(water) potential, thus permitting continuous uptake of water (Guerrier, 2006; Ghoulam et al, 2002).

Increasing the salinity of a medium in which is the root leads to a reduction in the osmotic potential of leaves (Sohan et al, 1999, Romero-Aranda et al, 2001). Reduced osmotic potential of leaves is reflected in many processes in plants. Several authors have reported that water and osmotic potential of plants become more negative with increase in nutrient solution salinity, while turgor pressure concomitantly increases (Meloni et al, 2001, Romero- Aranda et al, 2001). Ashraf, (2001) found that leaf water potential and evapotranspiration significantly decreased with increasing salt concentration in six species of the genus *Brassica*. At 200 mM NaCl *B. campestris* and *B. carinata* held a significantly higher water potential of leaves than other species in their experiment and therefore can be considered more tolerant to stress caused by salts. According to (Sohan et al, 1999), the decrease in water potential can be explained by: 1) The influence of high concentrations of salts due to which plants accumulate more NaCl in the leaves than usual, and 2) By the reduced flow of water from root to aboveground organs due to the reduction of water conductivity, causing water stress in the tissues of leaves. After (Katerji et al 1997), a decrease in RWC indicates loss of turgor which occurs due to disturbances in the increase in the area of individual leaves, in other words in leaf expansion. The connection between the impact of salt on gas exchange in leaves and growth isn't completely understood. Many experimental results indicate that gas exchange in leaves of plants remains unchanged under the influence of soil water potential, until it reaches a certain threshold value (Ritchie, 1981). Results of (Shalhevet, 1994) suggest that the expansion of leaves is the most affected by osmotic stress and that there was a linear relationship between transpiration and the synthesis of organic matter in different agro ecological conditions. The slope of this function represents the efficiency of water utilization by plants (water use efficiency, WUE). More recently, stomatal traits have been proven to critically affect WUE. In absence of stress, it has been demonstrated that low stomatal density reduces transpiration water fluxes (Zhang et al, 2001) and improves water use efficiency (Masle et al, 2005).

2.7. Nutrient concentration versus crop performance

In the absence of salinity, plant growth in relation to the concentration of an essential nutrient element in the root media is often described by the "generalized dose response curve" (Berry and Wallace, 1981). There is a nutrient-concentration window where plant growth is optimal. Concentrations below this optimal range are considered sub-optimal and growth is reduced. When the concentration or activity of the essential nutrient element exceeds this optimal range, growth may be inhibited due to either toxicity or to a nutrient-induced deficiency. It is important to mention that these dose response curves can apply not only to vegetative and reproductive organs of a particular crop in a quantitative sense but can be modified to include a qualitative aspect as well. For example, excessive NO_3^- accumulation in spinach leaves may not affect yield but may pose a health risk to the consumer. Therefore this window of nutrient adequacy would be narrowed and could be re-labelled "nutrient acceptability". (Marschner, 1995).

The plant may not exhibit the same response function under saline conditions as it does under non saline conditions. In some cases the optimal range may be widened, narrowed, or it may shift in one direction or the other depending upon the plant species or cultivar, the particular nutrient, the salinity level, or environmental conditions (Grattan and Grieve, 1994).

2.8. Salinity versus plant growth

Response of field crops to the presence of increased amounts of salts is primarily stunted growth (Romero-Aranda et al, 2001). The ultimate impact of excess salts is of course very dependent on the other environmental factors such as humidity, temperature, light and air pollution (Shannon et al, 1994). The accumulation of salts in the leaves cause premature aging, reduces the supply of plant parts with nutrients and products of carbon assimilation of the fastest-growing plant parts and thus impair the growth of the entire plant. In more sensitive genotypes salts accumulate more rapidly and because cells aren't able to isolate the salt ions in vacuoles to the same extent as more tolerant genotypes, the leaves of more sensitive genotypes usually die faster (Munns, 2002). Neumann,

(1997) suggests that growth inhibition due to excessive salt concentration in the leaves reduces the volume of new leaf tissue in which excess salts can accumulate and therefore, in combination with the continuous accumulation of salts, it can lead to an increase in salt concentration in the tissue.

It is often difficult to determine the relative influence of osmotic effect and the effect of the toxicity of specific ions on vegetable yield. In any case, yield losses due to osmotic stress can be very significant even before symptoms of toxicity on leaves become noticeable. Under the influence of salt stress growth of many species of vegetables is reduced, such as tomato (Romero-Aranda et al, 2001, Maggio et al, 2004), pepper, celery (De Pascale et al, 2003a,b) and peas (Maksimović et al, 2008, Maksimović et al, 2010).

There are significant differences in salt tolerance between plant species and genotypes and similar goes for the ability to tolerate water deficiency (Munns, 2002; Luković et al, 2009). Salinity causes anatomical changes in leaves of many plant species. For example, the epidermis and mesophyll leaves of beans, cotton and *Attriplex* become thick, length of palisade mesophyll cells and diameter of spongy mesophyll cells increase and thickness of palisade and spongy layers and increasing as well (Longstreth and Nobel, 1979). In some other plant species, there were recorded adverse effects. In spinach leaves the presence of salt reduces the intercellular spaces (Delfine et al, 1998) and stomatal density in tomato (Romero-

Aranda et al, 2001), but it increases stomatal density in pea (Maksimović et al, 2010).

2.9. Salinity versus plants mineral nutrition:

Increased salt concentration in the vicinity of the root system can interfere with mineral nutrition of plants and limit field crop yield due to salinity or osmotic value of the nutrient solution. Salinity affects nutrient availability to plants in many ways. It modifies binding, retention and transformation of nutrients in the solution and affects the uptake and/or absorption of nutrients by the root system due to antagonism of ions and reduced root growth. It disrupts the metabolism of nutrients in the plant, primarily through water stress, thus reducing the efficiency of utilization of nutrients. In the presence of increasing concentrations of salts some species-specific symptoms may be present, such as necrosis and burns of leaf edges because of the accumulation of Na^+ and Cl^- ions (Wahome, 2001). The high concentration of ions can disrupt the structure and function of cell membranes. Mineral nutrition of plants depends on the activity of membrane transporters which participate in the transfer of ions from the nutrient solution into the plant and regulate their distribution within and between cells (Marschner, 1995; Epstein and Bloom, 2005). Changes in membranes may finally lead to disturbances in chemical composition of cells and can therefore be displayed as symptoms of deficiency of some essential elements, similarly as it happens in the absence of salts (Grattan and Grieve, 1999). High concentrations of NaCl act antagonistically to the uptake of the other nutrients, such as K^+, Ca^{2+}, N, P (Cramer et al, 1991, Grattan and Grieve, 1999). Increased concentrations of NaCl increase concentrations of Na^+ and Cl^- and reduce concentrations of Ca^{2+}, K^+ and Mg^{2+} in many plant species (Bayuelo-Jimenez et al, 2003). In the presence of NaCl, the concentration of K^+, Ca^{2+} and P in vegetative parts decreased and in pods and grains increased. The deleterious effects of salinity on tomato biomass production can be ameliorated by an enhanced supply of calcium. Similarly to the effect on the uptake of macroelements, salt stress can exert stimulatory and inhibitory influence on the uptake of some trace elements (Grattan and Grieve, 1999).

Under the conditions of salt stress, the uptake of nitrogen is often disrupted and numerous studies have shown that excess salts can reduce the accumulation of nitrogen in plants (Pardossi et al, 1999, Silveira et al, 2001, Wahid et al, 2004). Increase in uptake and accumulation of Cl^- is accompanied by a reduction in the concentration of NO_3^- in eggplant (Savvas and Lenz, 2000) and NO_3^- reduction in pea plants (Shahid et al, 2012). There are authors who have attributed this reduction to the antagonism between Cl^- and NO_3^- (Bar et al, 1997) and those who explain it by reduced water uptake (Lea-Cox & Syvertsen, 1993). The rate of nitrate uptake or interactions between NO_3^- and Cl^- is associated with tolerance of examined plant species to salts; In addition, rate of nitrification of ammonia is often significantly reduced due to the large direct toxic effects of Cl^- and the total amount of salt on the activity of nitrifying bacteria (Stark and Firestone, 1995). Level of salinity doesn't affect necessarily the overall uptake of nitrogen by plants which may continue to accumulate nitrogen in the presence of excess salts despite a reduction in yield of dry matter. With the increase in nutrient solution salinity, total removal of nitrogen through the yield often decreases. Reduction in nitrogen fertilizer use efficiency is primarily a result of reduction of plant growth rate rather than the reduction of nitrogen uptake rate. Excess water and poor aeration that lead to anaerobic conditions can reduce the accessibility and absorption of nitrogen through the root system. In anaerobic conditions, the intensity of reduction of NO_3^- to NO_2^- is higher. Graham and Parker (1964) found that the highest EC that can tolerate Rhizobium strain compatible with pea is of 4.5 dS m^{-1}. On the basis of tolerance to salt concentration, (Elsiddig and Elsheikh, 1998) proposed the division of strains of bacteria from the genera Rhizobium and Bradyrhizobium in four groups: sensitive strains, 0-200 mM; moderately sensitive, 200-500 mM; tolerant, 500-800 mM; and highly tolerant, more than 800 mM. The classification should be considered with precaution, as a great influence on the overall tolerance to salinity has pH value of the nutrient solution, temperature and carbon source that bacteria use. Water stress, that is the result of high osmotic pressure of the nutrient solution, leads to the disturbance of nitrogen metabolism in plant tissues. In the presence of excess salts the synthesis of proteins is disturbed as well. (Nightingale and Farnham, 1936) found that with increase in osmotic pressure the amount of soluble organic nitrogen and proteins in sweet peas decreased, while the nitrate form of nitrogen accumulated. Naeem (2008) found that Nodulation was completely inhibited at Hoagland's nutrient concentration of half and one fourth strength whereas better nodulation was observed at one sixth and one-eighth nutrient concentrations after 14 days of inoculation. Frechilla et al (2001) found salinity affects the uptake of several nutrients in different ways, depending on the nitrogen source. Thus, chloride accumulated mainly in nitrate- fed plants, displacing nitrate, whereas sodium accumulated mainly in ammonium-fed plants, especially in roots, displacing other cations suck as ammonium and potassium. It is concluded that the nitrogen source (ammonium or nitrate) is a major factor affecting pea responses to saline stress, plants being more sensitive when ammonium is the source used. The different sensitivity is discussed in term of a competition for energy between nitrogen assimilation and sodium exclusion processes, (Yorgancilar and Gül Yeğin, 2012) found that the effects of different salt proportions in the nutrient solution (0, 25, 50, 100 mM NaCl) on pea plant (Pisum sativum L. cv. Jofs) macro and micro elements involved in its growth. Statistically the different salt proportion affects significantly, the quantities of some nutritional elements. The essential elements proportions in roots (P, Mg, S, B, Cu, Mn and Zn) and in stem (K, Ca, Mg, Na, B, Fe, Mn, and Zn) are different. Common essential elements in roots and stem are Mg, B, Mn and Zn.

The response of nine pea (*Pisum sativum*) genotypes, under salt stress, root/shoot sodium (Na^+) was increased with increasing salinity levels, which enhanced the Na^+: K^+ ratio and seemed to affect the bioenergetics processes of photosynthesis. Whereas, root and shoot of tested genotypes exhibited a considerable reduction in phosphorus (P) and potassium (K) contents, the tested genotypes were categorized into salt tolerant and salt sensitive categories. Tolerant genotypes were successful in maintaining the maximum dry matter, low Na^{+}, while high P and K^{+} under saline conditions(Shahid et al, 2012).

Nenova (2008) found both nutrient supply and nutrient balance are important factors for plant growth and development. Nutrient interactions consisting of mutual influence on absorption, distribution and functioning exist and proven by numerous data in literature, most interactions are complex i.e. a nutrient interacts simultaneously with more than one nutrient.

Besides the drop of Fe concentration in shoots and roots, Fe deficiency caused a decrease in shoot N, an increase in Mn, Cu, Zn, P and Na in shoots and roots; and an increase only in shoot K and Mg. Excess Fe decreased the shoot concentration of Mn, Zn and Na, and the root concentration of Mn, Cu and Mg. Besides the great increase in Na, salinity was associated with an increase in root P, Cu and Zn, with a decrease in K, Ca, Mg, Fe, Mn in both parts, and a decrease in shoot Cu and P. The interaction between nutrients can occur at the root surface or within the plant and might be due to: i) formation of precipitates and complexes between ions with different chemical properties, and ii) competition between ions with similar properties (Robson and Pitman, 1983; Fageria, 2001). Interactions between Fe and P fall in the first category, whereas interactions between (Fe and Zn, Mn and Cu) and between (Na and K, Ca and Mg) fall in the second category. More detailed information about the mechanisms of nutrient interactions might be found in (Foy et al, 1978; Grattan and Grieve, 1999; Fageria, 2001; Rabhi et al، 2007).

(Abdul Jabbar and Saud, 2012) found the rhizobia inoculation with phosphorus application for soybean crops caused increasing in both yield and its components (increasing nitrogen fixation).

2.10. Heavy metals uptake and impact:

Some of heavy metals (Fe, Cu and Zn) are essential for plants, plants need of these metals (140, 4.15, (8-100) mg/kg dry wt. respectively) (Nagajyoti P. et.al, 2010), the essential heavy metals (Cu, Zn, Fe, Mn and Mo) play biochemical and physiological functions in plants, two major functions of essential heavy metals are participation in redox reaction, and direct participation, being an integral part of several enzymes.

Plants are often sensitive both to the deficiency and to the excess availability of some heavy metal ions as essential micronutrients, at higher concentrations, the plants are exposed to poisoning. Researches have been conducted throughout the world to determine the effects of toxic heavy metals on plants (Fernandes and Henriques, 1991; Reeves and Baker, 2000).

Zinc (Zn) is an essential micronutrient that affects several metabolic processes of plants (Cakmak and Marshner, 1993). The phytotoxicity of Zn and Cd is indicated by decrease in growth and development, metabolism and an induction of oxidative damage in various plant species such as

Phaseolus vulgaris (Cakmak and Marshner, 1993) and *Brassica juncea* (Prasad et al, 1999). Cd and Zn have reported to cause alternation in catalytic efficiency of enzymes in *Phaseolus vulgaris* (Van Assche et al, 1988; Somasekharaiah et al, 1992) and pea plants (Romero-Puertas et al, 2004). Zinc toxicity in plants limited the growth of both root and shoot (Choi et al, 1996; Ebbs and Kochian, 1997, Fontes and Cox, 1998). Zinc toxicity also causes chlorosis in the younger leaves, which can extend to older leaves after prolonged exposure to high nutrient medium Zn levels (Ebbs and Kochian, 1997). The chlorosis may arise partly from an induced iron (Fe) deficiency as hydrated Zn^{+2} and Fe^{+2} ions have similar radii (Marschner, 1986). Excess Zn can also give rise to manganese (Mn) and copper (Cu) deficiencies in plant shoots. Such deficiencies have been ascribed to a hindered transfer of these micronutrients from root to shoot. This hindrance is based on the fact that the Fe and Mn concentrations in plants grown in Zn-rich media are greater in the root than in the shoot (Ebbs and Kochian, 1997). Another typical effect of Zn toxicity is the appearance of a purplish-red color in leaves, which is ascribed to phosphorus (P) deficiency (Lee et al, 1996), transport chain (Demirevska-kepova et al. 2004). Excess of Cu in nutrient medium plays a cytotoxic role, induces stress and causes injury to plants. This leads to plant growth retardation and leaf chlorosis (Lewis et al, 2001). Exposure of pea plants to excess Cu generates oxidative stress and ROS (Malecka, 2014; Stadtman and Oliver, 1991). Oxidative stress causes disturbance of metabolic pathways and damage to macromolecules (Hegedus et al, 2001).

Copper (Cu) is considered as a micronutrient for plants(Thomas et al. 1998) and plays important role in CO_2 assimilation and ATP synthesis. Cu is also an essential component of various proteins like plastocyanin of photosynthetic system and cytochrome oxidase of respiratory electron Iron (Fe) as an essential element for all plants has many important biological roles in the processes as diverse as photosynthesis(Nenova, 2006), chloroplast development and chlorophyll biosynthesis. Iron is a major constituent of the cell redox systems such as heme proteins including cytochromes, catalase, peroxidase and leghemoglobin and iron sulfur proteins including ferredoxin, acontiase and superoxide disumutase (SOD) (Marschner, 1995). The appearance of iron toxicity in plants is related to high Fe^{+2} uptakes by roots and its transportation to leaves and via transpiration stream. The Fe^{+2} excess causes free radical production that impairs cellular structure irreversibly and damages membranes, DNA and proteins (Arora et al, 2002; de Dorlodot et al, 2005). The presence of three metals iron, zinc and copper, happens interactions among them (Nenova, 2008). (Luo and Rimmer, 1995) found that Cu-Zn interactions in a soil were synergistic compared with an antagonistic effect in solution culture. Iron readily forms insoluble Fe-oxides and Fe-phosphates in solution, with these being unavailable to plants (Halvorsan and Lindsay, 1972; Cline et al, 1982). To keep Fe available and prevent deficiency, Fe is often added to nutrient solutions in chelated form. Many researchers have shown that chelates reduce the plant uptake of metals in nutrient solutions (Bachman and Miller, 1995). However, Cu and Zn uptake at low to medium solution concentrations has been shown to be increased by the presence of EDTA (Checkai et al, 1987). An increase in Zn supply resulted in a decrease in the concentrations of Ca, Mg, P in the roots and an increase of Ca and N levels in the stems and leaves. The amount of Zn in roots, stems and leaves increased with greater Zn rates (Stoyanova and Doncheva, 2002). Although only extremely small amounts of Mo and Cu are required for normal plant growth, reduced supply with Mo and Cu to the growth medium decreased activities of the enzymes (nitrate reductase and glutamine synthetase)(Hristozkova et al, 2006).

2.11. Accumulation of compatible osmolytes and osmotic stress:

One of the ways plants can adapt to conditions of osmotic stress is the accumulation of salt ions, if these salts are isolated in individual cell compartments by which their involvement in metabolism is prevented. The ability to regulate the concentration of salts through compartimentation is an important aspect of tolerance to increased salt concentrations (Romero-Aranda et al, 2001). In the presence of salts plants often accumulate low molecular weight substances which are called compatible osmolites. These substances don't interfere with normal biochemical reactions in cells (Hasegawa et al, 2000, Ashraf and Foolad, 2007). Compatible osmolites are low molecular weight molecules such as proline and glycine betaine (Ghoulam et al, 2002; Ashraf and Foolad, 2007). It is believed that under conditions of stress, proline has a role in osmotic adjustment of cells, enzymes and membrane protection and also as a source of nitrogen for a moment when conditions of stress are over (Ashraf and Foolad, 2007). The role of glycine betaine is also in maintaining pH of the cells, cell detoxification and binding of free radicals. Conditions of salt stress also lead to the accumulation of the other nitrogen compounds such as amino acids, amides, proteins and polyamines, which is often correlated with tolerance to salt (Mansour, 2000). Another group of compatible osmolytes are carbohydrates, both simple sugars (glucose, fructose, sucrose, fruktani), and starch. Their most important roles, beside in osmotic adjustment, is carbon storage and neutralization of free radicals (Parida et al, 2002). A similar role is attributed to the polyols that may accumulate under conditions of salt stress as well (Bohnert et al, 1995). Ionic status of plants is highly correlated with tolerance to salts so that it can serve as a selection criterion in breeding to help create genotypes more tolerant to excess salt (Ashraf and Khanum, 1997).

The beneficial effect of salt acclimation was also evident in the prevention of K^+ leakage and Na^+ accumulation, primary in roots, suggesting that here the physiological processes play the major role. 2.5% (polyethylene glycol) PEG 6000 wasn't as efficient as salt in enhancing salt tolerance and acclimation appears to be more related to ion-specific rather than osmotic component of stress. We also recorded an increase of the xylem K/Na in the salt acclimated plants. Therefore, the present study reveals that short-term exposure of the glycophyte P. sativum species activates a set of physiological adjustments enabling the plants to withstand severe saline conditions, and while acclimation takes place primary in the root tissues, control of xylem ion loading and efficient Na^+ sequestration in mesophyll cells are also important components of this process (Pandolfi et al, 2012).

2.12. Palestinian statistics about peas planting:

Field crops are an important crop in Palestine, which are considered as food for humans and animals, in 2011 were planted about 245,414 acres (PCBS, 2013). Peas were planted in 2007 on an area of approximately 4807 acres (PCBS, 2009), and the production of peas was 2218 tons (PCBS, 2013), the percentage of agricultural and arable land in a steady decline in the period (2000-2011) (FAOSTAT, 2014), **(Table 2)** shows area harvested, yield and production of peas in Palestine in the period (2010-2013).

