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الشكر والاهداء

لابد لنا ونحن نخطو خطواتنا الأخيرة في الحياة الجامعية من وقفة نعود إلى أعوام قضيناها في رحاب الجامعة مع أساتذتنا الكرام الذين قدموا لنا الكثير باذلين بذلك جهوداً كبيرة لتذليل كل العقبات التي واجهتنا، بعلمهم ورحابة صدرهم.

الى الذين مهدوا لنا طريق العلم والمعرفة ..... لكم مني جزيل الشكر بكل ما تحمله الكلمة من معنى.

الى جميع أساتذتنا الأفاضل وأخص بالذكر الدكتور جميل حرب حيث لم يدّخر جهداً في إبداء نصائحه وتحفيزي لإتمام ما قدمته بطريقة سليمة.

وقبل أن نمضي أتقدم بأسمى آيات الشكر والإمتنان والتقدير والمحبة إلى والدي ووالدتي اللذان لولاهما ما وصلت الى هنا.

كما أتقدم بجزيل الشكر إلى أساتذتي الموقرين في لجنة المناقشة رئاسة وأعضاء لقبولهم مناقشة هذه الرسالة

وأخيراً، أتقدم بجزيل شكري إلى كل الأهل و الأصدقاء الذين مدّوا لي يد العون والمساعدة في إتمام هذه الدراسة على أكمل وجه.

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Abstract

The intensive agriculture sector is one of the most important economic sectors in West Bank and Gaza Strip - Palestine, which is concentrated in the areas of Tulkarm, Qalqilya, Jenin, Jericho, and Gaza strip. The problem of intensive fertilization using inorganic chemical fertilizers is one of the most important problems facing this sector. Farmers in these areas rely heavily on the use of chemical fertilizers, as they think that it is the most suitable for supplying plants with all their nutritional needs. In addition, farmers believe that plants at the end of each season deplete all nutrients in the soil. This thought is directly related to the lack of equipped laboratories, which have the ability to examine the soil and plant tissues for their nutritional contents. Furthermore, the lack of information for farmers and extension officers about proper fertilization programs plays a role in this problem.

This study was conducted to evaluate the current nutritional programs (fertilization programs) in greenhouses in Tulkarm, Qalqilya, Jenin and Jericho regions. Sweet pepper cultivated in greenhouses was chosen, and at least three farms were selected in each geographical area. Soil samples were taken at three stages, before planting, during the fruiting phase and at the end of the season. All samples were dried and grinded in preparation for analyses for their minerals content using ICP-OES spectrophotometer. Further, soil pH and the salt content (electrical conductivity) of soil samples were measured. In addition, information about fertilization programs used by farmers has been collected.

The results showed that all the farms included in the research contain high levels of few essential elements, specially Nitrogen (in leaves tissues), Phosphorus and Magnesium. In addition, imbalanced ratios between few trace elements were found. Such imbalances affect negatively the uptake for some important elements such as Calcium, thus affecting the growth and development of the plant. This, in turn, indicates that the excessive use of chemical fertilizers, which makes the current fertilization programs unbalanced, is expensive and harmful to plants and soil, and may entails harmful effects on consumers.

Accordingly, short- and long-term solutions were proposed that may help solving the problem of excessive fertilization and its negative consequences. The most important solutions could be: the establishment of laboratories with the ability to analyze thousands of samples for their contents of minerals. In addition, research projects to design balanced fertilization programs based on the characteristics of each soil type, geographical area, plant type and growth phase is highly needed. This will also automatically reduce the economic losses due to fertilizers loss.