Table (2) Area harvested, yield and production of peas in Palestine in the period (2010-2013):

Item	Year	Area harvested (Ha)	Yield (Hg/Ha)	Production (Tones)
Peas, dry	2010	31(OD)	27741.94(FC)	86(IM)
	2011	40(F)	26250.00(FC)	105(F)
	2012	45(F)	24444.44(FC)	110(F)
	2013	46(F)	26086.96(FC)	120(F)
Peas, green	2010	305(OD)	74622.95(FC)	2276(IM)
	2011	250(F)	80000.00(FC)	2000(F)
	2012	240(F)	104166.67(FC)	2500(F)
	2013	----	----	----

Source :(FAOSTAT, 2013)

F:	**FAO estimate**	**IM:**	**FAO data based on imputation methodology**
FC:	**Calculated data**	**OD:**	**Official data**

It is noted that yield and production of green and dry peas in Palestine increase with time, and shows the importance of food for people and animals, **(Table 3)** shows the value of fertilizer consumed in Palestine in the period (2004-2008), as it shows an increase in fertilizer use over the years, and the resulting contamination of groundwater.

Table (3) The use of agricultural fertilizers in Palestine in the period (2004-2008):

Years	Value in thousands of US dollars
2004	34,446
2005	35,246
2006	36,595
2007	39,590
2008	47,290

Source: (PCBS, 2014)

Salinity of the water varies according to scattered areas in the Palestinian governorates, which is the least in Qalqilya and Tulkarm, and most in Jericho and the Gaza Strip, and the average salinity in all the provinces about 750 ppm (PWA,2013).

2.13. Summary:

The effect of salinity on plant reality is very complicated, depending on the duration of exposure to the salinity and type of nutrients (elements and ions) and the stage of growth(Gunes et al, 2000). The influence of the complex environmental stress resulting from salinity doesn't affect the property osmotic plant only, but includes toxic effects and unrest in nutrients within the plants (Yorgancilar and Gül Yeğin, 2012); (Munsuz et al, 2001). Also disturbing the absorption of ions by the plant and making the proportion of the nutritional elements unstable. The plants grown in cultural soil aren't absorbing the ions as per their present proportions in the solution; some ions are absorbed more than the others(Black, 1970). The accumulation of toxic ions take a long time, and the effects may be the emergence of a slower pace. Damage grade depends on the time of exposure to toxic substances, and the concentration of toxic ions, the sensitivity of the plant, and finally in the evapotranspiration from plant (Yurtseven, 2004). Crop performance may be adversely affected by salinity induced nutritional disorders. These disorders may result from the effect of salinity on nutrient availability, competitive uptake, transport or partitioning within the plant (Grattan and Grieve, 1999). Higher EC hinders nutrient uptake by increasing osmotic pressure, whereas lower EC may severely affect plant health and yield, Duzdemir et al (2009) stated pea plants is very sensitive to salinity. Since salinity causes high yield losses on pea, and Shahid et al (2012) said that there is variation in the ability of pea genotypes to tolerate various levels of salinity as Climax and Samarina zard, (Shahid et al, 2012) explained pea genotypes acclimated to salinity that is highly associated with concentration of osmolytes and antioxidant enzymes and (Nenova, 2008) stated that the impact of salt stress on the plant peas be greater if combined with the stress of iron deficiency and (Yorgancilar and Gül Yeðin, 2012) stated that the effects of salinity levels in the irrigation water on pea plant’s macro and micro elements involved in its growth. It affects significantly on the quantities of some nutritional elements. The essential elements proportions in roots (P, Mg, S, B, Cu, Mn and Zn) and in stem (K, Ca, Mg, Na, B, Fe, Mn, and Zn) are different. Common essential elements in roots and stem are Mg, B, Mn and Zn. The main cause of reducing plant growth in the presence of salt can be impairment of water regime, the period of growth and vegetation is shortened, water regime of plants is disrupted and the uptake and distribution of essential elements in both semi-controlled and field conditions is altered. The salinity leads to dramatic changes in root anatomy as stated (Kukavica et al, 2013). Plants are often sensitive both to the deficiency and to the excess availability of some heavy metal ions as essential micronutrient.

The demand for plant peas continues to increase in Palestine, despite the decline in the planting peas land, and to increase production; farmers used an increasing amount of fertilizer.

This study is important because studies and researches related to hydroponics in Palestine are still rare, and this study differs from previous studies in many things: First, the concentration of NaCl was between 750 ppm to 3750 ppm, whereas previous studies have relied on different concentrations , secondly, the conditions of the experiment were part of the circumstances, weather factors and natural disparate momentarily terms of temperature, humidity and wind speed, while the previous studies, the conditions and weather factors have been controlled and fixed during the planting season, thirdly, the nutrient solution, which used Cooper solution full concentration in one of the section of the experiment and quarter Cooper solution in another section, while other types of solutions have been used in previous studies such as solution Hoagland and Arnon solution and Steiner solution, and Fourthly, solution of 3.26 ppm zinc and 3.2 ppm Cu and 2 ppm iron have been used in one part of the experiment, the type and concentration of these elements have been used unique compared with other studies.

Chapter three

Materials and Methods

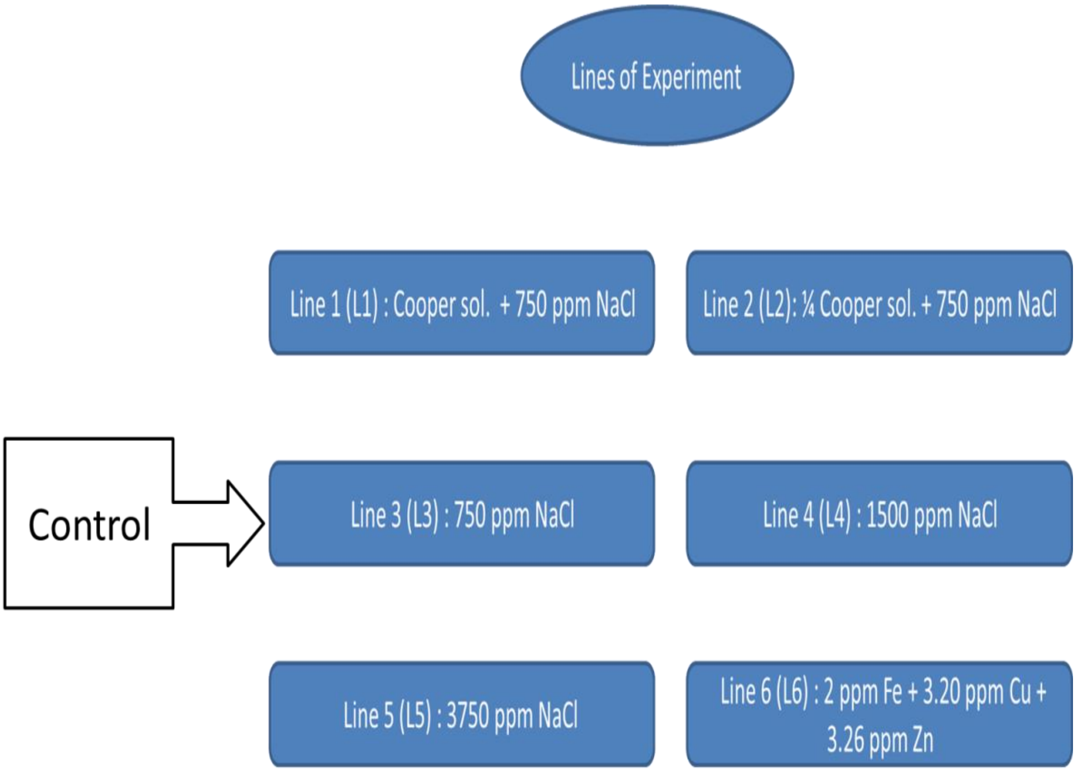
Materials and Methods

3.1. Research plan:

As already mentioned that the aim of the research is to study the effect of salinity on plant peas in hydroponics in terms of the nature of the plant (morphology) and nutrients uptake and concentration of chloride and sodium ions in different plant parts.

Therefore, measurement of biomass of fresh and dry plant, plant height, number of leaves, root length and the yield are the key things in this research as well as analysis of ions and salts in the nutrient solution and the various parts of the plant is also important to recognize the impact of the salinity of the nutrient solution to these ions in the plant.

The experiment was divided to six lines that were depended on composition of nutrient solutions, the schema below describes the different lines in experiment, and they had various salinity and concentration of nutrients and traces heavy metals. The experiment was under normal weather conditions, where the temperature was 13-25 ° C, relative humidity 53-73% and the rate for the number of hours of solar radiation brightness 8-9 hour \ Day (PCBS, 2015)



The third line was considered the control line, which contains a concentration of salinity 750 ppm NaCl, this resembles the salinity rate of the water in the various regions and governorates of the West Bank and Gaza Strip in Palestine (Jebreen, 2014).

Tools and materials required to conduct the experiment are as follows: 15 Plastic tubes 6" length 3 meters , Six pumps (1/2HP) Italy , plastic agro-tube 1", plastic agro-tube 1/2" , 120 sprayers nozzle ,30 plastic drain fittings 1", six plastic Water valves 1" inlet, 1" outlet ,60 plastic tube caps 6" and six tanks (120 Liter), As for the materials described in the section 3.3.2 page 38, and details of materials and procedures are described in below sections.

3.2. Experiment setup:

3.2.1. Introduction:

System which was used in the study, was used closed hydroponic system and constructed by using 6 inches plastic pipes and length 1.5 meters, where pipes was placed on the wooden stand at a height of almost 1 meter, and the system has provided a nutrient by pumps that pumped nutrients solution from drums to growth chambers (pipes), So that, nutrient solutions injected in the form of spray on the roots of seedlings of pea plants for distributing of nutrients to all plants equally.

3.2.2. Growth chambers construction:

During the process of seed germination (see section **3.3.1.**) was built growth chambers, Piped Hydroponics System that will be used for the cultivation of the plant peas can be installed as follows, see (Figure 1 and 2) bellow.

Figure (1) Represent a true picture of one pipe in the system.

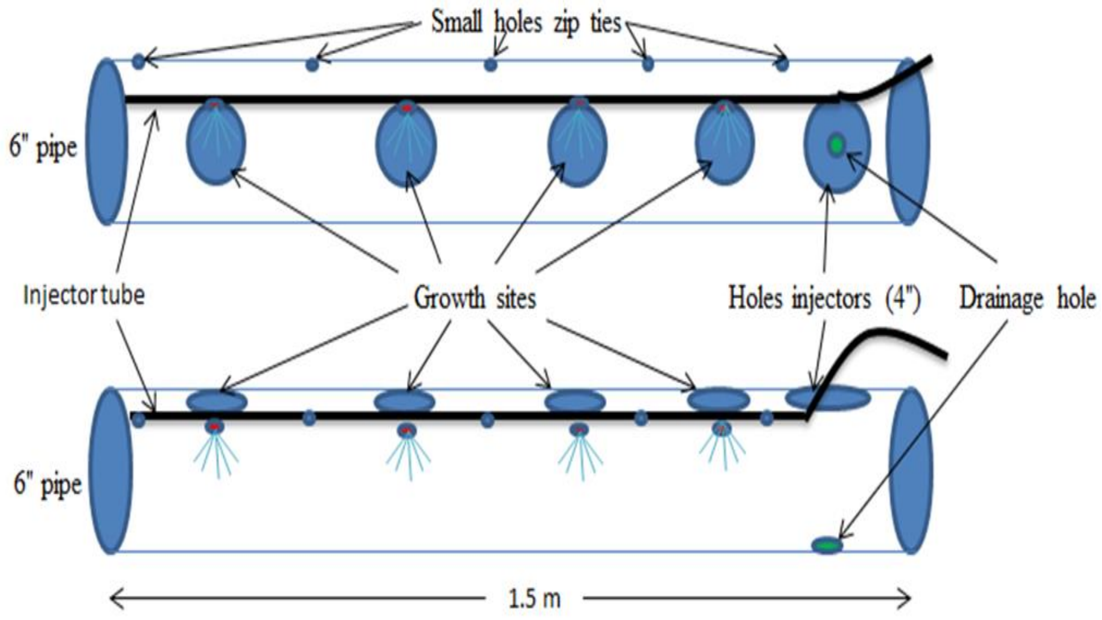


Figure (2) Represent general diagram of one pipe in (PHS).

The pipes had diameter of 6 inches and length 1.5m, then growth sites cut for seedlings (diameter 27/8" inches), drainage holes 1", and holes injectors4". (**Figure 2)** early explains this. Internal spray Lines (injector tubes) were fitted in the growth chambers by using half inch inside diameter flexible polyethylene. The spray Lines were attached inside of the chambers with the plastic zip ties by small holes. Nozzle sprayers were placed near the growth bin (growth site) exact around the roots of pea plants.

Every line of hydroponics consists of five pipes, so that each pipe accommodates four seedlings **(Figure 2)**, and injector tubes were connected with pumps, the pumps were received the nutrient solution from tanks **(Figure 3)**, and the nutrient solution were pumped to sprayers inside the chambers through injector tubes to increase the solubility of gases (particularly oxygen) in the nutrient solution to prevent root rot and distribution of nutrients to the seedlings evenly.

Each pipe was full of nutrients solution, so it was filled with more than half of the tube slightly, Nutrient solutions in excess of this level back to the tanks (reservoirs) through the drainage holes.

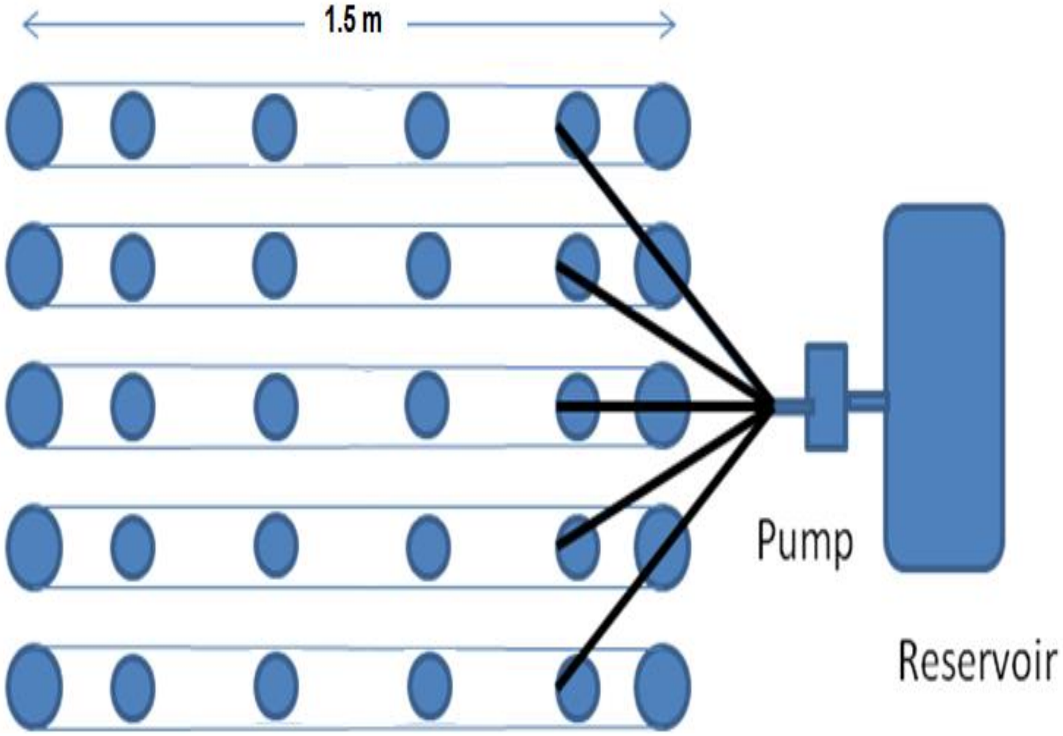


Figure (3) Represent the diagram of one line in Piped Hydroponic system.

3.2.3. Reservoir construction:

Tanks (reservoirs) which were contained nutrients solutions for each Line in the experiment, the size of about 120 liters, and the tanks were received solution returning from the pipe through the drain holes, which is connected to a pump that was moved solutions strongly to the injection pipes and sprinklers in the chamber.

The pump(1/2 HP) is connected to the tank(1 inch inlet) as described in the diagram as above (**Figure 3)** and a discharge from growth chamber(1 inch outlet).

Pipes in the experiment were raised from the ground, about one meter to allow for solutions to return to the tanks, depending on gravity, so the system was needed to support the pipeline, which was built by wood panels as in **(Figure 4)**.

After building the support system, the pipes had been placed on the system, that's where all five pipelines' within the single-Line, and the injection tubes were inserted in the growth chambers, and sprinklers were installed in the pipeline injection versus growth holes that seedlings had been put there.

Figure (4) Represent complete Piped hydroponic system.

3.3. Experiment program:

3.3.1. Introduction:

Experiment starts actually, after the process of planting seeds in organic soil, through that, the nutrient solutions are prepared. When the seedlings become limited length, and then they are transferred to the growth chambers containing tap water, and after a week of planting is replaced tap water with nutrient solutions, and through growth process follow-up seedlings and an interest to making sure the arrival of the nutrient solution to plants.

3.3.2. Seeds germination:

Pea seeds were chosen from agricultural shops in the Palestinian market, farmers use these seeds in agriculture land. These seeds were reserved and sterilized in special containers from exporting company, then seeds were planted in organic potting soil (ECO TERRA) for approximately 15 days (starting from the mid of January until the end of month of the year 2014), and the seedlings at that time became about 5-7 cm, then Seedlings were placed in a pots or a bins, they were installed by small stones(substrates) , they were transferred to the pipelines of growth chambers that contained tap water for a period of one week and so, they were adapted to a new situation, during that period, the pumps were operated to move the water through the pipes that prevented root rot and growth of algae and the roots of plants got oxygen required for normal growth.

3.3.3. Preparation of nutrient solutions:

3.3.3.1. Introduction:

The plants in different lines were put in growth chambers, they are wanted nutrient solutions that are divided into six solutions (S1, S2, S3, S4, S5 and S6), and the solutions have been prepared as **(Table 4)**.

3.3.3.2. Preparation of nutrient solutions for all lines:

Solutions nutrients necessary for plant growth has been prepared based on (**Table 4**)

Table (4) Nutrient solution components of six lines of the experiment:

Solution No.	Composition
Solution1	Cooper solution prepared as (Table 2 and 3) and 115.2g Sodium Chloride dissolved in 153.6 liters
Solution2	1/4 Cooper solution(1/4 amounts of Table 2 and 3) and 115.2g Sodium Chloride dissolved in 153.6 liters
Solution3	115.2 g Sodium Chloride dissolved in 153.6 liters
Solution4	230.4 g Sodium Chloride dissolved in 153.6 liters
Solution5	576 g Sodium Chloride dissolved in 153.6 liters
Solution6	2.2 g Zinc Sulfate, 1.93 g Copper Sulfate, 2.1g Iron-EDTA and 115.2 g Sodium Chloride dissolved in 153.6 liters

Cooper solution was prepared according to the concentrations shown in (**Table 5 and 6)**

Table (5) Concentration of nutrients in Cooper solution:

Nutrients	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B	Mo	S
Concentration (ppm)	200	60	300	170	50	12	2	0.1	0.1	0.3	0.2	69

Source: Trejo-Téllez et al. 2007

Table (6) Weight salts are required for preparing 153.6 liters of Cooper solution:

Salt	Chemical formula	Molecular weight(g/mol)	Required weight(g)
Calcium nitrate	$Ca(NO_3)_2.4H_2O$	236	154.06
Potassium nitrate	KNO_3	101	89.55
Monopotassium phosphate	KH_2PO_4	136	40.40
Magnesium sulphate	$MgSO_4.7H_2O$	246.5	78.80
Iron -EDTA	Fe-EDTA	367	12.13
Manganese sulphate	$MnSO_4.H_2O$	169	0.94
Boric acid	H_3BO_3	62	0.26
Copper sulphate	$CuSO_4.5H_2O$	249.7	0.06
Ammonium molybdate	$(NH_4)_6Mo_7O_{24}.4H_2O$	1236	0.06
Zinc sulphate	$ZnSO_4.7H_2O$	287.6	0.07

Previous salts had been divided into two solutions:

Solution I: calcium nitrate was dissolved well in 10 liters tap water and then salt iron- EDTA added to the calcium nitrate solution which was dissolved also well.

Solution II: Another salt were dissolved one by one in 10 liters tap water, with good stirring until dissolved completely.

After Preparation of the two solutions, they were mixed with tap water until the final solution became a total volume 153.6 liters, two solutions were separated so as not to precipitate salts.

3.4. System Operation:

3.4.1. Introduction:

The pumps are running, which paid the nutrient solutions to the growth chambers, which include plants, and the movement of the nutrient solutions constantly. This is important to prevent root rot, and when stems become long and begins to bend. Stems are connected with Tightropes and install, even stems grow vertically to the top.