ملخص الدراسة

يعتبر قطاع الزراعة المكثفة من أهم القطاعات الاقتصادية الموجودة في فلسطين، والذي يتركز في مناطق طولكرم، قلقيلية، جنين وأريحا وكذلك قطاع غزة. وتعد مشكلة التسميد المكثف باستخدام الأسمدة الكيميائية غير العضوية من المشكلات الأهم التي تواجه هذا القطاع. حيث يعتمد المزارعون في هذه المناطق على استخدام الأسمدة الكيميائية بكثرة ظنا منهم أنها الأنسب لتغذية النباتات وتوفير جميع احتياجاتها من عناصر الغذائية. ولكن المشكلة تكمن في هذا الاستعمال المكثف لها لاعتقادهم أن النبات في نهاية كل موسم يستنفذ جميع العناصر الغذائية الموجودة في التربة، وهذا له علاقة مباشرة بعدم توفر مختبرات مجهزة تجهيزا كاملا بحيث يكون لها القدرة على فحص مكونات التربة والأنسجة النباتية لمحتوياتها التغذوية، بالإضافة إلى افتقار المزارعين والمرشدين الزراعيين إلى المعلومات التي يحتاجونها حول التسميد وأنواعه.

وقد جاءت هذه الدراسة لتقييم البرامج الغذوية الحالية (برامج التسميد) المتبعة في مزارع البيوت المحمية في كل من المناطق التالية: طولكرم، قلقيلية، جنين وأريحا. تم اختيار نبات الفلفل الحلو المستزرع في البيوت المحمية، وتم تحديد ثلاث مزارع على الأقل في كل منطقة جغرافية، وتم أخذ عينات ترب على ثلاثة مراحل: قبل الزراعة، منتصف نمو الموسم (مرحلة الإثمار) وبعد نهاية الموسم، بالإضافة إلى عينات الأوراق التي تم أخذها في منتصف نمو الموسم. جميع العينات تم تجفيفها وطحنها وتم فحص محتواها التغذوي من العناصر الغذائية المهمة للنبات . بالإضافة لذلك تم قياس درجة الحموضة للترب ومحتواها الملحي. وبعد ذلك تم جمع المعلومات من المزارعين حول برامج التسميد التي تم استخدامها.

أظهرت النتائج أن جميع المزارع التي شملها البحث تحتوي على نسبة عالية من بعض العناصر الأساسية التي يحتاجها النبات وخصوصا عناصر النيتروجين (في الأنسجة الورقية) والفسفور والمغنيسيوم، بالإضافة إلى عدم توازن االعناصر الصغرى مما يؤثر سلبيا على امتصاص النبات لبعض العناصر المهمة مثل الكالسيوم، وبالتالي التأثير على نمو وتطور النبات. وهذا بدوره يدل على أن الإستعمال المفرط للأسمدة الكيميائية هو ما يجعل برامج التسميد المستعملة غير متوازنة ومكلفة وذات ضرر على النباتات المستزرعة والترب وربما كذلك المستهلك.

وبناءا عليه تم اقتراح عدد من الحلول قصيرة المدى وأخرى طويلة المدى التي من شأنها أن تحل اشكالية التسميد المفرط وما يترتب عليه من نتائج سلبية. أهم هذه الحلول أو التوصيات: انشاء مختبرات ذات قدرة على تحليل محتويات الترب والأنسجة النباتية من العناصر الغذوية، بالإضافة إلى العمل على استكمال ابحاث علمية واسعة في هذا المجال للتمكن من الحصول على برامج تسميد متوازنة تعتمد على خصائص كل منطقة جغرافية من أجل تحسين نوعية وكمية الإنتاج في البيوت المحمية. وهذا أيضا سوف يؤدي تلقائيا إلى تقليل الأضرار الاقتصادية المصاحبة لهذه المشكلة.

Chapter One: Introduction

Background

Fertilization is the process by which a natural or synthetic, chemical-based substance is added to plant or soil in order to enhance plant growth and soil fertility (Maximum yield), thus fertilization (organic and non-organic) can be considered as agricultural technology, that is necessary for having a proper yield crop (quality and quantity) (Savci, 2012). But the intensive and uncontrolled use of fertilizers would have many negative side effects on human health and environment including water, soil and air (Savci, 2012).

Bell pepper (*Capsicum annum* L.) belongs to the Solanaceae family that includes also tomato (*Lycopersicon esculentum*) and eggplant (*Solanum melongena* L.) (Basu et al., 2003). This plant species was first cultivated in Central America and Mexico, but now it's produced globally with a production rate of 25 million metric tons (Abu Zahra et al., 2013). Bell pepper can be consumed fresh or processed into sauces and powders, and it is considered as a fruit with high nutritional value, due mainly to their minerals and vitamins content (Naidu, 2003).

Bell pepper was chosen for this study because Palestinian farmers are expanding its culture in greenhouses, and it is considered as one of the most promising intensive cultures in Palestine (Mohamed, 2014). Bell pepper is planted mostly in the greenhouses in the agricultural regions such as Jericho, Qalqilya, Tulkarm and Jenin. Moreover, it is a good fruit to study under experimental conditions, since it was found by some studies that bell pepper can tolerate different levels of saline conditions (Mohamed, 2014).

Farmers in Palestine are tending to use the greenhouses for cultivating bell pepper in order to increase their productivity, which is attributed to warm temperatures inside greenhouse, mainly during autumn and winter seasons, in addition to the intensive use of chemical fertilizers and pesticides. Moreover, the high density of plantings leads to substantial increases in the productivity to levels that sometimes exceed 50% of the productivity levels of the developed countries.

Despite the high production rate in greenhouses, the intensive use of chemical fertilizers and agricultural pesticides cause the most problematic issue. A previous study (Harb et al., 2016) that was based on interviews proved that the Palestinian farmers use excessive amounts of chemical fertilizers and pesticides. Such usage is believed to be one of the reasons for the health problems affecting the local consumers, and also for difficulties in exporting fresh products from Palestine.

Study problem:

The research problem of the study is the intensive fertilization using inorganic chemical fertilizers and its side effects on plant growth and yield.

Study aim and objective:

This study aims to assess the current fertilization programs used by the Palestinian farmers in Jenin, Tulkarm, Qalqilya and Jericho governorates, for a final aim of optimizing the mineral nutrients programs for bell pepper

Study hypotheses:

1. Palestinian farmers add chemical fertilizers much more than needed to plants to meet their needs of the nutritional elements.
2. The intensive addition of chemical fertilizers causes economic losses and health risk.

Chapter two: Literature Review

In order to achieve successful growth and development for vegetative and reproductive tissues, plants must uptake essential elements from their environment, particularly from the soil (Grusak et al., 2001). An element is considered to be essential if it is needed for plant metabolism and life cycle completion. Other category includes "beneficial elements", and these are elements that are not required by all plants; they may enhance plant's growth and may help in resisting stresses. In addition, they also may improve productivity and/or quality of certain plants, but their absence has no negative impact on the plant life cycle (Pilon-Smits et al., 2009). In this category there are few elements including silicon, cobalt, sodium, selenium, and vanadium (McGrath & Penn, 2014). Accordingly, there are 17 elements that are considered to be essential elements (C, H, O, Ca, K, Mg, N, S, P, Cl, B, Zn, Cu, Fe, Mn, Mo, Ni); three of them, namely carbon (C), oxygen (O) and hydrogen (H), are non-mineral elements, and are taken up from water and air (Tripathi et al., 2014); these constitute the highest concentration in plants. The mineral elements that are absorbed by plants roots from the soil (Tripathi et al., 2014) are divided into two main groups: macronutrients (nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), and sulfur (S)), and micronutrients (copper (Cu), manganese (Mn), iron (Fe), boron (B), nickel (Ni), molybdenum (Mo), chloride (Cl) and zinc (Zn)). These two groups are named upon their abundancy in plant's tissue: macronutrient concentration in plant tissue is more than 0.2 % of the plant's dry weight basis, whereas the micronutrient concentration in plant's tissue is less than 0.01 % (McGrath & Penn, 2014).

2.1. Macronutrients

The roles of these nutrients are numerous including protein synthesis, photosynthesis (as integral elements of chlorophyll), osmoregulation, membrane and cell wall stabilization. Further, they also have vital roles in plant metabolism, as some macronutrients are constituents of proteins, coenzymes and phytohormones (Hawkesford et al., 2012). In this respect, they are known to influence crop yield, improve growth and quality for cultivated plant species (Tripathi et al., 2014).