3.4.2. Transfer solutions to growth chambers:

After the seedlings were planted in pipes which contained tap water, the pipes have been discharged from the tap water, and prepared nutrient solutions (S1, S2, S3, S4, S5 and S6) see **(Table 4)** were transferred to growth chambers (Line 1, Line 2, Line 3, Line 4, Line 5 and Line 6) respectively, and pumps were run three times for entirety 1.5 to 2 hours a day.

3.4.3. Monitoring and caring of plants

Pea plants have been installed with yarns and ropes, so that seedlings grow in a vertical and observe plants on a daily basis and continuously.

3.5. Experiment management:

3.5.1. Introduction:

To identify the effect of different levels of salinity, nutrients and heavy metals on plants peas through measurements of the physical properties and morphological characteristics and chemical analyzes of nutrients in the nutrient solution and parts of various plants.

3.5.2. Physical measurements of plants:

Length of seedlings were measured centimeter unit once a week, and metal ruler was used in the measurement, and leaves were counted, which were divided into three kinds of: large, middle and small, as well as the pods and flowers of peas were counted once a week, and that work had started from the beginning of February until the end of March of the year 2014.

At the end of the season (end of March), all seedlings were harvested, and they were cut into leaves, stems, pods and roots, where those parts had been dealt with individually, the length of the stems had been measured, and the leaves had been counted which were calculated the total area, the pods were counted, length of roots were measured centimeter unit and metal ruler was used in the measurement.

Fresh stems, fresh leaves, fresh roots and fresh pods were weighed by a sensitive balance, then weighted parts plants were placed in a furnace under 80 ^{o} C for two days in order to dry well.

After plants parts had dried, weighed and the relative water content (RWC) was calculated for the different parts of plants.

RWC = ((fresh weight – dry weight)/fresh weight) X 100

Leaves each plant area was measured by counting squares on graph paper, painted with horizontal and vertical lines, so that the distance between each two adjacent was 0.5 cm, leaves are arranged on graph paper, and then calculate the area per plant which is equal to the length of leaves position multiplied by the width.

3.5.3. Chemical measurement:

Chemical analysis were conducted on nutrient solutions and parts of various plants in the six sections of the experiment.

3.5.3.1. Analysis of plants:

Preparation methods of samples of plants and solutions had been adopted by (ICARDA) called (Dry Ashing), plant samples were Weighed 0.5 – 1.0 g dry matter of plants (pods , leaves , stems or roots) and plant material were put in a 30 – 50 mL porcelain crucibles . porcelain crucibles were placed into a cool muffle furnace, and temperature were increased gradually to 550 °C for 7 hours after attained 550 °C, the muffle furnace were Shut off and opened the door cautiously for rapid cooling, when had cool, took out the porcelain crucibles carefully, cold ash were dissolved in 10 mL portions 2 N HCl and mix with a plastic rod. After 15 – 20 minutes, brought to the volume 250-mL used distilled water, mixed thoroughly, allowed standing for about 30 minutes, and used the supernatant. the aliquots were Analyzed for P by Colorimetry(ascorbic acid, ammonium molybdate, sulfuric acid 5N, potassium antimonyl tartrate) **(Figure 5**) , for Na by Flame Photometry, for Cl by titration with silver nitrate, and for other by ICP-MS, for S by Colorimetry (by Hydrochloric acid and Barium chloride) .

Figure (5) Samples are ready to measure the concentration of phosphate in plant nutrients or solutions:

3.5.3.2. Analysis of nutrient solutions:

Samples from nutrient solutions were taken four times (**Table 7)**, In order to compare nutrient concentrations before and after planting seedlings.

Table (7) The date of obtaining samples of nutrient solutions.

First	Second	Third	Fourth
26/1/2014	16/2/2014	6/3/214	26/3/2014

Nutrient solutions had been mitigated, even devices could be measured within acceptable concentration, and nutrients have been measured in a manner similar to measure nutrients in plants.

3.6. Chemicals and reagents:

Hydrochloric acid 2N is used to prepare solutions from ash of plant.

Nitrate reagent: HI93728-0, for measuring the concentration of nitrate in nutrient solution and plants.

Phosphate reagent :(ascorbic acid, ammonium moly date, sulfuric acid 5N, potassium antimonyl tartrate) had used to measuring the concentration of phosphate in nutrient solution and plants.

Sulfate reagent :(25% $BaCl_2$, 1N HCl) had used to measuring the concentration of sulfates in nutrient solution and plants.

Silver nitrate (0.0141M) and potassium dichromate (indicator): for measuring the concentration of chloride in nutrient solution and plants.

3.7. Chemical analysis:

The ICP-MS analysis is equipped with an Agilent 7500s ICPMS for the determination of trace elements at the ppb and sub-ppb concentration levels.

Nitrate meter: HANNA Instrument, HI 93728-0.

Spetronic 21D spectrophotometer has used to determining of phosphate and sulfate (Colorimetry).

3.8. Statistical analysis:

Treatments in the experiment were arranged in a Completely Randomized Design (CRD), with five pipes, four replicate in each pipe. Collected data were subjected to the analysis of variance (one way ANOVA) using SPSS program version 21. Means separated will be used to Tukey HSD at 0.05 level of probability. Microsoft excel vs 2010 is used to make some tables and diagrams in results, and Pearson correlation is used to find the relation between the concentrations of nutrients and dates sampling.

Chapter four

Results and Discussion

4.1. Results and Discussion

4.1.1. Introduction:

The results are classified into two main parts, first, results competent in the impact of salinity and nutrient concentration on chemical properties of solutions and nutrients in different of pea plant parts include the value of electrical conductivity and concentrations of nutrients, and second, results competent in the morphological and physical characteristics include the number of pods and leaves and stems length and roots and biomass weight and water content of different pea plant parts.

4.1.2. Nutrients solutions:

Electrical conductivity and the concentration of nutrients must be measured in an experiment to determine what effect of the nutrient solution on plants.

4.1.2.1. Electrical conductivity (EC):

The electrical conductivity of the various nutrient solutions had decreased with time, indicating that the plants had absorbed the proportion of ions nutrient solution with growth stages.

A Pearson product-moment correlation was run to determine the relationship between date sampling and the salinity at different lines. The data showed no violation of normality, linearity or homoscedasticity. There are a strong, negative correlation between date sampling and the salinity at Lines 3 and 6, which are statistically significant, (**Table 8)**.

(Table 8) shows the electrical conductivity(ms/cm) at different times in nutrient solutions of various lines, although it was noted that the electrical conductivity has increased slightly at a specific time, and the reason of increasing in the electrical conductivity might result from plants to get rid of some of the ions e.g. Potassium and nitrate affected by the increase of salinity in plants (Pandolfi et al. 2012).

Table (8) The electrical conductivity (ms/cm) at different times in nutrient solutions of various lines:

Date	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6
25th Jan. 2014	4.43	3.19	2.83	4.34	8.56	2.84
16th Feb. 2014	4.60	3.34	2.70	4.14	8.27	2.70
06th Mar. 2014	4.35	3.18	2.60	4.22	8.29	2.45
26th Mar. 2014	3.81	2.83	2.31	3.56	6.93	2.34
Average EC	4.30	3.14	2.61	4.07	8.01	2.58
Pearson correlation	-0.798	-0.741	-0.969*	-0.842	-0.857	-0.989*
Sig.(2-tailed)	0.202	0.259	0.031	0.158	0.143	0.011

***Correlation is significant at the 0.05 level (2-tailed).**

ms/cm:millisiemens/centimeter

4.1.2.2. Nutrients concentrations of solutions:

A Pearson product-moment correlation was run to determine the relationship between date sampling and nutrients concentrations at Line 1. The data showed no violation of normality, linearity or homoscedasticity. There are strong, negative correlations between date sampling and nutrient concentrations as phosphate, sulfate, chloride, magnesium, iron and calcium, which are statistically significant, **(Table 9).**

The concentration of nutrients in all lines solutions decreased with over time, due to be absorbed by pea plants in growth chambers , but potassium and nitrate often had increased with over time , due to interact between the sodium and chloride with other nutrients. Potassium ions have been replaced by sodium, while nitrates have been replaced by chloride ions (Gomez et al. 1996; Silveira et al. 1999), and nitrate concentrations had increased due to nitrogen fixation and the pea plants are considered of leguminous plants(Fatima et al. 2008), see **(Tables 9-14**).

Table (9) Nutrient concentrations (ppm) in solution of line 1 at different times in 2014:

Nutrients	25th Jan.	16th Feb.	6th Mar.	26th Mar.	Pearson correlation	Sig. 2-tailed
Phosphate	29.00	16.00	8.96	5.46	-0.964*	0.036
Sulfate	60.00	46.75	23.75	13.50	-0.990*	.010
Nitrate	354.28	487.14	752.86	647.22	+0.842	0.158
Chloride	749.83	699.84	649.85	624.86	-0.990*	0.010
Sodium	290.20	263.00	255.50	254.50	-0.886	0.114
Magnesium	67.61	65.11	63.46	60.72	-0.996**	0.004
Iron	10.66	6.39	2.91	2.62	-0.949	0.051
Manganese	2.11	0.43	0.04	0.04	-0.836	0.164
Copper	0.17	0.05	0.01	0.01	-0.889	0.111
Zinc	0.21	0.05	0.06	0.05	-0.771	0.229
Potassium	336.54	1413.36	1413.36	1413.36	-0.775	0.225
Calcium	93.50	81.17	76.92	69.23	-0.980*	0.020
Molybdenum	0.20	0.01	0.01	0.01	-0775	0.225

***Correlation is significant at the 0.05 level (2-tailed).**

****Correlation is significant at the 0.01 level (2-tailed).**

A Pearson product-moment correlation was run to determine the relationship between date sampling and Nutrient concentrations at Line 2. The data showed no violation of normality, linearity or homoscedasticity. There was a strong, negative correlation between date sampling and nutrient concentrations as phosphate, sulfate, chloride and magnesium, which are statistically significant, see **(Table 10)**.

Table (10) Nutrients concentration (ppm) in Line 2 solution at different times in 2014:

Nutrients	25th Jan.	16th Feb.	6th Mar.	26th Mar.	Pearson correlation	Sig. 2-tailed
Phosphate	16.18	10.733	5.022	3.078	-0.981*	0.019
Sulfate	37.50	28.125	13.75	12.125	-0.964*	0.036
Nitrate	296.71	243.57	177.14	388.89	+0.303	0.697
Chloride	732.68	674.84	649.85	624.86	-0.974*	0.026
Sodium	291.96	264.25	256.25	251.50	-0.923	0.077
Magnesium	38.84	38.177	38.0743	37.24	-0.964*	0.036
Iron	1.85	0.6727	0.41	0.304	-0.890	0.110
Manganese	1.17	0.1232	0.004	0.003	-0.826	0.174
Copper	0.10	0.058	0.093	0.064	-0.407	0.593
Zinc	0.12	0.0594	0.0639	0.0564	-0,797	0.203
Potassium	109.02	94.3667	103.5207	98.045	-0.479	0.521
Calcium	54.09	46.6226	48.5385	46.48	-0.758	0.242
Molybdenum	0.0349	0.0044	0.0046	0.0043	-0.776	0.224

***Correlation is significant at the 0.05 level (2-tailed).**

****Correlation is significant at the 0.01 level (2-tailed).**

A Pearson product-moment correlation was run to determine the relationship between date sampling and Nutrient concentrations at Line 3. The data showed no violation of normality, linearity or homoscedasticity. There are strong, negative correlations between date sampling and nutrient concentrations as chloride, sodium and copper, which are statistically significant, see **(Table 11)**.

Table (11) Nutrients concentration (ppm) in Line 3 solution at different dates in 2014.

Nutrients	25th Jan.	16th Feb.	6th Mar.2014	26th Mar	Pearson correlation	Sig. 2-tailed
Phosphate	0	0	0	0	-----	-----
Sulfate	13.900	13.750	13.250	12.250	-0.944	0.056
Nitrate	31.200	44.268	43.400	175.000	+0.818	0.182
Chloride	669.492	654.8591	649.853	624.859	-0.965*	0.035
Sodium	292.001	264.000	255.250	242.500	-0.967*	0.033
Magnesium	31.343	28.6728	31.046	26.0309	-0.709	0.291
Iron	0.205	0.1646	0.1525	0.1136	-0.982*	0.018
Manganese	0.0757	0.009	0.0017	0.0009	-0.829	0.171
Copper	0.0265	0.0218	0.0215	0.0155	-0.954*	0.045
Zinc	0.0268	0.0177	0.0153	0.0134	-0.927	0.073
Potassium	33.1753	34.1747	38.8519	33.6002	+0.292	0.708
Calcium	40.9501	19.9921	22.4434	18.9259	-0.793	0.207
Molybdenum	0.0088	0.0066	0.0051	0.0054	-0.899	0.101

***Correlation is significant at the 0.05 level (2-tailed).**

****Correlation is significant at the 0.01 level (2-tailed).**

A Pearson product-moment correlation was run to determine the relationship between date sampling and Nutrient concentrations at Line 4. The data showed no violation of normality, linearity or homoscedasticity. There was a strong, negative correlation between date sampling and Nutrient concentrations as sulfate, chloride, iron and copper, which are statistically significant, see **(Table 12)**.

Table (12) Nutrients concentration (ppm) in Line 4 solution at different dates in 2014.

Nutrients	25th Jan	16th Feb	6th Mar	26th Mar.	Pearson correlation	Sig. 2-tailed
Phosphate	0	0	0	0	----	----
Sulfate	13.95	13.25	12.5	12	-0.997**	0.003
Nitrate	32.111	75.2871	55.8	155.56	+0.846	0.154
Chloride	1298.65	1284.74	1279.71	1249.72	-0.951*	0.049
Sodium	584.8733	363.75	350.75	345	-0.815	0.185
Magnesium	31.769	30.8971	31.948	27.23	-0.737	0.263
Iron	0.199	0.1404	0.133	0.0772	-0.966*	0.034
Manganese	0.0675	0.0033	0.0035	0.0012	-0.791	0.209
Copper	0.0265	0.0235	0.0206	0.0119	-0.958*	0.042
Zinc	0.0288	0.0157	0.0273	0.0173	-0.439	0.561
Potassium	32.7695	37.0972	39.3635	34.15	+0.280	0.720
Calcium	38.8224	19.6159	20.3788	17.2856	-0.828	0.172
Molybdenum	0.0081	0.0055	0.0091	0.0071	+0.050	0.950

***Correlation is significant at the 0.05 level (2-tailed).**

****Correlation is significant at the 0.01 level (2-tailed).**

A Pearson product-moment correlation was run to determine the relationship between date sampling and Nutrient concentrations at Line 5. The data showed no violation of normality, linearity or homoscedasticity. There was a strong, negative correlation between date sampling and Nutrient concentrations as molybdenum, which is statistically significant, see (**Table 13**).

Table (13) Nutrients concentration (ppm) in Line 5 solution at different times in 2014.

Nutrients	25th Jan	16th Feb	6th Mar	26th Mar.	Pearson correlation	Sig. 2-tailed
Phosphate	0	0	0	0	----	----
Sulfate	13.5	12.5	12	12	-0.913	0.087
Nitrate	32.4	66.8714	60.6714	166.67	+0.873	0.127
Chloride	4097.29	3824.1	2399.46	2349.47	-0.933	0.067
Sodium	1479.359	801.5	778.5	761.5	-0.803	0.197
Magnesium	32.00	31.72	32.18	31.78	-0.092	0.908
Iron	0.21	0.196	0.21	0.20	-0.105	0.895
Manganese	0.0712	0.0104	0.007	0.0023	-0.835	0.165
Copper	0.03	0.0213	0.0569	0.0344	+0.415	0.585
Zinc	0.0293	0.0118	0.0126	0.011	-0.796	0.204
Potassium	33.4588	40.3779	44.5178	40.1451	+0.683	0.317
Calcium	39.2342	23.871	25.165	2.593	-0.928	0.072
Molybdenum	0.0086	0.0072	0.0062	0.0027	-0.959*	0.041

***Correlation is significant at the 0.05 level (2-tailed).**

****Correlation is significant at the 0.01 level (2-tailed).**

A Pearson product-moment correlation was run to determine the relationship between date sampling and Nutrient concentrations at Line 6. The data showed no violation of normality, linearity or homoscedasticity. There was a strong, negative correlation between date sampling and Nutrient concentrations as chloride and sodium, which are statistically significant, see **(Table 14)**.

Table (14) Nutrients concentration (ppm) in Line 6 solution at different times in 2014.

Nutrients	25th Jan	16th Feb	6th Mar	26th Mar	Pearson correlation	Sig. 2-tailed
Phosphate	0	0	0	0	----	----
Sulfate	15.45	13.5	12	12	-0.935	0.065
Nitrate	31.00	79.71	60.99	166.67	+0.860	0.140
Chloride	669.49	654.86	649.853	624.859	-0.965*	0.035
Sodium	290.92	254.75	228.75	161.25	-0.979*	0.021
Magnesium	31.99	31.079	31.61	31.60	-0.218	0.782
Iron	1.91	0.234	0.148	0.192	-0.787	0.213
Manganese	0.0716	0.0043	0.0049	0.0095	-0.732	0.268
Copper	2.78	1.26	1.09	1.042	-0.837	0.163
Zinc	3.01	1.67	1.2723	1.054	-0.922	0.078
Potassium	33.12	37.94	37.78	36.85	+0.632	0.368
Calcium	38.88	21.24	21.71	22.86	-0.723	0.277
Molybdenum	0.0086	0.0084	0.004	0.0057	-0.762	0.238

***Correlation is significant at the 0.05 level (2-tailed).**

****Correlation is significant at the 0.01 level (2-tailed).**

Finally the relationship between the date of sampling and the concentration of nutrients in nutrient solutions mostly, isn't linear because of the complex interactions among themselves and the availability of nutrients for plants and the effect of salinity on nutrient uptake by plants.

4.1.3. Characteristics of plants:

Morphological characteristics of the pods, leaves, stems and roots should be known to determine the impact of the above factors on plants.

4.1.3.1. Survival percentage:

The percentage of survival in pea plants was depended on the concentration of nutrients and salinity levels, and (**Table 15)** shows the relationship between the salinity levels and survival percentage of pea plants.

Table (15) Relationship between survival percentage of pea plant and salinity levels (ms/cm):

Line number	Average Salinity(ms/cm)	Survival percentage %
Line 1	4.3	100
Line 2	3.14	95
Line 3	2.61	90
Line 4	4.07	80
Line 5	8.01	50
Line 6	2.58	70

A Pearson product-moment correlation was run to determine the relationship between salinity levels and survival percentage. The data showed no violation of normality, linearity or homoscedasticity. There is a strong, negative correlation between salinity levels and survival percentage, which is statistically significant (r = - 0.999, $p < 0.05$), while there isn't a strong, positive correlation between nutrients levels and survival percentage, which is statistically significant (r = 0.984, $p > 0.05$).

4.1.3.2. Pods characteristics:

The number and fresh and dry biomass weight of the pods of pea plants in different lines had differed depending on the quality and quantity of nutrients and salinity in the nutrient solutions, according to analysis of variance (ANOVA) the (**Table 16)** shows the average number and fresh and dry biomass weight of the pods in different lines, the average of measurements were significantly differed at ($\alpha \leq 0.05$).

Table (16) The average number, fresh and dry biomass weight of pods in different treatments.

Treatment	Average number of pods	Fresh pods weight (gram/plant)	Dry pods weight (gram/plant)
Line 1	2.55a	6.53a	1.175a
Line 2	1.58b	3.70b	0.687b
Line 3	1.17b	2.16c	0.3983c
Line 4	1.20b	1.10cd	0.202d
Line 5	----------	----------	----------
Line 6	0.35c	0.022de	0.014de

- **Averages in columns with the same small letters are not significantly different at P≤0.05 level, according to Tukey HSD.**

It is found that number, fresh and dry weight increased significantly in the solution which owned more of the nutrients , as Line 1 more than Line 2, and the number of pods and weight decreased significantly when the increase of salinity in the nutrient solution (Line 5 less than Line 4 and Line 4 less than Line 3), but number of pea pods has increased in Line 4 plants(contained 1500 ppm NaCl) compared in Line 3(contained 750 ppm NaCl), it may be due to a period of premature aging and to maintain the life cycle of a physiologically, and this result supports the findings of (Duzdemir, 2009; Farooq et el, 2009) and in plants of Line 6 (contained heavy metals) was owned pod, fresh and dry biomass pods weight less than Line 3 (Control Line) , While plants Line 5 (containing 3750 ppm NaCl) hadn't produce pods, it can be seen clearly in **(Table 16)**.

(Table 16) shows the average of number and fresh and dry biomass weight of pods in plants of Line 1 more than Line 2, because the plants of Line 1 had absorbed the adequacy of nutrients, whereas the plants of Line 2 didn't get adequacy of essential nutrients that are required for metabolic processes and performance in pea plants, But increasing the salinity of the nutrient solution lead to stress the plants and then lead to low and poor metabolic processes and the performance of plants, the number and fresh and dry biomass of pods pea plant were increased significantly in Line 3 more than Line 4, Line 4 more than Line 5 , that consistent with (Nenova V., 2008 and Yorgancilar M. et.al., 2012).

Line 6 was contained 2 ppm Fe, 3.2 ppm Cu and 3.26 ppm Zn, Copper is an essential heavy metal for higher plants particularly for photosynthesis, Cu is a constituent of primary electron donor in photosystem of plants. Because Cu can readily gain and lose an electron, it is a cofactor of oxidase, mono- and di-oxygenase (e.g., amine oxidases, ammonia monoxidase, ceruloplasmin, and lysyl oxidase) and of enzymes involved in the elimination of superoxide radicals (e.g. Superoxide dismutase and ascorbate oxidase).

Several enzymes contain Zn, such as carbonic anhydrase, alcohol dehydrogenase, superoxide dismutase and RNA polymerase, Zinc is required to maintain the integrity of ribosome, and it takes part in the formation of carbohydrates and catalyzes the oxidation processes in plants. Zinc also provides a structural role in many transcription factors and is a cofactor of RNA polymerase; Iron Fe is an essential element in many metabolic processes. (Nagajyoti P. et.al, 2010).

The number, fresh and dry biomass weight of pods of pea plants in Line 6 less than Line 3, because of the presence of nutrients, iron, copper and zinc in the nutrient solution which have a significant role in biological processes in pea plants, but the concentrations of copper and zinc in a solution of Line 6 have been high, so the plants have been exposed to a case of toxicity which reduces the production of pods.

Average of number, fresh and dry biomass of pod in Line 1 significantly differ than other lines but they don't significantly among Lines 2, 3 and 4, and the average of Line 6 significantly differ than Line 3 (Control Line), according to tukey HSD test.

(**Figures 6, 7 and 8)** show the averages of number and fresh and dry biomass weight of pods at different pipes in each line, each line had five pipes and four replications in each pipe, the average of number and fresh and dry biomass of pods of pea plant among pipes in each line were not differ depending on Tukey HSD ,($P > 0.05$), With the exception of the fifth pipe of each line, where it is often value more than the other pipes in all measurements on the pods, and the reason for that, it is expected, the fifth pipe in each line was exposed to the sun more than other pipes.

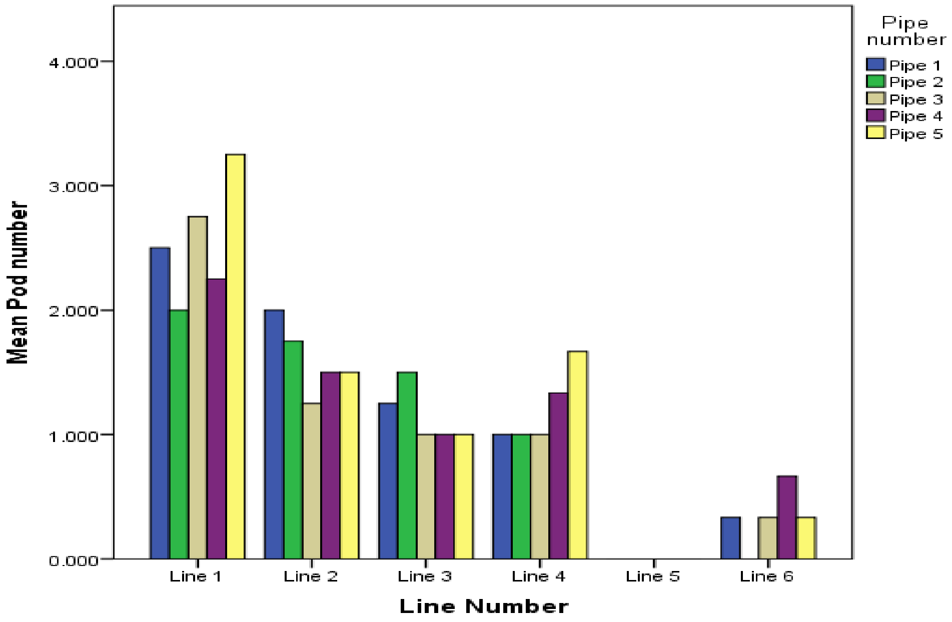


Figure (6) Average of pods number of pea plants at different pipes in each line; each value is the average of four replications in each pipe, Tukey HSD, P ≥ 0.05

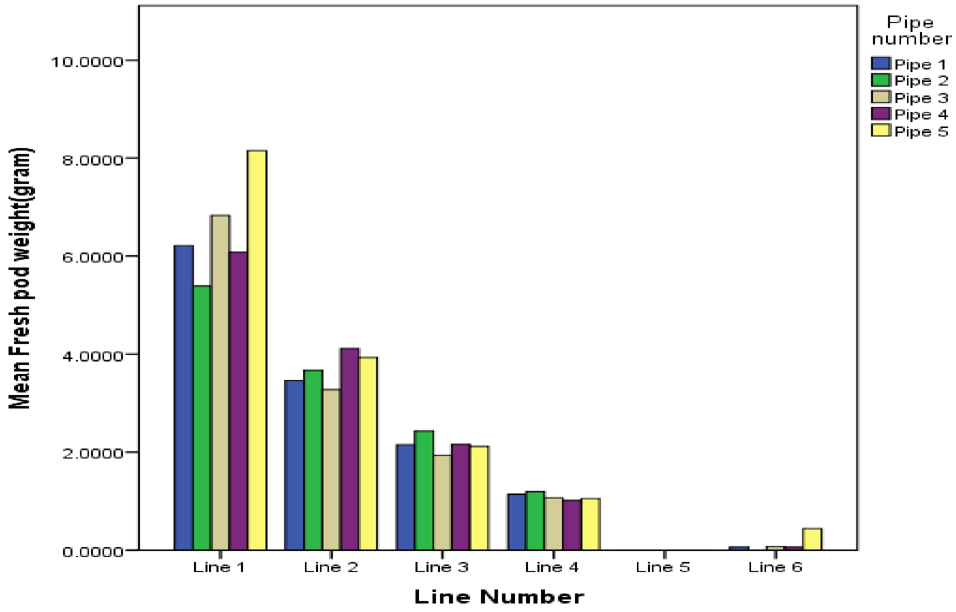


Figure (7) Average of fresh weight of pods of pea plants at different pipes in each line; each value is the average of four replications in each pipe, Tukey HSD, P ≥ 0.05

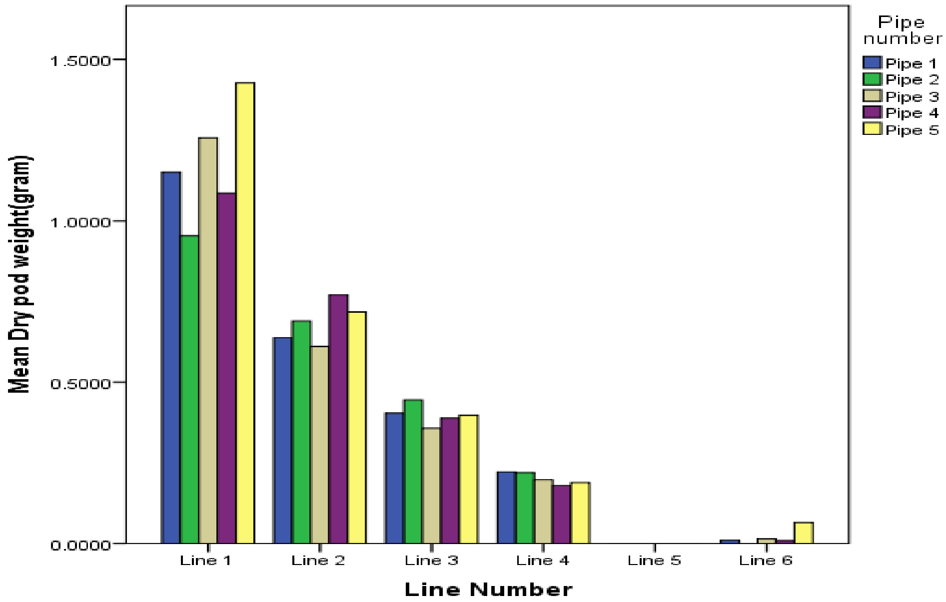


Figure (8) Average of dry biomass weight of pods of pea plants at different pipes in each line; each value is the average of four replications in each pipe, Tukey HSD, $P \geq 0.05$

4.1.3.3. Leaves characteristics:

The area, fresh and dry biomass weight of the leaves of pea plants in different lines had differed depending on quality and quantity of nutrients and salinity in the nutrient solutions, according to analysis of variance (ANOVA), **(Table 17)** shows the average area, fresh and dry biomass weight of the leaves in different lines, the average of measurements were significantly differed at ($\alpha \leq 0.05$), It was found that the area of leaves, fresh and dry biomass weight increased significantly in the solution which owned more of the nutrients, as Line 1 more than Line 2, and the area of leaves and weight decreased significantly when the increase of salinity in the nutrient solution (Line 5 less than Line 4 and Line 4 less than Line 3) and in the Line 6 was owned area, fresh and dry biomass leaves weight less than Line 3 (Control Line).

Table (17) Average the area, fresh and dry biomass weight of leaves pea plants at different lines:

Treatment	Area of leaves (cm^2)	Fresh leaves weight (g/ plant)	Dry leaves weight (g/ plant)
Line 1	119.00a	1.81a	0.212a
Line 2	41.11b	1.13b	0.103b
Line 3	23.44bc	0.41c	0.095c
Line 4	17.67bc	0.38c	0.089bc
Line 5	8.90c	0.23c	0.042bc
Line 6	8.14c	0.36c	0.075c

- **Averages in columns with the same small letters are not significantly different at P≤0.05 level, according to Tukey HSD.**

(Table 17) shows the average of area, fresh and dry biomass weight of leaves that are found in plants of Line 1 was more than Line 2, because the plants of Line 1 had absorbed the adequacy of nutrients, while the plants of Line 2 didn't get adequacy of essential nutrients, that increased metabolic processes and performance in pea plants in Line 1, but the increase in salinity led to stress the plants and then decrease and weakness the metabolic processes and performance of plants, the area and fresh and dry biomass of leaves pea plants were increased no significantly in Line 3 more than Line 4 , Line 4 more than Line5 ,that is consistent with (Nenova V., 2008 and Yorgancilar M. et.al., 2012 and Shahid M. etal, 2013).

Line 6 was contained 2 ppm Fe, 3.2 ppm Cu and 3.26 ppm Zn, Copper is an essential heavy metal for higher plants particularly for photosynthesis, Cu is a constituent of primary electron donor in photosystem of plants.

Because Cu can readily gain and lose an electron, it is a cofactor of oxidase, mono- and di-oxygenase (e.g., amine oxidases, ammonia monoxidase, ceruloplasmin, and lysyl oxidase) and of enzymes involved in the elimination of superoxide radicals (e.g. Superoxide dismutase and ascorbate oxidase).

Several enzymes contain Zn, such as carbonic anhydrase, alcohol dehydrogenase, superoxide dismutase and RNA polymerase, Zinc is required to maintain the integrity of ribosome, and it takes part in the formation of carbohydrates and catalyzes the oxidation processes in plants. Zinc also provides a structural role in many transcription factors and is a cofactor of RNA polymerase; Iron Fe is an essential element in many metabolic processes. (Nagajyoti P. et.al, 2010).

The area, fresh and dry weight of leaves of pea plants in Line 6 less than Line 3, and that because of the presence of nutrients, iron, copper and zinc in the nutrient solution which have a significant role in biological processes in pea plants, but the concentrations of copper and zinc in a solution of Line 6 has been high, so the plants have been exposed to a case of toxicity, which reduces metabolism and production of leaves.

The average of area, fresh and dry biomass of leaves in Line 1 and Line 2 significantly differ than other lines, but they don’t significantly among Line 3,4 and 5, and the average of Line 6 significantly differs than Line 3 (control sample), according to Tukey HSD test.

(**Figures 9, 10 and 11)** describes the averages of area and fresh and dry biomass weight of leaves at different pipes in each line, each line had five pipes and four replications in each pipe, the average of area and fresh and dry biomass of leaves of pea plant among pipes in each line wasn't differ depending on Tukey HSD ,(P > 0.05), with the exception of the fifth pipe of each line, where it is often value more than the other pipes in all measurements on the leaves, and the reason for that, it is expected, the fifth pipe in each line was exposed to the sun more than other pipes.

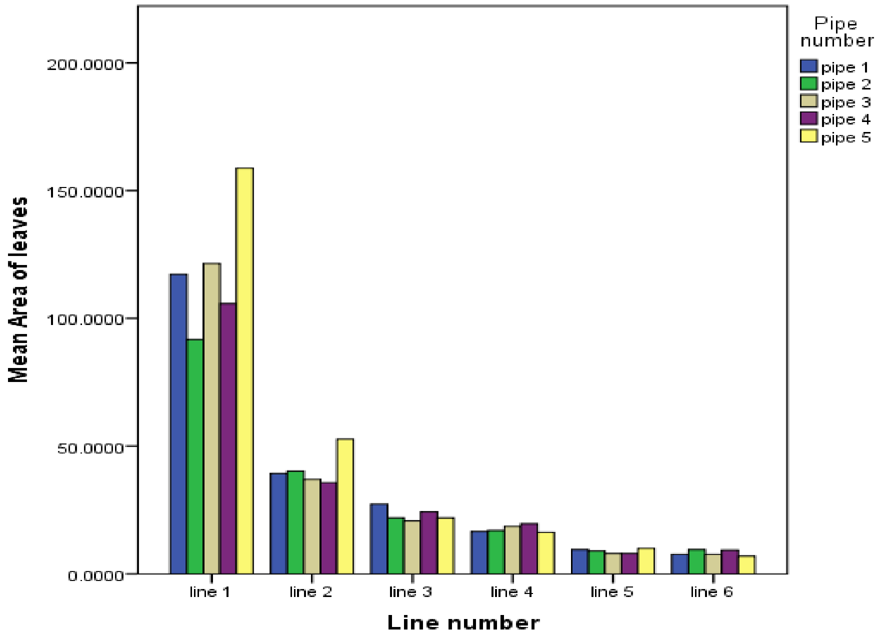


Figure (9) Average area of leaves of pea plants at different pipes in each line; each value is the average of four replications in each pipe, Tukey HSD, P ≥ 0.05

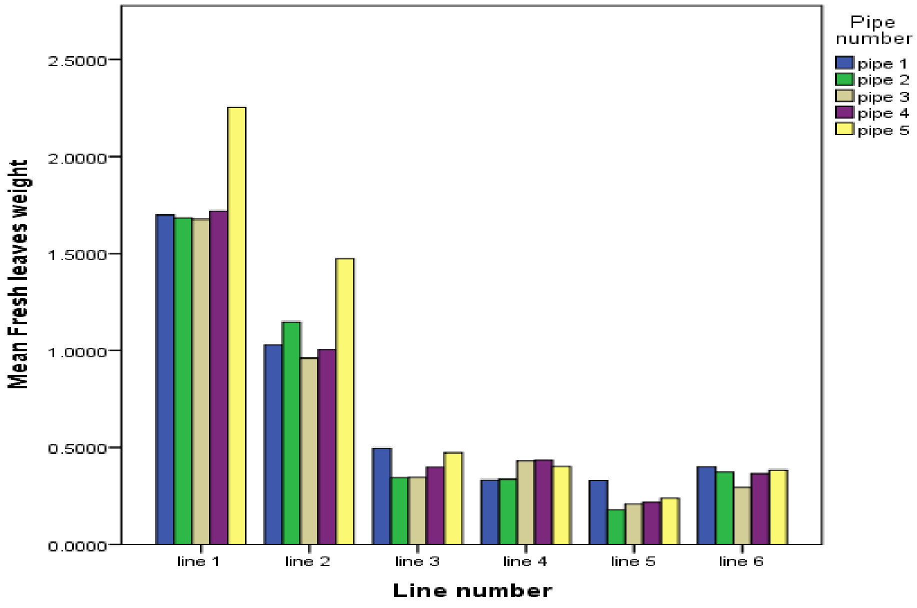


Figure (10) Average fresh weight of leaves of pea plants at different pipes in each line; each value is the average of four replications in each pipe, Tukey HSD, P ≥ 0.05

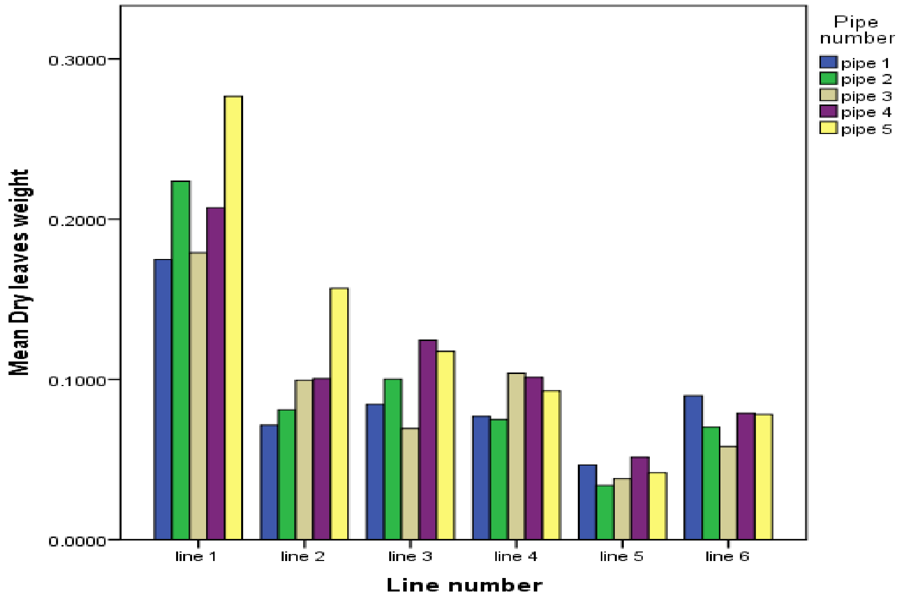


Figure (11) Average of dry biomass weight of leaves of pea plants at different pipes in each line; each value is the average of four replications in each pipe, Tukey HSD, P ≥ 0.05

4.1.3.4. Stems characteristics:

The length and fresh and dry biomass weight of the stems of pea plants at different lines had differed depending on quality and quantity of nutrients and salinity in the nutrient solutions, according to analysis of variance(ANOVA) the **(Table 18)** shows the average length , fresh and dry biomass weight of the stems at different Lines, the average of measurements were significantly differed at ($\alpha \leq 0.05$) , It was found that the length of stems and fresh and dry biomass weight increased significantly in the solution which owned more nutrients , as the Line 1 more than Line 2, and the length and weight of stems decreased significantly when the increase of salinity in the nutrient solutions (Line 5 less than Line 4 and Line 4 less than Line 3) , and Line 6 owned stems length more than Line 3 (control line), but the fresh and dry biomass weight of stems of pea plants less than control Line(L3) .

Table (18) average length, fresh and dry biomass of stems pea plants at different Lines:

Treatment	length of stems (cm)	Fresh stems weight (g/plant)	Dry stems weight (g/plant)
Line 1	32.65a	1.58a	0.152a
Line 2	24.05b	1.13b	0.099b
Line 3	19.25c	0.58c	0.094bc
Line 4	15.80cd	0.41cd	0.087bc
Line 5	14.20d	0.21d	0.048c
Line 6	20.21bc	0.30cd	0.058bc

- **Averages in columns with the same small letters are not significantly different at $P \leq 0.05$ level, according to Tukey HSD and Multiple Comparisons.**

(**Table 18)** pervious shows the average of each length, fresh and dry biomass weight of stems that are found in plants of Line 1 was more than Line 2, because the plants of Line 1 had absorbed the adequacy of nutrients, while the plants of Line 2 did not get adequacy of essential nutrients ,which led to increase metabolic processes and performance in pea plants, but the increase in salinity led to stress the plants and then led to decrease and weakness the metabolic processes and performance of plants, the length and fresh and dry biomass of stems pea plants were increased no significantly in Line 3 more than Line 4 , Line 4 more than Line 5, That is consistent with (Nenova V., 2008 and Yorgancilar M. et.al., 2012 and Shahid M. et al., 2013).

Line 6 contained 2 ppm Fe, 3.2 ppm Cu and 3.26 ppm Zn, as mentioned earlier, the importance of these elements in biological processes in plants peas. That is consistent with (Nagajyoti P. et.al,2010).