2.1.1. Primary macronutrients:

Nitrogen (N): nitrogen constitutes 1.5- 2 % of plant dry matter (McGrath & Penn, 2014), with approximately 16 % of plant total proteins (Tripathi et al., 2014). The main source for the available nitrogen in our planet is atmospheric N_2, which is fixed by rhizobia bacteria through an energy intensive process (Peoples et al., 1995). However, most plants, other than N-fixing plants, can only use N in the form of nitrate (NO_3^-) or ammonium (NH_4^+) (McGrath & Penn, 2014), which necessitates the addition of fertilizers for cultivated plants (Kant et al., 2010). Nitrogen is considered to be one of the most important elements for plants since it is needed for the biosynthesis of chlorophyll, nucleic acids and amino acids. Moreover, it is important not only for energy transformation in the metabolic processes, but also it improves and increases the fruit and seed production (Kant et al., 2010).

Phosphorus (P): P is a nonmetallic element that is taken by the plant in the form of phosphate (Schachtman et al., 1998). Plants can only utilize phosphate from the soil in the forms of either dihydrogen phosphate ($H_2PO_4^-$) or hydrogen phosphate (HPO_4^{-2}); the form is influenced highly by soil pH (Schachtman et al., 1998). Usually phosphorus availability in soil is low, thus it is added as organic phosphate to the soil (Sharpley, 2000). The importance of phosphorus is directly related to its role as an important constitute of cell membrane, DNA, RNA and ATP.

Potassium (K): Alkaline, quite mobile macronutrient that is found mainly in the younger parts of the plant (Wakeel et al., 2011). Potassium has roles in many physiological processes in plant life cycle, such as osmoregulation, photosynthesis, protein synthesis, enzyme activation, and transportation. Further, it has roles in pH stabilization, which is required for organic anions diffusion and enzymatic reactions. Moreover, it was found that potassium can minimize risk of drought stress and some agronomic problems such as heavy metals stress (Wang et al., 2013).

2.1.2. Secondary macronutrients

Calcium (Ca): Ca is an immobile element that is used in the form of calcium ions (Ca^{+2}), and required for many biological functions in plants, including cell growth, division and elongation. Moreover, it contributes to enzyme activation and salt balance; it is also involved in developing plant tissue resistance (Poovaiah, 1986).

Magnesium (Mg): Mg is a mobile element, which is used by plants as a cation (Mg^{+2}). It constitutes an integral part of chlorophyll molecule, but also important for enzymes activation, protein synthesis and respiration process (Uchida, 2000).

2.2. Micronutrients

Most of the micronutrients have key roles in activating enzymes or structural roles in protein stabilization (Hansch & Mendel, 2009) The functions of few micronutrients are summarized below: Copper (Cu) is taken up by plants in the form of Cu^{+2}, and needed for chlorophyll synthesis and serve as enzyme catalyst (Uchida, 2000). Manganese (Mn) has a role similar to copper and it is taken by plant in the form of Mn^{+2} and Mn^{+3} (Uchida, 2000). Boron (B) is taken in the form of H_3BO_3, BO_3^- and B_4O_7-^{2} (Hajduk et al., 2017). It has essential role in pollen germination, growth of new meristematic tissue, and translocation on nitrogen, phosphorous, sugars and starches (Uchida, 2000). Molybdenum (Mo) is taken by plants in the form of MoO_4^{-2} (Kaiser et al., 2005), and is required for the activation of the enzymes responsible for the reduction of NO_3^- to NH_4^+ in plants (Uchida, 2000). Moreover, it is required for N fixation by the rhizobia bacteria (Uchida, 2000). Chloride (Cl) is taken by plants in the form of Cl^- and it is essential for activating enzymes, improving drought and diseases resistance (McGrath & Penn, 2014). Furthermore, it regulates the stomata guard cells (McGrath & Penn, 2014). Finally, zinc (Zn) is taken by plants as Zn^{+2}, and required for chlorophyll synthesis, growth hormones (auxins) and carbohydrates production (McGrath & Penn, 2014).