The stems of pea plants in Line 6 taller than the stems of plants in Line 3, because of the presence of nutrients: iron, copper and zinc in the nutrient solution which have a significant role in biological processes in pea plants, but the concentrations of copper and zinc in a solution of the sixth line had been high, so the plants had been exposed to a case of toxicity, which decreases the production of stems.

Although the toxic effect on plants peas by copper and zinc, under the given concentrations. Interaction effects of metals on plant growth in nutrient solution culture can be different to those found in soil. (Luo and Rimmer, 1995) found that Cu-Zn interactions in a soil were synergistic compared with an antagonistic effect in solution culture. (Luo and Rimmer, 1995) attribute this difference to the effects on availability of metal adsorption onto soil particles. (Taylor et al. (1998) suggest that these differences are likely to be because most nutrient solution studies are conducted at high ionic strength compared to soil solutions. (Gadallah M., et al., 1997) suggest the higher concentration of zinc improve especially in root and enhance xylem in safflower, While the weight of the biomass of stems of pea plants in Line 6 was less than Line 3 (control) , that has been due to the thinnest stems of plants.

There is a significant difference in average length of plants stems of Line1 and other lines(p=0.000), but there is no difference between Line 2 and Line 6(p=0,146),there are no differences between Line 3 and all of Line 4(p=0.259), Line 5(p=0.062) and Line 6(p=0.991), as well as there are no differences between Line 4 and all of Line 3(p=0.259), Line 5(p=0.947) and Line 6(p=0.089).

There is a significant difference in fresh weight of plants stems of Line 1 and other lines(p=0.000) , there is a significant difference in fresh weight of plants roots of Line 2 and other lines(p=0.000), but there are no differences between Line 3 and all of Line 4 (p=0,667), Line 5 (p=0.059) and Line 6 (p=0.180), there are no differences between Line 4 and all of Line 5(p=0.667), Line 6(p=0.950) , as well as there is no differences between Line 5 and Line 6(p=0.983).

There is a significant difference in dry stems plants weight of Line1 and other lines (p=0.000) , but there are no differences between Line 2 and all of Line 3 (p=1.000), Line 4 (p=0.969) and Line 6 (0.091), there are no differences between Line 3 and all of Line 4 (p=0.997), Line 5 (p=0.100) and Line 6 (p=0.213), there are no differences between Line 4 and both of Line 5 (p=0.251) and Line 6 (p=0.471) , as well as there are no differences between Line 5 and Line 6 (0.994), according to Tukey HSD test and Multiple Comparisons.

(**Figures 12, 13 and 14)** describe the averages of length, fresh and dry biomass weight of stems at different pipes in each line, that had five pipes and four replications in each pipe, the average of length, fresh and dry biomass of stems of pea plant among pipes in each line weren't differ depending on Tukey HSD ,(P > 0.05), With the exception of the fifth pipe of each Line, where it is often value more than the other pipes in all measurements on the stems, and the reason for that, it is expected, the fifth pipe in each line was exposed to the sun more than other pipes.

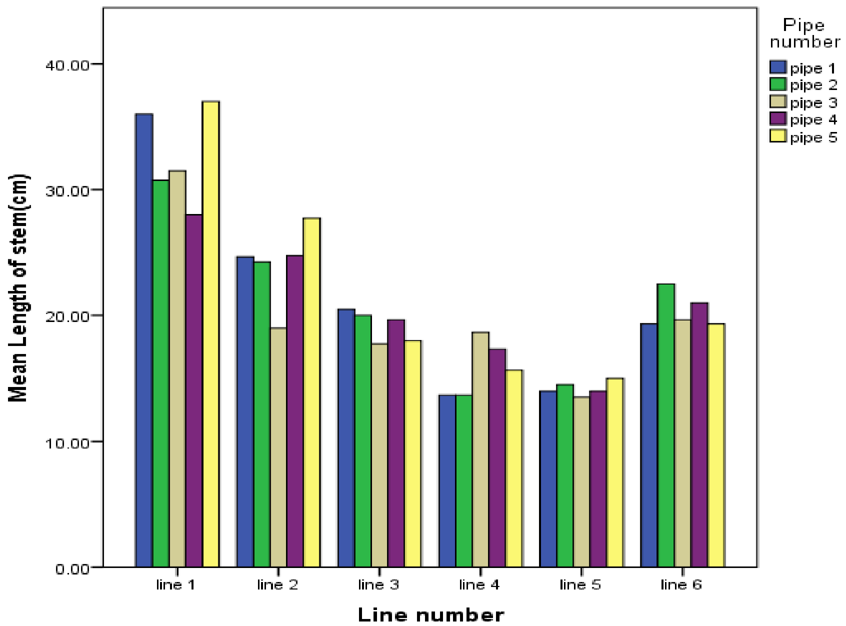


Figure (12) Average length of stems of pea plants at different pipes in each line; each value is the average of four replications in each pipe, Tukey HSD, P ≥ 0.05

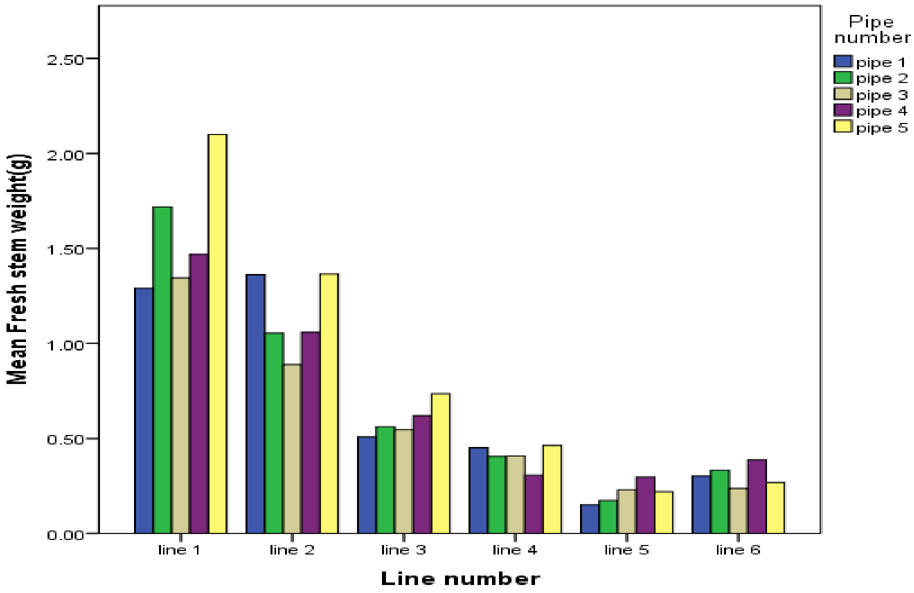


Figure (13) Average fresh biomass weight of stems of pea plants at different pipes in each line, each value is the average of four replications in each pipe, Tukey HSD , P ≥ 0.05

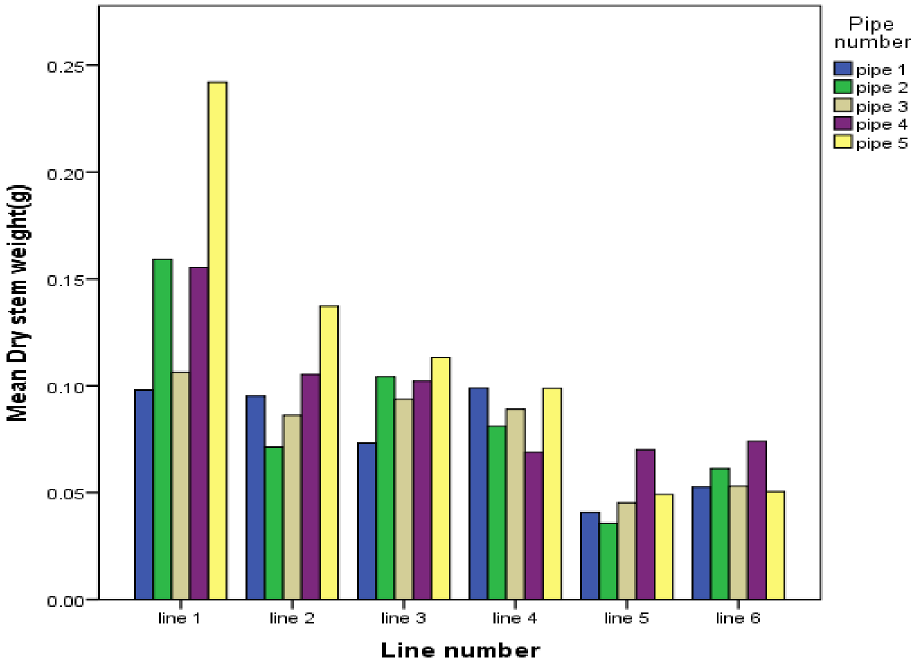


Figure (14) Average of dry biomass weight of stems of pea plants at different pipes in each line; each value is the average of four replications in each pipe, Tukey HSD, P ≥ 0.05

4.1.3.5. Roots characteristics:

The length, fresh and dry biomass weight of the roots of pea plants at different lines had differed depending on quality and quantity of nutrients and salinity in the nutrient solutions, according to analysis of variance(ANOVA) the **(Table 19)** shows the average length, fresh and dry biomass weight of the roots at different lines, the average of measurements were significantly differed at ($\alpha \leq 0.05$) , It was found that the length of roots, fresh and dry biomass weight of roots increased significantly in the solution which owned more nutrients , as line 1 more than Line 2, and the length, fresh and dry biomass weight of roots decreased significantly with increasing of salinity in the nutrient solutions (Line 5 less than Line 4), but the length, fresh and dry weight of root at Line 4 more than Line 3, despite the salinity in Line 4 higher than Line3 and in the Line 6 was owned length of roots more than Line 3 (control), but the fresh and dry weight of root less than Line 3.

Table (19) Average length, fresh and dry biomass of roots pea plants at different lines:

Line number	Length of roots (cm)	Fresh roots weight (g/plant)	Dry roots weight (g/plant)
Line 1	28.70a	1.60a	0.114a
Line 2	20.21b	0.88b	0.071b
Line 3	17.25bc	0.46bc	0.049bc
Line 4	22.73ab	0.47bc	0.073b
Line 5	9.80c	0.15c	0.034c
Line 6	21.07ab	0.22c	0.039bc

- **Averages in columns with the same small letters are not significantly different at P ≤0.05 level, according to Tukey HSD and Multiple Comparisons.**

Through **(Table 19)** can observed that the average of each length, fresh and dry biomass weight of roots that are found in plants of Line 1 was more than Line 2, the effect of nutrients on plants appear when taking the amount of needed nutrients, and led to the vital activities in the plants, such as metabolic processes and performance, but the increase in salinity led to stress the plants and then led to decrease and weakness the metabolic processes and performance of plants, the length , fresh and dry biomass of roots pea plants were decreased no significantly in Line 3 (was contained 750 ppm NaCl) less than Line 4 (was contained 1500 ppm NaCl) , despite the fact that roots present in the aqueous medium, but they faced difficulty to absorb the water from the nutrient solution, so they were forced to increase the length of roots , Line 4 more than Line 5 (was contained 3750 ppm NaCl), due to the increase of salinity (3750 ppm NaCl), which led to the weakening of root growth and the efficiency of the membranes.

According to the nutrient solution components of the line 6، as mentioned earlier, the importance of these elements in biological processes in plants peas. That is consistent with (Nagajyoti P. et.al, 2010).

The roots of pea plants in Line 6 taller than the roots of plants in Line 3, the average length of Line 6 did not significantly differ with Line4 that because of the presence of nutrients: iron, copper and zinc in the nutrient solution which have a significant role in biological processes in pea plants, but the concentrations of copper and zinc in a solution of the Line 6 had been high, so the plants had been exposed to a case of toxicity, which decreased the performance of roots.

Although the toxic effect of copper and zinc on peas plants under the given concentrations. Interaction effects of metals on plant growth in nutrients solution culture can be different to those found in soil. Luo and Rimmer (1995) found that Cu-Zn interactions in a soil were synergistic compared with an antagonistic effect in solution culture. Luo and Rimmer (1995) attribute this difference to the effects on availability of metal adsorption onto soil particles. Taylor et al (1998) suggest that these differences are likely to be because most nutrient solution studies are conducted at high ionic strength compared to soil solutions. Gadallah, et al. (1997) suggests the higher concentration of zinc improve especially in root and enhance xylem in safflower. It is expected that the roots of plants peas for being long, because the roots of plants resisted the osmotic stress, access to fresh water and absorption of ions to increase the osmotic potential inside the root tissues, while the weight of fresh and dry of roots of pea plants in Line 6 less than Line 3 (control), that has been due to the thinnest roots of plants. (Kopittke and Menzies, 2006).

There is a significant difference in average length of plants roots of Line1 and other lines(p=0.000),exception Line 4 (p=0.183), but there are no differences between Line 2 and Line 3(p=0.846),Line 4 (p=0.921) and Line 6 (0.999), there are no differences between Line 3 and all of Line 4(p=0.318), Line 5(p=0.137) and Line 6(p=0.721), as well as there are no differences between Line 4 and Line 6(p=0.991) .

There is a significant difference in average fresh weight of plants roots of Line1 and other lines(p=0.000), but there is no difference between Line 2 and Line 4(p=0,061),there are no differences between Line 3 and all of Line 4(p=1.000), Line 5(p=0.435) and Line 6(p=0.586), as well as there are no differences between Line 4 and all of Line 5(p=0.410) and Line 6(p=0.556) and there is no difference between Line 5 and Line 6(p=0.999) There is a significant difference in dry weight of plants roots of Line1 and other lines(p=0.000) , but there are no differences between Line 2 and Line 3(p=0,356),Line 4 (p=1.000), Line 5(p=0.061) and Line 6 (p= 0.073), there are no differences between Line 3 and all of Line 4 (p=0.300), Line 5(p=0.891) and Line 6(p=0.964), as well as there are no differences between Line 4 and all of Line 5 (p=0.051) and Line 6(p=0.062), according to Tukey HSD test and Multiple Comparisons.

(Figures 15, 16 and 17) describes the averages of length, fresh and dry biomass weight of roots at different pipes in each Line, each Line had five pipes and four replications in each pipe, the average of length and fresh and dry biomass of roots of pea plant among pipes in each line wasn't differ depending on Tukey HSD, ($P > 0.05$), With the exception of the fifth pipe of each line, where it is often value more than the other pipes in all measurements on the roots, and the reason for that, it is expected, the fifth pipe in each Line was exposed to the sun more than other pipes.

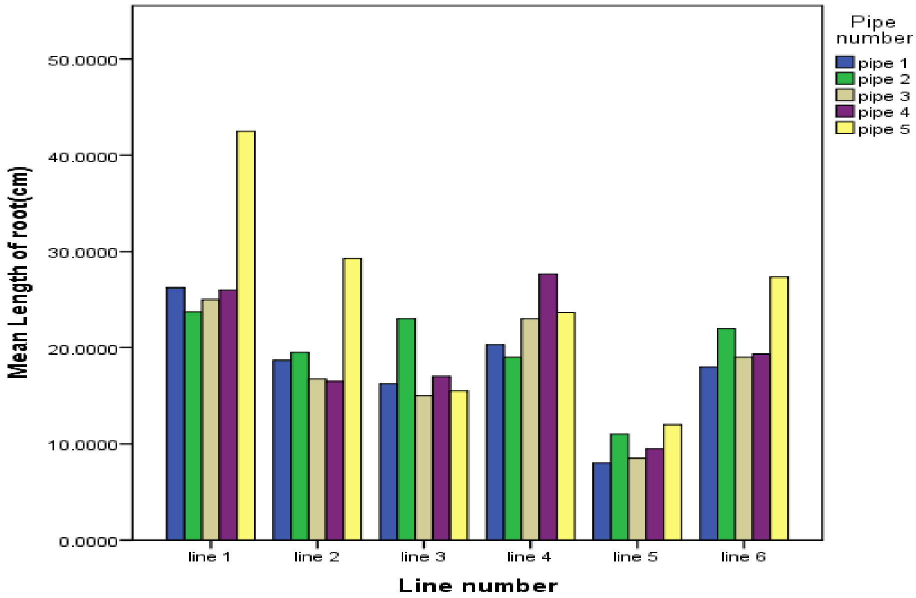


Figure (15) Average length of roots of pea plants at different pipes in each Line; each value is the average of four replications in each pipe, Tukey HSD, P ≥ 0.05

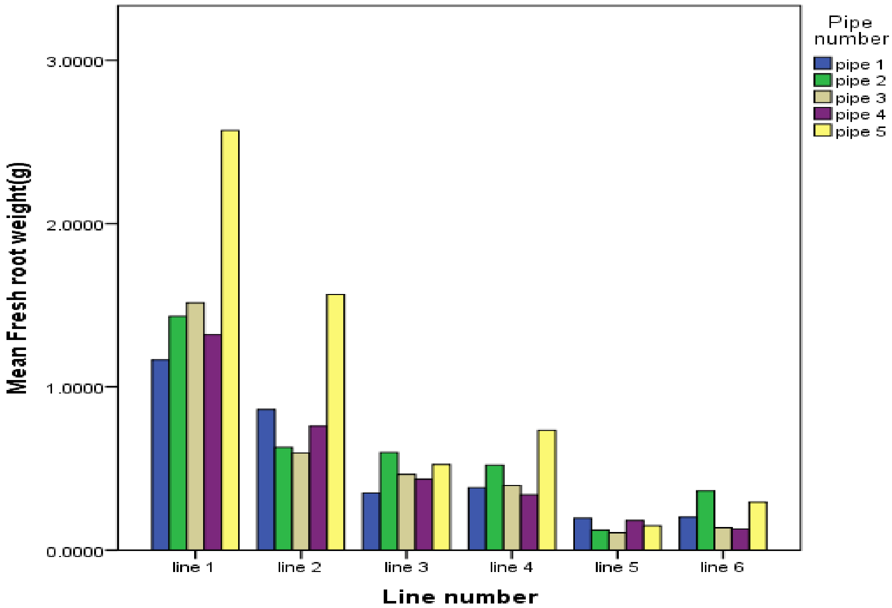


Figure (16) Average fresh biomass weight of roots of pea plants at different pipes in each Line, each value is the average of four replications in each pipe, Tukey HSD , P ≥ 0,05

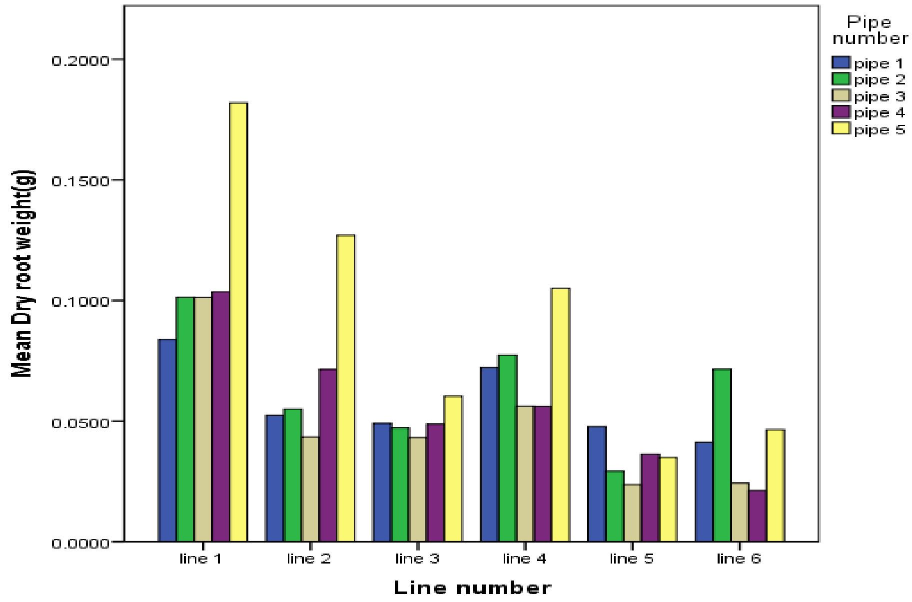


Figure (17) Average dry biomass weight of roots of pea plants at different pipes in each Line, each value is the average of four replications in each pipe, Tukey HSD , $P \geq 0.05$

4.1.4. The effect of salinity on whole plants:

In this section, the relation between weight of pea plants in different lines and salinity which was expressed by the electrical conductivity (ms/cm) **(Table 8)** , that's where fresh and dry weight plants only affected by salinity significantly, which appeared decrease in the weight of peas plants, and also the relative water content (RWC), according to statistical analysis using analysis of variance (ANOVA) at ($\alpha \leq 0.05$), show the differences in the average of weight plants and relative water content at different salinity levels (Electrical conductivity of various lines), the results were illustrated in the **(Table 20)**.

Table (20) Average fresh and dry weight and relative water content of whole plant of pea at different salinity levels (Electrical conductivity (EC) of various lines):

Treatment	EC (ms/cm)	Fresh weight (gram/plant)	Dry weight (gram/plant)	RWC (%)
Line1	4.3	11.52a	1.65a	85.67a
Line2	3.14	6.51b	0.91b	86.00a
Line3	2.61	3.27c	0.58c	82.20b
Line4	4.07	2.39cd	0.46c	80.84bc
Line5	8.01	0.60de	0.13d	79.10d
Line6	2.58	0.71e	0.14d	80.61cd

- **Averages in columns with the same small letters are not significantly different at P≤0.05 level, according to Tukey HSD.**

Fresh and dry biomass of pea plants had been decreased by increasing salinity significantly, as well as nutrients in the nutrient solution, but Line 6 (contained 3.26 ppm zinc and 3.2 ppm Cu and 2 ppm iron and 750 ppm NaCl) had lower average fresh and dry biomass of whole plants, despite they are salinity less than other lines, the reason may be a toxic effect from copper and zinc, which are found in the nutrient solution, which affected the biological processes and performance in plants.

Average relative water content (RWC) in various lines are differ significantly at ($P<0.05$) and Tukey HSD, RWC was decreased when salinity increased (Line5 < Line4 < Line3 < Line1< Line2). Although the salinity in the Line 6 was the least, but the relative water content of less than Line 4, can be explained, copper and zinc had increased the transpiration process in leaves and impacted on membrane integrity which led to the decrease in the relative water content (Stoyanova and Doncheva, 2002). Although the Line 2 was larger salinity than line 3, but it has largest relative water content; because plants can adapt to conditions of osmotic stress is the accumulation of salt ions as osmolyte (Romero-Aranda et al, 2001).

4.1.5. Nutrients in plants:

4.1.5.1. Percentage of sodium and chloride in all parts of plants:

There are an increase in the Na^+ and Cl^- concentration in leaves and roots with increasing salinity levels in the root medium (nutrient solutions); (**Table 21)** shows the average percentage of chloride and sodium in pods, leaves, stems and roots of pea plants.

Table (21) average percentage of chloride and sodium (g/g plant x 100%) in all parts of pea plants at different lines:

Line	Pods		Leaves		Stems		Roots	
	Cl %	Na%	Cl %	Na%	Cl %	Na%	Cl %	Na%
Line 1	0.039c	0.034d	1.572d	1.424d	2.214de	1.909de	1.913c	1.477d
Line 2	0.033d	0.029d	2.227cd	1.420d	2.806d	2.850d	3.380bc	1.621d
Line 3	0.061b	0.052c	2.294cd	2.977cd	3.568c	3.076d	3.578b	2.746c
Line 4	0.31a	0.269a	3.307b	3.850b	4.829b	4.163c	3.685b	3.004b
Line 5	-	-	4.530a	4.905a	7.087a	6.110a	5.163a	4.451a
Line 6	0.288a	0.248b	2.654c	3.481c	4.537bc	4.635b	3.675b	2.306c

- **Averages in columns with the same small letters are not significantly different at P≤0.05 level, according to Tukey HSD.**

(Table 22) shows the output of the ANOVA analysis and whether they have a statistically significant difference between our group means at the significance level ($p < 0.05$); there is a statistically significant difference in the mean percentage of chloride and sodium at different plant parts.

Table (22) The output of the ANOVA analysis and whether they have a statistically significant difference between percentage of sodium and chloride in plant parts:

		Sum of Squares	df	Mean Square	F	Sig.
Sodium%	Between Groups	39.770	3	13.257	9.432	.000
	Within Groups	26.705	19	1.406		
	Total	66.474	22			
Chloride%	Between Groups	50.025	3	16.675	12.232	.000
	Within Groups	25.902	19	1.363		
	Total	75.927	22			

Significance level < 0.05

Chloride and sodium were compared in terms of percentage in the different parts of plants, as shown in **(Table 21)**, where it was noted that an increase nutrients in the nutrient solution led to a shortage of chloride and sodium percentage in parts of plants (Line 2 > Line 1), and increasing salinity in the nutrient solution led to the increase of chlorine and sodium in different parts (Line 5 > Line 4 > Line 3).

Line 6 has a high percentage of sodium and chloride ions that compared with Line 3, because of the complex interactions between chloride and sodium with copper, zinc and iron in pea plants.

Through **(Table 21)** have been both percentage of sodium and chloride have been high in the stems and the percentage of sodium in the leaves more than in the roots and the percentage of chloride in the roots more than in the leaves and these results consistent with (M. Shahid, et al. 2013), and the concentration of chloride and sodium in pods were less than other parts of pea plants

4.1.5.2. Calcium in plant parts:

In the cell, calcium can combine with bicarbonate to form the base, calcium bicarbonate that is an effective neutralizing agent for acids formed during cellular metabolism. Calcium is also an activator of the enzymes amylase and ATP. A primary role for calcium is as a cementing or cross-linking agent within the plant cell walls that adds to the general vigor and strength of the plant.

Generally the percentage of calcium in all parts of pea plant was decrease with increasing salinity, **(Table 23)** shows average percentage of calcium in all parts of pea plants at different lines, calcium percentage has increased when nutrient decreased in nutrient solution, because other nutrients in the nutrient solution hinder and compete in the absorption of calcium, so calcium concentration is found in plants of Line 2 is greater than plant of Line 1 , exception calcium percentage in roots are decreased, calcium has increased insignificantly in parts of plants for Line 4 more than plants of Line 3, but it decreased in line 5 (8.01ds/m) and the percentage of calcium in Line 6 has found a close to Line 3, exception the root of Line 6 more than the roots of Line 3 (1.74% , 1.57% respectively), that consistent with (Yorgancilar and Gül Yeğin, 2012).

Table (23) Average percentage of calcium (gr./gr. plant x 100%) in all parts of pea plants at different Lines:

Treatment	Pods	Leaves	Stems	Roots
Line 1	0.584d	2.13c	1.42c	3.76a
Line 2	0.674c	3.01a	1.84a	2.63b
Line 3	0.791b	2.08d	1.50b	1.57cd
Line 4	0.935a	2.33b	1.61ab	1.77c
Line 5	-	2.15c	1.23cd	1.56c
Line 6	0.701c	2.10d	1.38c	1.74c

- **Averages in columns with the same small letters are not significantly different at P≤0.05 level, according to Tukey HSD.**

(Table 24) shows the output of the ANOVA analysis and whether they have a statistically significant difference between our group means at the significance level is ($p < 0.05$); there is a statistically significant difference in the mean percentage of calcium at different plant parts.

Table (24) The output of the ANOVA analysis and whether they have a statistically significant difference between percentages of calcium in plant parts:

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.370	3	2.790	11.131	.000
Within Groups	4.762	19	.251		
Total	13.132	22			

Significance level < 0.05

The percentage of calcium in leaves, exception Line 1 has more than roots in different lines, then in stems , at last in pods, average percentage of calcium in all parts of pea plants at different Lines, each value is the average of 5 pipes,4 replications in each pipe , P ≤ 0,05, (**Table 23)** shows the result.

4.1.5.3. Magnesium in plant parts:

Magnesium is an essential macronutrient found from 0.2-0.4% dry matter and it is necessary for normal plant growth, Magnesium has an important role in photosynthesis because it forms the central atom of chlorophyll.

Average percentage of magnesium decreased with decreasing magnesium in nutrients solution , the plants in Line 1 has Mg% more than Line 2, while it decreased with increasing the salinity until 1500 ppm NaCl(Line 4), and It rose slightly when 3750 ppm NaCl(Line5), the **(Table 25)** shows the average percentage of magnesium in pea plants at different Lines.

Table (25) Average percentage of magnesium(gr./gr. plant x 100%) in pea plants at different lines.

Treatment	Pods	Leaves	Stems	Roots
Line 1	0.257	0.459	0.440	0.221
Line 2	0.253	0.378	0.359	0.217
Line 3	0.268	0.258	0.246	0.210
Line 4	0.234	0.237	0.225	0.203
Line 5	-	0.251	0.238	0.211
Line 6	0.449	0.295	0.276	0.213

(Table 26) shows the output of the ANOVA analysis and whether they have a statistically significant difference between our group means at the significance level is ($p > 0.05$); there isn't a statistically significant difference in the mean percentage of magnesium at different plant parts.

Table (26) The output of the ANOVA analysis and whether they have a statistically significant difference between percentages of magnesium in plant parts:

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.036	3	.012	2.173	.125
Within Groups	.106	19	.006		
Total	.143	22			

Significance level < 0.05

(Table 25) shows the relation between the nutrient (Mg) concentration in nutrient solution (Line 1 and Line 2), and between the different salinities (NaCl concentrations) with the average percentage of Mg in all parts plants at various Lines (Line 3,Line 4 and Line 5), It has been observed that the effect of increasing salinity lead to magnesium deficiency in different parts of the plant, but an increase in copper and zinc, as in Line 6 leads to increased magnesium insignificant, Stoyanova and Doncheva, (2002) **;**Yorgancilar and Gül Yeğin, (2012) support the result taken from Line 5 where the salinity increased to about 3750 ppm lead to a slight increase in the percentage of magnesium in parts plants .

4.1.5.4. Potassium in plant parts:

Maintenance of adequate levels of K is essential for plant survival in saline solutions. Potassium is the most prominent inorganic plant solute, and as such makes a major contribution to the low osmotic potential in the stele of the roots that is a prerequisite for turgor-pressure-driven solute transport in the xylem and the water balance of plants (Marschner, 1995).

(Table 27) shows average percentage of potassium in all parts of plants at different lines and shows the impact of the shortage of potassium ion concentration of potassium in different parts of the plants, where it is noted that the increase potassium in nutrient solutions led to increase the potassium in plant tissues (Line1 > Line2). As shown in **(Table 27)** that an increase in the salinity of the nutrient solutions lead to a shortage of potassium ion concentration in different tissues of plants.

Table (27) Average percentage of potassium (gr./gr. plant x 100%) in all parts of plants at different lines:

Treatment	Pods	Leaves	Stems	Roots
line 1	1.18b	4.73a	5.71b	4.94a
line 2	1.15bc	4.74a	6.09a	3.95b
line 3	1.09c	2.51bc	2.97c	2.19c
line 4	1.01d	2.10c	2.03d	1.71cd
line 5		1.63d	1.51e	1.42d
line 6	1.49a	2.62b	2.30cd	1.23d

- Averages in columns with the same small letters are not significantly different at $P \leq 0.05$ level, according to Tukey HSD.

(Table 28) shows the output of the ANOVA analysis and whether they have a statistically significant difference between line means. It was seen that the significance level is ($p < 0.05$); there is a statistically significant difference in the mean percentage of potassium at different plant parts.

Table (28) The output of the ANOVA analysis and whether they have a statistically significant difference between percentages of potassium in plant parts:

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	26.355	5	5.271	3.060	.038
Within Groups	29.287	17	1.723		
Total	55.642	22			

Significance level < 0.05

The shortage of the concentration of potassium ions in plants has been due to the increased concentration of sodium ions in the parts of the plants, which interact with the potassium and replaced in the tissues, when the concentration of NaCl was 3750 ppm, led to slightly increase in potassium in all parts of plants and it increased in Line 6 compared with Line 3. The results are consistent with previous the Nenova V. (2008), Yorgancilar and Gül Yeðin, (2012), and Tavori et al, (2004).

4.1.5.5. Phosphate in plant parts:

The interaction between salinity and phosphorus (P) nutrients in plants is complex. The interaction is highly dependent upon the plant species (or cultivar), plant developmental age, the composition and level of salinity and the concentration of P in the substrate (Zhukovskaya, 1973), according to analysis of variance (ANOVA), $\alpha \leq 0.05$, it was seen that the significance level is ($p < 0.05$), there is a statistically significant difference in the mean percentage of phosphate at different plant parts. **(Table 29)** shows the average percentage of phosphate in all parts of pea plants at different lines and describes the variation in the percentage of phosphorus in all parts of the plant peas, where it found that the concentration of phosphorus in the pods has reduced, when nutrient phosphorus decreased, as Line 1> Line 2, and it has observed increase the concentration of phosphorus in the pods when the salinity increased (Line 4 > Line 3), While the line 5 hasn't produce pods , but the concentration of phosphorus in the stems and leaves relied on salinity clearly, where the concentration of phosphorus in plants of Line 2 is more than plants of Line 1, because decreasing the salinity in plants of Line 2, and the concentration of phosphorus has decreased with increasing the salinity (Line 5 < Line 4 < Line 3), but concentration of phosphorus increased slightly in leaves of Line 5, the concentration of phosphorus in roots has decreased with increasing the salinity, while the concentration of phosphorus in Line 6 was highly in pods and stems compared to Line 3 due to increase the ions: copper , zinc and iron in nutrient solution and interaction among the ions.

Table (29) Average percentage of phosphate (gr./gr. plant x 100%) in all parts of pea plants at different lines.

Treatment	Pods	Leaves	Stems	Roots
Line 1	0.28b	0.42bc	0.57ab	1.11a
Line 2	0.15d	0.55a	0.74a	1.10a
Line 3	0.20cd	0.47ab	0.66ab	0.67b
Line 4	0.27bc	0.41bc	0.54ab	0.48bc
Line 5	---	0.42bc	0.50b	0.39c
Line 6	0.37a	0.39c	0.71a	0.46bc

- **Averages in columns with the same small letters are not significantly different at P≤0.05 level, according to Tukey HSD.**

(**Figure 18)** shows average percentage of phosphate in whole plants in different lines, it was found that the concentration of phosphorus in Line2 is greater than Line 1, due to the low salinity in the nutrient solution. Also shows a slight increase in plants of Line 5. The results are consistent with previous the Nenova, (2008), Yorgancilar and Gül Yeðin, (2012) and Tavori et al, (2004).

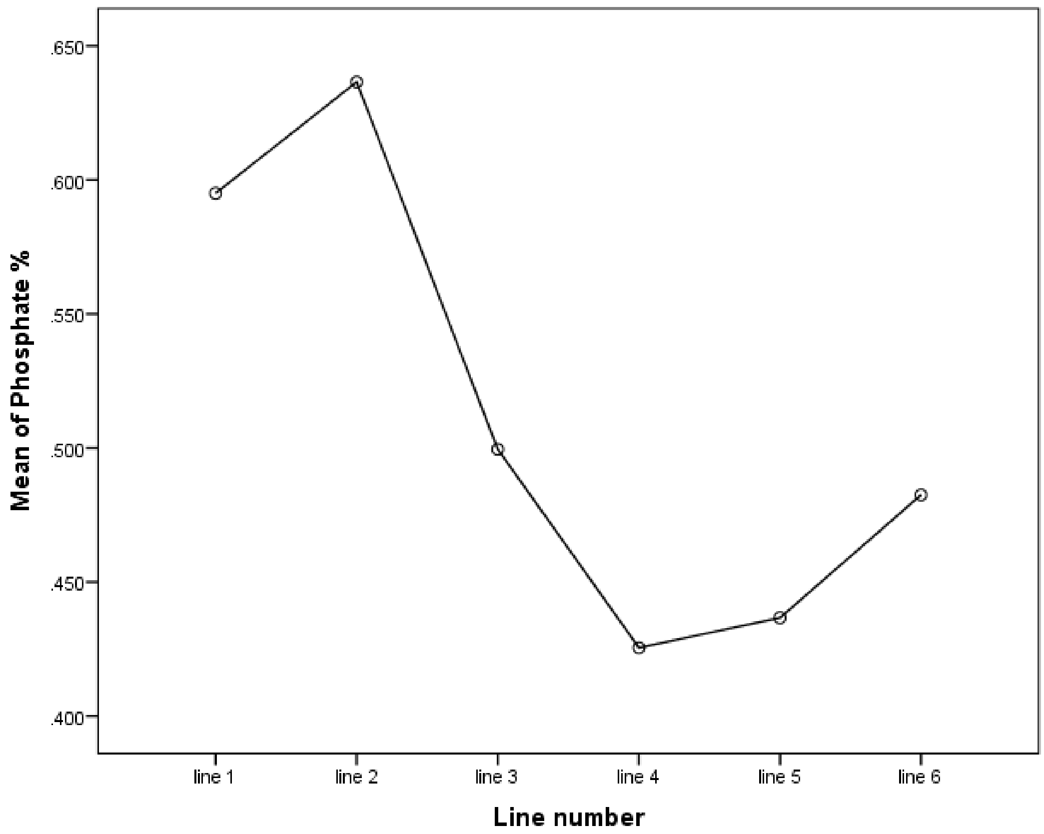


Figure (18) Average percentage of phosphate in whole pea plants at different lines, each value is the average of five pipes, four replications in each pipe, HSD Tukey, $P \leq 0.05$

4.1.5.6. Sulfate in plant parts:

Sulfates, which are usually involved in metabolic processes of plants as an integral part of proteins and enzymes, can also disrupt the metabolism of plants. They are usually more toxic than chlorides, according to analysis of variance (ANOVA), $\alpha \leq 0.05$, it was seen that the significance level is (p <

0.05), and there is a statistically significant difference in the mean percentage of sulfate at different plant parts. **(Table 30**) shows average of sulfate in all parts of pea plants at different lines, and describes the variation in the percentages of sulfate in various parts plants peas at different lines, where it was noted that the increase of salinity in the nutrient solutions has resulted in the increase sulfates in the leaves, stems, roots and pods, but sulfate decreased slightly in stems of plants in Line 4 (1.36%) , while the concentration of sulfates continued to rise in the roots with increasing salinity but it decreased in Line 5 (2.55%) , The concentration of sulfate in plants of Line 1 has been less than Line 2, and the reason for that interaction and competition between ions of nutrient solutions, which reduced available of sulfate in plants, while the concentration of sulfate in leaves and stems of the plants in Line 6 had more than Line 3 (1.02% and 1.74% respectively), but in pods less than Line 3 (0.11%) , and this shows the effect of ions of copper and zinc and iron in the nutrient solution on sulfates in plants, generally the concentration of sulfate in roots more than other parts of pea plants .

Table (30) Average percentage of sulfate (gr./gr. plant x 100%) in all parts of pea plants at different lines.

Treatment	Pods	Leaves	Stems	Roots
Line 1	0.30b	0.87bc	1.02d	4.35b
Line 2	0.30b	1.13a	1.09d	5.63a
Line 3	0.23bc	0.31e	1.37bc	3.39cd
Line 4	0.74a	0.74cd	1.36bc	4.02c
Line 5	------	0.94b	1.50b	2.55e
Line 6	0.11d	1.02ab	1.74a	3.08d

- **Averages in columns with the same small letters are not significantly different at P≤0.05 level, according to Tukey HSD.**

(Figure 19) describes average percentage of sulfate in whole pea plants at different lines, it was found that the concentration of sulfate in Line 2 more than Line 1, because of the interactions between the components of the nutrient solution that has a high concentration of salts, As noted, increasing the concentration of sulfates when salinity increased, but the increase in salinity of more than 3750 ppm of sodium chloride led to a decrease in the concentration of sulfate in plants.

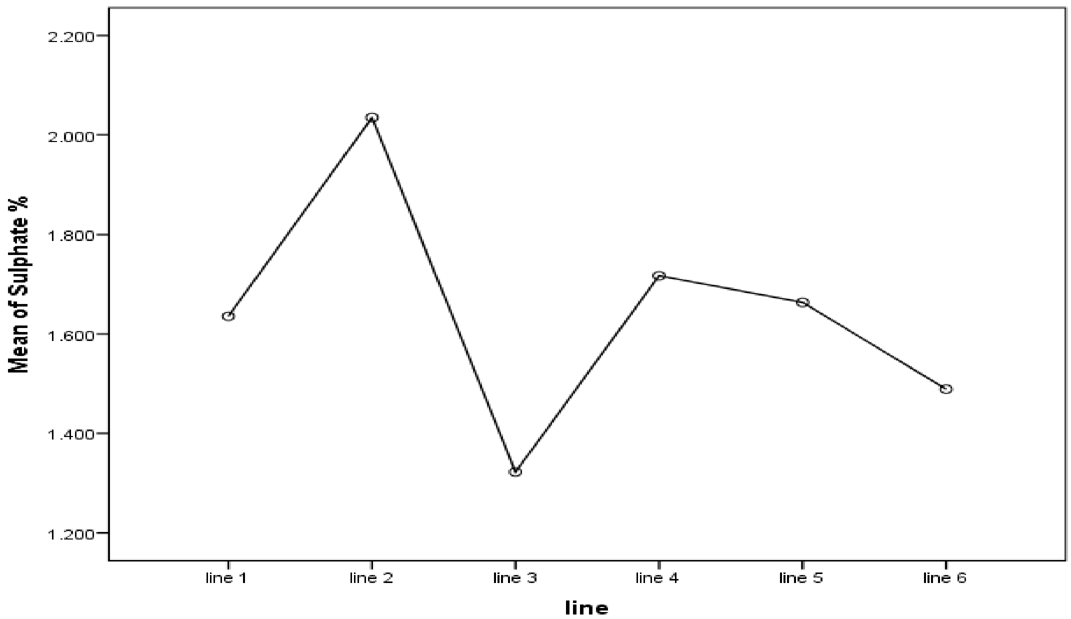


Figure (19) Average percentage of sulfate in whole pea plants at different Lines, each value is the average of five pipes, four replications in each pipe, according to HSD Tukey at $P \leq 0.05$.