2.3. Nutrients interactions

As each essential element has its unique role in plant life cycle completion, the interaction between these elements could affect significantly plants growth and production. As stated by Fageria (2006), the effect of nutrient interactions may be synergistic (positive effect) or antagonistic (negative effect). The interactions happen between nutritional elements when the addition of one element affects the absorption and the utilization of the other elements, especially when one element is found in high concentration that is much more than needed compared to other elements. The interactions have two types:

1. The interaction between ions that can form chemical bonds together and as a result precipitates forming complexes. As an example, adding calcium to acid soil will decrease most micronutrients, except molybdenum (Robson & Pitman, 1983).
2. The interaction between the ions that have similar chemical properties (similar charge, size, etc.), which lead these interacted elements to compete for site of absorption, function and transport on root surface or within the plant parts. This type on interaction is more common between calcium, potassium, sodium and magnesium ions (Robson & Pitman, 1983).

Many other factors besides elements concentrations can also affect the interactions between the elements. Some of these factors are temperature, soil moisture and aeration, soil pH, light intensity, root system, plants species, and respiration rate (Fageria, 2006).

2.4. Chemical fertilizers and soil fertility

The intensive use on chemical fertilizers can leave behind many environmental problems and can affect water, soil and air:

- The effect of chemical fertilizers on air:

Uncontrolled usage of chemical fertilizers, specially nitrogen fertilizers will cause air pollution by nitrogen oxides (NO, N_2O and NO_2) emissions. Moreover, ammonium fertilizers can result in NH_3 evaporation which will damage vegetation, and can be oxidized into nitric acids and sulfuring acid causing acid rain which will also damage vegetation and organisms (Savci, 2012).

- The effect of chemical fertilizers on soil:

The direct and indirect application of chemical fertilizers would affect the chemical, physical and biological properties of the soil (Belay et al., 2002). Specially fertilizers with high levels of sodium and potassium would negatively affect soil pH and cause soil structure deterioration (Savci, 2012). Studies also showed that chemical fertilizers would affect microbial biomass and numbers of bacteria (Belay et al., 2002).

- The effect of chemical fertilizers on water:

Nitrogen fertilizers have the major effect on water environment, especially when nitrogen accumulate and leach to reach the depth of soil. Since nitrate is negatively charged it can reach ground water causing its pollution. It may also reach drinking water causing dangerous disease in infants “methemoglobinemia” when found in high concentrations (Savci, 2012).

As noted above, essential elements must be added in forms that are available to plants. Most of these nutrients are found in the soil, although part is applied to leaves. Available nutrients are dissolved in soil water, and if exist in non-available from (e.g. Ca) plants may show deficiency symptoms. Accordingly, farmers usually add plant nutrients in the form of chemical fertilizers. The direct delivery of fertilizers through drip irrigation demands the use of soluble fertilizers and pumping and injection systems for introducing the fertilizers directly into the irrigation system (Latina, 1999). Concerning forms of chemical fertilizers; specially forms that contain sodium and chlorine such as potassium chloride fertilizer, which vary widely, there are still no studies in Palestine to define the best forms.

As for soil fertility, which is defined as “the quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants or crops” (Alkhouri, 2014), manmade activities (e.g. agricultural and industrial activities) and natural causes (e.g. climatic change) affect highly soils, and may render them unproductive. Among the negative effects are the soil erosion and salinization. In Palestine, salinization is an urgent issue in certain regions such as Jericho and Gaza strip. The causes of salinization are divers, but intensive agriculture techniques, and the excessive use of agrochemicals (e.g. synthetic chemical fertilizers) are among the major causes (Alkhouri, 2014). In Florida, one of their goals is to minimize the possible movement of nitrate-nitrogen from cultivated plants to watersheds through the use of controlled-release fertilizers without negatively impacting yields or quality (Simonne & Hutchinson, 2005).