4.1.5.7. Nitrate in plant parts:

The nitrogen is a part of every "amino" acid and therefore every protein. It is also a part of nucleic acids (RNA and DNA) and the chlorophyll molecule (necessary for photosynthesis). Nitrogen stimulates aboveground growth (stems and leaves) and helps the plant produce the "healthy green" color. It also stimulates the increase of proteins in fruits and grains and helps in the utilization of other nutrients including phosphorus and potassium, nitrogen, represented by NO^{3-}, is a vital component in all living systems because it is the most readily assimilated form of nitrogen by plants. According to analysis of variance (ANOVA), $\alpha \leq 0.05$, it is found that the significance level is ($p < 0.05$); there are statistically significant differences in the mean percentages of nitrate at different plant parts. (**Table 31)** shows average percentage of nitrate in all parts of pea plants at different lines and describes the variation of average percentage of nitrate in all parts of pea plants, It was noted that the concentration of nitrate has been a shortage in all parts of the plants when increased salinity, but noted a slight increase in the concentration of nitrate in leaves of plants at 1500 ppm NaCl (Line 4) became (0.71%) , while the nitrate concentration increased slightly in the stems of plants at 3750 ppm NaCl (Line 5) became (0.53%) (Nenova V. ,2008), and the concentration of nitrate in plants Line 6 high compared with Line 3, but in roots less than Line 3 (0.24% vs 0.16%).

Table (31) Average percentage of nitrate (gr./gr. plant x 100%) in all parts of pea plants at different Lines.

Treatment	Pods	Leaves	Stems	Roots
Line 1	1.16a	1.38a	0.75a	1.02a
Line 2	0.71b	0.89b	0.25c	0.47b
Line 3	0.37d	0.69c	0.23c	0.24c
Line 4	0.26de	0.71c	0.22c	0.17cd
Line 5	------	0.48d	0.53b	0.12d
Line 6	0.64bc	0.71c	0.52b	0.16cd

- **Averages in columns with the same small letters are not significantly different at $P \leq 0.05$ level, according to Tukey HSD.**

(Figure 20) describe average percentage of nitrate in whole plants at different Lines, It is noted that the concentration of nitrate has been reduced with increasing of salinity in the nutrient solutions, which reflected negatively on the concentration of nitrates, As noted in (**Figure 20)** low nitrate concentration led to decrease the concentration of the nutrient nitrogen in plants , and this is evident in the decline of Line 2 than Line 1, The surprisingly high concentration of nitrate in Line 6 compared with Line3.

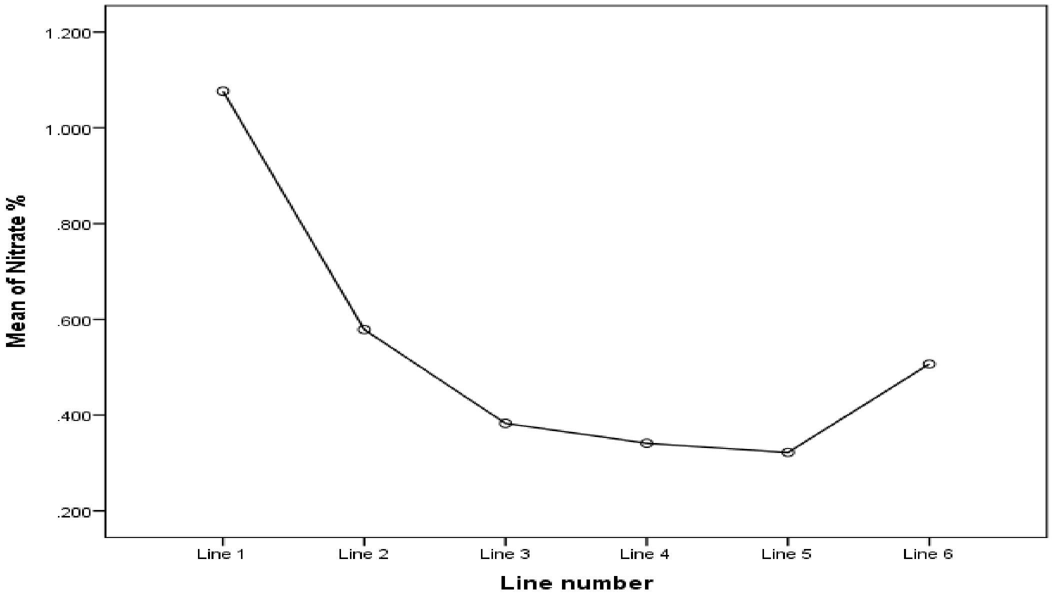


Figure (20) Average percentage of nitrate in whole pea plants at different lines, each value is the average of five pipes, four replications in each pipe, according to HSD Tukey at P ≤ 0.05.

4.1.5.8. Weight of micronutrients in plant parts:

The availability of most micronutrients depends on the pH and pE of the nutrient solution, in saline and sodic solutions, the solubility of micronutrients (e.g. Cu, Fe, Mn, Mo and Zn) is particularly low (Page et al., 1990), but not in all cases. Differences can be attributed to plant type, plant tissue, salinity level and composition, micronutrient concentration, growing conditions and the duration of study, consequently, the relationship between salinity and trace element nutrition is complex and salinity may increase, decrease, or have no effect on the micronutrient concentration in plants.

4.1.5.8.1. Copper in plant parts:

(Table 32) shows average concentration of copper ion Cu^{+2} in all parts of pea plants at different Lines, it was observed the concentration of copper has decreased when salinity increased in nutrient solutions , as it was observed that the concentration of copper in the roots more than leaves, the leaves more than stems and stems over pods in each Line .

Table (32) Average weight of copper (mg/Kg dry plant) in all parts of pea plants at different Lines:

Treatment	Pods	Leaves	Stems	Roots
Line 1	15.31b	22.63b	19.01b	25.25b
Line 2	13.36bc	19.6c	16.64c	21.96c
Line 3	10.44d	12.76d	11.8d	14.45d
Line 4	9.40d	12.2d	10.17de	12.79de
Line 5	-	9.1de	9.09e	10.32e
Line 6	26.93a	33.48a	30.32a	36.05a

- **Averages in columns with the same small letters are not significantly different at $P \leq 0.05$ level, according to Tukey HSD.**

(Table 33) shows the output of the ANOVA analysis and whether they have a statistically significant difference between our group means. It is found that the significance level is ($p < 0.05$); there are statistically significant differences in the mean copper weights at different plant parts.

Table (33) The output of the ANOVA analysis and whether they have a statistically significant difference between mean copper weight in plant parts:

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1303.083	5	260.617	27.364	.000
Within Groups	161.911	17	9.524		
Total	1464.994	22			

(Table 32) shows the decrease in the concentration of copper in the various parts of the plants in different pipes, and also shows that the concentration of copper in the roots has been more than other parts of the plants, and it was the largest concentration of copper(36.05 mg/kg dry plant) in the roots of plants in Line 6, and because the nutrient solution has its own contained a high concentration of copper (2.78 ppm Cu^{+2}), and the concentration of copper in plants of Line1 more than line 2, because the concentration of copper in the nutrient solution in line 2 is quarter concentration of copper in Line 1, these results are consistent with the findings of each (Nenova, 2008; Yorgancilar and Gül Yeðin, 2012), the largest concentration of copper has been at the roots and then leaves.

4.1.5.8.2. Iron in plant parts:

(Table 34) shows average concentration of Iron ion Fe^{+3} in all parts of pea plants at different Lines, it was been observed that the concentration decreased when salinity increased in nutrient solution , but Fe concentration increased when the salinity increased as Line5 (3750 ppm

NaCl), also it was observed that the concentration of iron in the leaves more than stems, the stems more than roots and pods .

Table (34) Average weight of Iron (mg/kg dry plant) in all parts of pea plants at different Lines:

Treatment	Pods	Leaves	Stems	Roots
Line 1	35.67a	147.98a	138.38a	39.98a
Line 2	32.15b	111.06b	101.73b	23.93b
Line 3	17.46c	44.25d	37.86c	16.34c
Line 4	9.00d	19.20e	18.18d	14.67c
Line 5	-	26.63e	24.95cd	15.19c
Line 6	31.88b	98.22c	96.96b	23.46b

- **Averages in columns with the same small letters are not significantly different at $P \leq 0.05$ level, according to Tukey HSD.**

(Table 35) shows the output of the ANOVA analysis and whether they have a statistically significant difference between our group means. It was seen that the significance level is ($p < 0.05$); there are a statistically significant difference in the mean iron weight at different plant parts.

Table (35) The output of the ANOVA analysis and whether they have a statistically significant difference between mean iron weight in plant parts:

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	13598.093	3	4532.698	3.225	.046
Within Groups	26706.061	19	1405.582		
Total	40304.154	22			

(Table 34) shows the decrease in the concentration of iron in the various parts of the plants in different Lines, and also shows that the concentration of iron in the leaves has been more than other parts of the plants, and it was the largest concentration of iron (147.90 mg/kg dry plant) in the leaves of plants in Line 1, and because the nutrient solution has its own contained a high concentration of iron(10.7 ppm Fe^{+3}), these results are consistent with the findings of each (Nenova, 2008; Yorgancilar and Gül Yeðin ,2012; and Tavori G. et al, 2004).

4.1.5.8.3. Manganese in plant parts:

(Table 36) shows average concentration of manganese ion (Mn^{+2}) in all parts of pea plants at different Lines, it was observed that the concentration decreased when salinity increased in nutrient solutions, but (Mn^{+2}) slightly increased insignificant at 3750 ppm in leaves and stems, as it was observed that the concentration of manganese in the leaves more than roots and stems, generally the roots had Mn^{+2} more than stems, and the stems more than pods in each line .

Table (36) Average weight of manganese (mg/Kg dry plant) in all parts of pea plants at different Lines:

Treatment	Pods	Leaves	Stems	Roots
Line 1	34.79a	47.42a	43.67a	44.74a
Line 2	26.03b	36.67b	33.07b	32.00b
Line 3	17.66c	22.10c	21.72c	25.22c
Line 4	16.30d	19.10d	18.76d	22.27d
Line 5	----	20.05cd	19.77cd	19.61e
Line 6	17.02c	22.32c	21.48c	20.95de

- **Averages in columns with the same small letters are not significantly different at $P \leq 0.05$ level, according to Tukey HSD.**

(**Table 37)** shows the output of the ANOVA analysis and whether they have a statistically significant difference between our group means. It is found that the significance level is ($p < 0.05$); there are statistically significant differences in the mean manganese weights at different plant parts.

Table (37) The output of the ANOVA analysis and whether they have a statistically significant difference between mean manganese weights in plant parts:

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1753.573	5	350.715	28.104	.000
Within Groups	212.145	17	12.479		
Total	1965.718	22			

(Table 36) shows the concentration of manganese in the various parts of the plants in different lines, and also shows that the concentration of manganese in the leaves has been more than other parts of the plants, and it was the largest concentration of manganese (47.42 mg/kg dry plant) in the leaves of plants in Line 1; because the nutrient solution has contained a high concentration of manganese (2.11 ppm Mn^{+2}), It was also observed that the concentration of manganese has increased slightly in Line 5 than Line 4, these results are consistent with the findings of each (Nenova, 2008; Yorgancilar and Gül Yeðin ,2012; and Tavori G. et al, 2004).

4.1.5.8.4. Zinc in plant parts:

Zinc is an essential micronutrient for plant growth and plays an important role in the catalytic part of several enzymes (Fageria NK. 2002), the threshold of Zn toxicity varies among plant species, time of exposure to Zn stress and composition of the nutrient growth medium. Plant growth inhibition Pisum sativum became inhibited after 1000 μM Zn application (Doncheva SZ, Stoyanova V. Velikova, 2001)

(**Table 38)** shows average concentration of zinc ion (Zn^{+2}) in all parts of pea plants at different Lines, it has been observed that the concentration has decreased when salinity increased in nutrient solution , as it was observed that the concentration of zinc in the roots more than leaves and stems, and the concentration of zinc was increased slightly in pea plants of Line 5 with comparing with Line 3 and Line 4, concentration of Zn in Line 6 more than the other line at different parts of pea plants, and largest Zn weight in roots of Line 6 (211.58 mg/kg dry plant) .

Table (38) Average weight of zinc (mg/kg dry plant) in all parts of pea plants at different Lines:

Treatment	Pods	Leaves	Stems	Roots
Line 1	31.21b	36.14b	35.11b	66.20b
Line 2	24.52c	33.45bc	32.24cd	57.76bc
Line 3	22.56cd	30.34c	30.13d	50.38cd
Line 4	20.01d	26.01d	24.28e	43.96d
Line 5	-----	32.81bc	32.26cd	39.44d
Line 6	45.79a	161.25a	162.40a	211.58a

- **Averages in columns with the same small letters are not significantly different at P ≤ 0.05 level, according to Tukey HSD.**

(Table 39) shows the output of the ANOVA analysis and whether they have a statistically significant difference between our group means. It was see that the significance level is ($p < 0.05$); there are statistically significant differences in the mean zinc weights at different plant parts.

Table (39) The output of the ANOVA analysis and whether they have a statistically significant difference between mean zinc weights in plant parts:

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	40419.085	5	8083.817	8.065	.000
Within Groups	17040.250	17	1002.368		
Total	57459.335	22			

4.1.5.8.5. Molybdenum in plant parts:

Molybdenum is needed by plants for chemical changes associated with nitrogen nutrition; it helps in the fixation of atmospheric nitrogen by the root nodule bacteria. Legumes need more molybdenum to fix nitrogen than to utilize nitrates Hristozkova M.,et al, (2006).

(Table 40) shows the output of the ANOVA analysis and whether they have a statistically significant difference between our group means. It was see that the significance level is ($p < 0.05$); there are statistically significant differences in the mean molybdenum weights at different plant parts.

Table (40) The output of the ANOVA analysis and whether they have a statistically significant difference between mean molybdenum weights in plant parts:

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9.276	5	1.855	3.647	.020
Within Groups	8.649	17	.509		
Total	17.926	22			

(Table 41) shows average weight of Molybdenum ion (Mo^{+6})(mg/kg dry plant) in all parts of pea plants at different Lines, it was been observed that weight of molybdenum decreased when salinity increased in nutrient solutions , as it was observed that weight of molybdenum in the stems more than leaves and roots, exception roots of Line 1 higher than other Lines and the concentration of molybdenum was increased slightly in pea plants of Line 5 comparison with Line 3 and Line 4, concentration of Mo in leaves (0.90 mg/kg dry plant) of pea plants in Line 6 more than the other parts at the same Line , and it was the largest concentration of molybdenum (3.48 mg/kg dry plant) in the roots of plants in Line 1, and because the nutrient solution has its own contained a high concentration of molybdenum (0.21 ppm Mo^{+6}).

Table (41) Average weight of molybdenum (mg/kg dry plant) in all parts of pea plants at different Lines:

Treatment	Pods	Leaves	Stems	Roots
Line 1	0.71a	1.23a	3.40a	3.48a
Line 2	0.62b	1.06b	2.43b	2.06b
Line 3	0.46c	0.57d	0.73cd	0.55d
Line 4	0.40cd	0.54de	0.71cd	0.51d
Line 5	-	0.57d	0.83c	0.61cd
Line 6	0.37d	0.90c	0.66d	0.69c

- **Averages in columns with the same small letters are not significantly different at $P \leq 0.05$ level, according to Tukey HSD.**

4.2. Summary:

4.2.1. Electrical conductivity:

Electrical conductivity of solutions at different sections of experiment have decreased with various times, indicating that pea plant parts have absorbed the salts from nutrient solutions, but they are increased salinity at a certain time (16th Feb. 2014) in Lines 1 and 2, because the concentration of potassium, and nitrates have increased in that time, see **(Table 8),** This result is consistent with (Pandolfi et al. 2012).

4.2.2. Nutrients concentrations in solutions:

The concentration of nutrients in all lines solutions decreased with over time, due to be absorbed by pea plants in growth chambers , but potassium and nitrate often had increased with over time, due to interact between the sodium and chloride with other nutrients, potassium was replaced with sodium, and nitrate was replaced with chloride, This result is consistent with (Silveira et al. 1999), and nitrate concentrations had increased due to nitrogen fixation because the pea plants are considered of leguminous plants, This result is consistent with (Fatima et al. 2008), see **(Tables 10-15)**.

4.2.3. Survival percentage:

The percentage of germination in pea plants was depended on the concentration of nutrients and salinity levels, there was a strong, negative correlation between salinity levels (8.01ms/cm) and germination percentage (50%), there wasn't a strong positive correlation between nutrients levels (4.3 and 3.14 ms/cm) and germination percentage (100% and 95% respectively).

4.2.4. Pods characteristics:

It was found that the number, fresh and dry biomass weight of pods are increased significantly in the solution which owned more nutrients and the number and weight of pods are decreased significantly when the increase of salinity in the nutrient solution, but number of pea pods has increased in plants of line 4 (contained 1500 ppm NaCl) compared with plants of line 3, it may be due to a period of premature aging and to maintain the life cycle of a physiologically, and this result supports the findings of (Duzdemir 2009), while plants Line 5 (containing 3750 ppm NaCl) had not produced pods, see **(Table 17)**, Pipe fifth in most lines was to produce fruit, more than other pipes see **Figures 6, 7 and 8 .**

4.2.5. Leaves characteristics:

It is found that the area of leaves and fresh and dry biomass weight increased significantly in the solution which owned more nutrients and the area and weight of leaves are decreased significantly when the increase of salinity levels in the nutrient solution, this is consistent with (Nenova, 2008 and Yorgancilar et.al., 2012 and Shahid et al, 2013), and in plants of line 6 (contained heavy metals) were owned area and fresh and dry biomass leaves weight less than plants of line 3 (contained 750 ppm NaCl), that because of the presence of nutrients, iron, copper and zinc in the nutrient solution, which have a significant role in biological processes in pea plants, but the concentrations of copper and zinc in a solution of the sixth line has been high, so the plants have been exposed to a case of toxicity, which block metabolism and production of leaves, see **(Table 18)**, the fifth pipe of each line, where it is often value more than the other pipes in all measurements on the leaves, and the reason for that, it is expected, the fifth pipe in each line was exposed to the sun more than other pipes show **Figures 9, 10 and 11 .**

4.2.6. Stems characteristics:

It was found that the length of stems and fresh and dry biomass weight of pea plants increased significantly in the solution which owned more nutrients , as the line 1 (contained cooper solution) more than line 2 (contained quarter cooper solution), and the length and weight of stems are decreased significantly when the increase of salinity in the nutrient solutions, and in the line 6 was owned stems length slightly more than Line

3 (control line), but the fresh and dry biomass weight of stems of pea plants less than control Line(L3), see **(Table 19)** . The fifth pipe of each line, where it is often value more than the other pipes in all measurements on the stems, and the reason for that, it is expected, the fifth pipe in each line was exposed to the sun more than other pipes shows **Figures 12, 13 and 14**. This is consistent with (Nenova, 2008 and Yorgancilar et.al, 2012 and Shahid et. al, 2013).

4.2.7. Roots characteristics:

It was found that the length of roots and fresh and dry biomass weight of roots increased significantly in the solution which owned more nutrients, as the line 1 (contained cooper solution) more than line 2 (contained quarter cooper solution), and the length and fresh and dry biomass weight of roots decreased significantly when the increase of salinity in the nutrient solution (750, 1500 and 3750 ppm NaCl), despite the salinity in Line 4 higher than Line 3, but the length and fresh and dry weight of roots in Line 4 more than Line 3, despite the fact that roots present in the aqueous medium, but they faced difficulty to absorb the water from the nutrient solution, so they were forced to increase the length of roots, and in the Line 6 was owned length of roots more than Line 3 (control), but the fresh and dry weight of root less than Line3, the fifth pipe of each line, where it is often value more than the other pipes in all measurements on the roots, and the reason for that, it is expected, the fifth pipe in each line was exposed to the sun more than other pipes.

4.2.8. Whole plants characteristics:

Fresh and dry biomass of pea plants had been decreased by increasing salinity significantly, as well as nutrients in the nutrient solution, but Line 6 (contained 3.26 ppm zinc and 3.2 ppm Cu and 2 ppm iron and 750 ppm NaCl) had lower average fresh and dry biomass, despite they are salinity less than other lines, the reason may be a toxic effect from copper and zinc, which are found in the nutrient solution, Which affected the biological processes and performance in plants, average relative water content(RWC) in various lines were decreased when salinity increased (L5 < L4 < L3 < L1< L2), see (**Table 21)**, although the salinity in the Line 6 was the least, but the relative water content less than Line 4, can be explained; copper and zinc had increased the transpiration process in leaves and impacted on membrane integrity which led to the decrease in the relative water content, This result is consistent with the (Stoyanova Z. and Doncheva S. (2002))

4.2.9. Sodium and chloride in plant parts:

It was noted that an increase nutrients of the nutrient solutions led to decrease percentage of chloride and sodium in parts of plants, as Line 2 more than Line 1, because the electrical conductivity at Line 1 more than Line 2, exception in the pods that led to increase the percentage of sodium and chloride(0.034% to 0.029% ,0.039% to 0.033% respectively) and increasing salinity in the nutrient solution led to the increase of chlorine and sodium in different parts (Line 5 > Line 4 > Line3), Line 6 has a high percentage of sodium and chloride ion that compared with other lines, see **(Table 22)**, due to the complex interactions between chloride and sodium with copper, zinc and iron in pea plants, the percentage of sodium in the leaves more than in the roots and the percentage of chloride in the roots more than in the leaves and these results consistent with (Shahid, et al. 2013), and the concentration of chloride and sodium in pods were less than other parts of pea plants.

4.2.10. Calcium in plant parts:

Calcium percentage has increased when nutrient decreased in nutrient solution, because quality of nutrients in the nutrient solution hinder and compete in the absorption of calcium, so calcium percentage found in Line 2 is greater than Line 1, exception, calcium percentage in roots decreased (3.76 , 2.63 respectively), calcium has increased insignificantly in parts of plants for Line 4 more than plants of Line 3, but it decreased in line 5(8.01ds/m) and the percentage of calcium in Line 6 has found a close to Line 3, exception the root of Line 6 more than the roots of Line 3 (1.74% , 1.57% respectively) see **(Table 24)** , this is consistent with Yorgancilar and Gül Yeğin (2012).

4.2.11. Magnesium in plant parts:

The percentage of magnesium was decreased with decreasing magnesium in nutrients solution , the plants in Line1 have Mg% more than Line2, while average percentage of magnesium decreased with increasing the salinity from 750 ppm NaCl(Line 3) to 1500 ppm NaCl(Line 4), and it rose slightly when 3750 ppm NaCl(L5), but an increase in copper and zinc, as in Line 6 led to increased magnesium insignificant, Yorgancilar and Gül Yeğin (2012) and Stoyanova and Doncheva (2002) supports the result taken from Line 5 where the salinity increased to about 3750 ppm lead to a slight increase in the percentage of magnesium in parts plants, see **(Table 26)**.

4.2.12. Potassium in plant parts:

It was noted that the increase in potassium nutrients in solution led to increase the potassium in plant tissues of Line 1 (contained 300 ppm K) more than Line 2 (contained 75 ppm K), and an increase in the salinity of the nutrient solutions led to a shortage of potassium ion concentration in different tissues of plants see **(Table 28)**, when the concentration of NaCl was 3750 ppm (Line 5) led to slightly increase in potassium in all parts of plants. The results are consistent with (Nenova , 2008), (Yorgancilar and Gül Yeðin , 2012), (Tavori et al, 2004).

4.2.13. Phosphate in plant parts:

It was found that the concentration of phosphorus in the pods has reduced, when nutrient phosphorus decreased, as Line 1(0.28%) more than Line 2 (0.15 %) , and it has observed increase the concentration of phosphorus in the pods when the salinity increased as Line 4 (0.27 %) more than Line 3 (0.20 %) , While the line 5 had not produced pods, but the concentration of phosphorus in the stems and leaves relied on salinity clearly, where the concentration of phosphorus in plants of Line 2 is more than plants of Line 1, because decreasing in salinity at plants of Line 2, and the concentration of phosphorus in the stems and leaves decreased with increasing the salinity (Line 5 < Line 4 < Line 3), but concentration of phosphorus increased slightly in leaves of Line 5, the concentration of phosphorus in roots has decreased with increasing the salinity, while the concentration of phosphorus in Line 6 was highly in pods and stems compared with Line 3 (0.37% and 0.71% respectively). The greatest phosphate percentage in whole plants was in Line 1 (0.64%). The results are consistent with Nenova V. (2008), Yorgancilar M. and Gül Yeðin Z. (2012), and Tavori G. et al. (2004).

4.2.14. Sulfate in plant parts:

It was noted that the increase of salinity in the nutrient solutions has resulted in the increase sulfates in the leaves, stems , roots and pods, but sulfates decreased slightly in stems of plants in Line 4 (1.36%) , while the concentration of sulfates continued to rise in the roots with increasing salinity but it decreased in plants of Line 5 (2.55%), The concentration of sulfate in plants of Line 1 has been less than Line 2, While the concentration of sulfate in leaves and stems of the plants in Line 6 had more than Line 3 (1.02% and 1.74% respectively), but in pods less than Line 3 (0.11%), generally the concentration of sulfate in roots more than other parts of pea plants, As noted, increasing the concentration of sulfates when salinity increased, but the increase in salinity of more than 3750 ppm of sodium chloride led to a decrease in the concentration of sulphate in plants.

4.2.15. Nitrate in plant parts:

It was noted that the concentration of nitrate has been a shortage in all parts of the plants when increased salinity, but it was noted a slight increase in the concentration of nitrate in leaves of plants at 1500 ppm NaCl (Line 4) became (0.71%), while the nitrate concentration increased slightly in the stems of plants at 3750 ppm NaCl (Line 5) became (0.53%) (Nenova ,2008), and the concentration of nitrate in plants Line 6 high compared with Line 3, but in roots less than Line 3 (0.16% vs 0.24%), It is noted that the concentration of nitrate has been reduced with increasing of salinity in the nutrient solutions, which reflected negatively on the concentration of nitrates see **(Table 32)**, As noted in **(Figure 19)** low nitrate concentration led to decrease the concentration of the nutrient nitrogen in plants , and this is evident in the decline of Line 2 than Line 1, the surprisingly high concentration of nitrate in Line 6 compared with Line3 .

4.2.16. Copper in plant parts:

It was observed the concentration of copper has decreased when salinity increased in nutrient solutions , as it was observed that the concentration of copper in the roots more than leaves, the leaves more than stems and stems over pods in each Line, and it was the largest concentration of copper(36.05 mg/kg dry plant) in the roots of plants in Line 6, and because the nutrient solution has its own contained a high concentration of copper(2.8 ppm Cu^{+2}),), and the concentration of copper in plants of Line1 more than 2 line, because the concentration of copper in the nutrient solution in line 2 is quarter concentration of copper in Line 1, these results are consistent with the findings of the each of the (Nenova, 2008;

Yorgancilar and Gül Yeðin, 2012), and the largest concentration of copper has been at the roots and then leaves.

4.2.17. Iron in plant parts:

It was observed that the concentration decreased when salinity increased in nutrient solution , but Fe concentration increased when the salinity increased as Line 5 (3750 ppm NaCl), also the concentration of iron in the leaves has been more than other parts of the plants, and it was the largest concentration of iron (147.90 mg/kg dry plant) in the leaves of plants in Line 1, and because the nutrient solution has its own contained a high concentration of iron(10.7 ppm Fe^{+3}) see **(Table 10 and 35) ,** These results are consistent with the findings of (Nenova, 2008), (Yorgancilar and Gül Yeðin, 2012), (Tavori G. et al, 2004).

4.2.18. Manganese in plant parts:

It was observed that the concentration decreased when salinity increased in nutrient solutions, the concentration of manganese in the leaves has been more than other parts of the plants, and it was the largest concentration of manganese (47.42 mg/kg dry plant) in the leaves of plants in Line 1, and because the nutrient solution has contained a high concentration of manganese (2.11 ppm Mn^{+2}), It was also observed that the concentration of manganese has increased slightly in Line 5 than Line 4, the results are consistent with (Nenova V. 2008), (Yorgancilar M. and Gül Yeðin Z. 2012), and (Tavori G. et al. 2004).

4.2.19. Zinc in plant parts:

It was been observed that the concentration of zinc in plants decreased when salinity increased in nutrient solution, as it was observed that the concentration of zinc in the roots more than leaves and stems, and the concentration of zinc increased slightly in pea plants of Line 5 comparing with Line 3 and Line 4, concentration of Zn in Line 6 more than the other Line at different parts of pea plants, largest Zn weight in roots of Line 6 (211.58 mg/kg) see **(Table 39)**.

4.2.20. Molybdenum in plant parts:

It was been observed that weight of molybdenum decreased when salinity increased in nutrient solutions , as it was observed that weight of molybdenum in the stems more than leaves and roots, exception roots of Line 1 higher than other Lines and the concentration of molybdenum was increased slightly in pea plants of Line 5 comparison with Line 3 and Line 4, concentration of Mo in leaves (0.90 mg/kg dry plant) of pea plants in Line 6 more than the other parts at the same Line, and it was the largest concentration of molybdenum (3.48 mg/kg dry plant) in the roots of plants in Line 1, and because the nutrient solution has its own contained a high concentration of manganese (0.21 ppm Mo^{+6}).

The results that have been reached were not far from the results of previous studies in general, but there is a slight discrepancy in terms of the values that were measured and it was due to weather conditions surrounding plants.

The experiment was obstruction and response some of the problems, and the most important problems that have affected plant life and came close to destroying the experiment, the case weather, because the plant peas require low temperature between (10-17 ° C) and high humidity, and the other problem is the birds that had been attacking seedlings and the type of system used in the cultivation of peas was a hindrance sometimes, because the roots of the plants remain continuously in the nutrient solution, which allows deposition of salts on the roots of plants, experience had already been implemented, and at the end of the summer of 2013, but because of the previous factors experiment has failed.

Conclusion:

The study is to identify the effect of salinity, nutrients and some heavy metals on pea plants in piped hydroponics in the natural conditions of climate without modification, and this study is important in terms of social and research, because it shows the extent of carrying a pea plant to stress caused by salinity and plant nutrients necessary within the different levels of salinity, The outcome of this experiment are as follows:

- The first experiment failed, project experience has been implemented in the summer of 2013, where the plants were grown peas in the previous six lines, and because of the difficult weather conditions on the possibility of afford peas. In terms of high temperature and low humidity occasion led to the death of all seedlings planted in piped hydroponic.

- The concentration of nutrients in solution decreases with time, but potassium and nitrate concentration have increased at a certain time, the electrical conductivity accompanied this change directly proportional, because peas from leguminous plants, so it can reduce the use of nitrogen fertilizer.
- The effect of nutrients on plant peas have been positive, but increased nutrient value that needs the plant does not lead to growth, yield and production more than usual, but may adversely affect the plants, Therefore, the excessive use of fertilizers has little benefit, it is inferred from comparison of growth, yield and production of peas in nutrient solutions containing Cooper solution and quarter strength of Cooper solution. If there is damage to the plant, and this is not only because the excessive use of fertilizers leads to environmental pollution, such as groundwater contamination.
- Growth, performance of peas have been negatively affected by high levels of salinity, while plants at 3750 ppm NaCl had not produce pods and survival percentage 50%, So it can be grown in a nutrient solution peas salt concentration which does not exceed 1500 ppm NaCl, In other words, farmers can exploit the water in regions that are salty waters in the cultivation of peas within the salinity which can be resisted and absorbed by plant.
- Growth and performance have declined under ideal concentration of iron and high concentrations of copper and zinc, but stems and roots length have increased, In view of this can be used both copper and

zinc nutrients to promote growth of roots, stems, and that by using limited concentrations, so that doesn't effect on growth, yield and production of peas.

- The increase in nutrients of the nutrient solution that contains a certain concentration of salt leads to high chlorine and sodium ions in the parts of the plant, so it must reduce the concentration of nutrients in this case because the increase in the concentration of chloride and sodium ions, especially chloride are causing to poisoning case of plants.
- In terms of nutrition, depending on the results influenced by the concentration of most elements and nutrients in parts of peas on the concentration of nutrients in the nutrient solution, so it can take advantage of this effect in the increase or decrease of certain nutrients such as reducing nutrients in the nutrient solution leads to increased calcium.

These results, which got similar to many previous studies, but there are differences in terms of chemical analysis of nutrients, as the values of concentrations or physical measurements differed from the results of previous studies, and the reason for that is the circumstances surrounding the experiment and the system that was used in the cultivation of plants, and type of nutrients solution , salinity levels ,planting date, cultivation duration and growth place differed from previous studies.

Recommendations of the Palestinian community in general, civil society and the private, and the application of this system on a large scale, because the system does not need a big space so that it can exploit the rooftops of agricultural production, and this system does not require a large quantity of fertilizer that lead to financial and environmental loss, as well as the exploitation with low quality water, and the recommendations for researchers:

- Cultivation of pea plants in the system (PHS), because according to the expected growth of the plants will be better because of preventing the deposition of salts on the roots that lead to block the absorption of water and salts necessary for plants, in addition to aeration roots.
- Study the effect of salinity on pea plants in hydroponics at different levels of salinity between the extent (1500 - 3750) ppm, in order to determine the maximum tolerable in peas without affecting the growth and performance of the plant.
- Study the effect of a few types (pairs) of nutrients within different levels of salinity, due to the existence of relationships and complex interactions occur between the ions in nutrient solutions and within the plant tissue.

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تأثير الملوحة، المغذيات، العناصر الثقيلة والمواد العضوية على نمو، عطاء وامتصاص البازيلاء المزروعة في نظام الزراعة المائية بالانابيب

إعداد
محمد اسعد سعيد الجدع

إشراف
أ.د. مروان حداد

قدمت هذه الرسالة استكمالاً لمتطلبات الحصول على درجة الماجستير في العلوم البيئية بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس فلسطين.
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إعداد

محمد اسعد سعيد الجدع

إشراف

أ. د. مروان حداد

الملخص

زيادة النمو السكاني في فلسطين، ينتج عنه استهلاك المياه وتآكل الأراضي الصالحة للزراعة وانخفاض في المياه العذبة الصالحة للزراعة، ولذلك الزراعة المائية قد تكون البديل الأنسب في هذه الظروف. الهدف الرئيسي من هذا البحث هو دراسة تأثير ثلاثة مستويات من الملوحة (750، 1500 و 3750 جزء بالمليون كلوريد الصوديوم)، مستويين من المغذيات (كوبر، 4/1 كوبر الحل) والمعادن الثقيلة (3.26 جزء في المليون الزنك، 3.20 جزء في المليون النحاس و 2 جزء في المليون الحديد) على النمو، المحصول وامتصاص نباتات البازلاء تزرع في الأنابيب، وقد استخدمت الأنابيب البلاستيك (PVC) بقطر ستة انشات في الزراعة المائية المغلقة، التي تحتوي على المواقع النمو، وأنابيب الحقن، والرشاشات، أنبوب الصرف الصحي، فضلا عن 120 الطبول لتر والمضخات (2/1 عدد الاحصنة). تم تقسيم التجربة إلى ستة خطوط التي تعتمد على مكونات المحاليل الغذائية على النحو المذكور أعلاه، وشمل كل سطر على خمسة أنابيب، كل أنبوب يحتوي على أربعة الشتلات، كما تم رفع جميع الأنابيب على حامل خشبي طوله 1 م . ثم زرعت البذور في التربة العضوية ما يقرب من 15 يوما، ثم وضعت الشتلات في اوعية أو كواوير مثقبة، وتم تثبت جذورها بواسطة الحجارة الصغيرة (ركائز) ونقلت إلى خطوط في مواضع النمو التي زودت بماء الصنبور لمدة أسبوع واستبدالها بالمحاليل المغذيات التي تم إعدادها وثم تشغيل المضخات لثلاث

مرات، لمدة 1.5 إلى 2 ساعة في اليوم. وقد أظهرت التجربة أن نسبة البقاء على قيد الحياة في الخطوط الستة: 100٪، 95٪، 90٪، 80٪، 50للقرون،على التوالي، وبعد ذلك النباتات

فصلت وقسمت إلى القرون والأوراق والسيقان والجذور، ومن ثم أجريت عليها القياسات الفيزيائية و الكيميائية . وقد لوحظ أن اختلاف نسبة الملح والمواد المغذية والمعادن الثقيلة تؤثر تأثيرا كبيرا على كميات بعض العناصر المغذية، ولها تأثير سلبي على الخصائص المورفولوجية للنباتات مع ارتفاع ملوحة المحلول المغذي، حيث ان النباتات تحت 3750 جزء في المليون لم تنتج ثمار القرون . وكان أفضل نمو ومحصول وكتلة حيوي في نباتات الخط رقم 1، حيث كان وزن الكتلة الحيوية الطازجة للقرون ، الأوراق ، السيقان والجذور (6.53، 1.81، 1.58، 1.60 جم / كجم من النبات)، على التوالي. وكان أقل نمو ومحصول وكتلة حيوي في نباتات الخط 5، حيث كان وزن الكتلة الحيوية الطازجة للقرون، الأوراق، السيقان والجذور (0.00، 0.23، 0.21 و g0.15/ كغم من النبات)، على التوالي. السيقان وجذور النباتات التي نمت في الخط 6، لقد كان لديها طول 20.21، 21.07 سم أكبر من الخط 3 (المرجع). وقد انخفض أداء النباتات تحت المحلول المغذي الذي كان لديه عوز، وانخفاض محتوى الماء النسبي مع زيادة الملوحة بين 79.10٪ و 86.00٪، حيث المحتوى المائي النسبي تعتمد مباشرة على ملوحة المحاليل، باستثناء الخط 6 كان أقل من المتوقع. زيادة تركيز كلوريد الصوديوم في المحلول المغذي التي أدى بشكل عام إلى زيادة تركيز أيونات الصوديوم وكلوريد في أجزاء النبات، وعلى وجه الخصوص زيادة تركيز الكلوريد في جذور (أكبر قيمة 5.16٪ في السطر 5) والصوديوم في الأوراق و السيقان (أكبر القيم 4.90٪ و 6.11٪ في السطر 5). تراكيز النيترات والبوتاسيوم في النباتات قد انخفض نتيجة لتأثير والتفاعل مع أيونات كلوريد و الصوديوم على التوالي.

نسبة الكالسيوم الموجود في الخط 2 أكبر من الخط 1، ولكن في جذور انخفض (3.76٪، 2.63٪ على التوالي)، في جذور الخط 6 أكثر من الخط 3 (1.74٪،1.57٪ على التوالي) ، و أكبر نسبة للفوسفات في النباتات كاملة في الخط 1 (0.64٪). بشكل عام الملوحة العالية أدت إلى تقليل العناصر في أجزاء النبات، ولكن زيادة بعض العناصر في أجزاء النبات مثل الفسفور في الجذور، وزادت عناصر أخرى في الأوراق أو السيقان، مثل المغنيسيوم والكالسيوم والفوسفات في القرون ، ولكن لوحظ زيادة طفيفة للنترات في أوراق في 1500 جزء في

المليون كلوريد الصوديوم (الخط 4) أصبح (0.71٪). تم العثور على أكبر الوزن للنحاس والزنك في جذور الخط 6 (36.05 و 211.58 ملغ / كغ النبات الجاف على التوالي). وقد أثرت المغذيات على البازلاء إيجابياً، ولكن زيادة المغذيات فوق حاجة النباتات لا تؤدي إلى نمو، محصول وإنتاج أكثر من المعتاد ،والتي انخفضت مع زيادة الملوحة، ولكن هناك تفاعلات معقدة بين الأيونات داخل النباتات. توصيات للمجتمع الفلسطيني، فمن المستحسن استخدام PHS لأنها لا تحتاج إلى مساحة كبيرة وتوفير الأسمدة ، وكذلك يمكن استخدام المياه التي لديها التوصيل الكهربائي حوالي 4 مللي / سم، بالإضافة إلى ذلك فإنه مجدياً اقتصاديا، والتوصيات للباحثين: دراسة تأثير الملوحة على نباتات البازلاء في الزراعة المائية على مستويات مختلفة من الملوحة بين مدى (1500 – 3750) جزء في المليون كلوريد الصوديوم، وذلك لتحديد الحد الأقصى مقبولة في البازلاء دون التأثير على نمو وأداء النباتات ودراسة تأثير لأنواع قليلة (أزواج) من المغذيات ضمن مستويات مختلفة من الملوحة، وذلك بسبب وجود علاقات وتفاعلات معقدة تحدث بين الأيونات في المحاليل المغذية وداخل الأنسجة النباتية.