Concerning sweet pepper, which is the subject of our case study, Sabli et al. (2010) noted that higher pepper fruit yield is due to higher fertilizer use. Further, the increase in nitrogen addition increases its uptake by plants which will also stimulate the uptake of potassium and phosphorus through synergistic effect (Qawasmi, et al, 1999).

Concerning the economic significance of intensive agriculture in Palestine, the optimization of the usage of agrochemicals in order to guarantee productivity, but also to conserve soils and prevent any harm to soils and consumers is highly needed.

Chapter three: Experimental part

3.1. Selection of farms:

Farms cultivating sweet pepper in greenhouses were chosen in four regions (Jenin, Tulkarm, Qalqilya and Jordan valley). In each region three farms (three replicates) for the selected plant type (Bell pepper) were included in the study. Following analyses, farms from Tulkarm and Qalqilya were clustered together, as few farms in both regions terminated their production cycle before the end of the season. Accordingly, in the results sections, both regions are referred to as TUL&QAL.

3.2. Collecting samples:

For each geographic region, and in each farm, soil samples were collected (randomly from the farm) from the soil upper layer (20- 30 cm soil depth) in three stages: Stage one: before planting, stage two: after planting, during the fruiting, stage three: at the end of the season.

In addition to soil samples, plant tissue samples were collected during the growing season. Three samples (three replicates) were taken from each farm, and each sample is composed of 20 complete leaves. According to that, approximately 12 months were needed to collect all samples.

3.3. Soil sampling and plant material:

All samples (soil and leaves samples) were dried and prepared (soil samples were also sieved) according to the standard methods used in the laboratories of Munich University of Applied Sciences, Freising – Germany.

3.4. Chemical analyses of samples:

The collected samples were analyzed for their contents of plant nutrients using standard protocols as described below.

3.4.1. Analysis of soil samples:

3.4.1.1. Determination of soil pH:

12 g of air-dried soil sample were mixed with 30 ml distilled water, mixed, and incubated for 90 minutes. Further, samples were manually shacked for a second time after 60 minutes. Measurements were conducted using InoLab pH meter ((WTW/ STH 600); pH, Level 2).

3.4.1.2. Determination of Mg, Na, Cu, Mn, Zn, and B using CAT (Calcium chloride DTPA) extract:

CAT stock solution: the solution was prepared by adding 14.7 g calcium chloride dihydrate or 21.9 g calcium chloride hexahydrate, and 7.88 g DTPA in one-liter beaker with 800 ml of water and heated at 80 ºC. Solution was cooled and completed to one liter with deionized water. The final concentration of the solution is 0.1 M $CaCl_2$ and 0.02 M DTPA.

CAT final working solution: 100 ml from the CAT stock solution were added to one-liter beaker and the volume completed to one liter with deionized water. The final concentration of the working solution is 0.01 M $CaCl_2$ and 0.002 M DTPA.

Determination Protocol: 30 g of air-dried sample were mixed with 300 ml of the pre-prepared CAT solution, shacked for 90 min, followed by filtration. The filtrate was used for nutrients analysis using ICP-OES spectrophotometer.

3.4.1.3. Determination of P and K using CAL (Calcium- Acetate- Lactate) extraction:

CAL stock solution: the solution was prepared by adding 770 g calcium lactate ($C_6H_{12}CaO_6.5H_2O$), and 395 g calcium acetate ($(CH_3COO)_2Ca.H_2O$), dissolved in three liters of hot water and then cooled. 895 ml of acetic acid were added and volume was completed to 10 liters with water

CAL final working solution: 10 liters from the CAL stock solution were diluted with 50 liters of water and the solution final concentration was 0.05 M calcium acetate and lactate, and 0.3 M acetic acid.

Determination Protocol: 15 g air-dried soil were mixed with 300 ml of the pre-prepared CAL working solution; shacked for 60 minutes, followed by filtration. The filtrate was used for nutrients analysis using ICP-OES spectrophotometer.

3.4.1.4. Determination of salt content of soil (electrical conductivity (EC)):

30 g of air-dried soil were mixed with 300 distilled water, followed by shaking for 60 minutes, and finally filtrated. The filtrate was used to determine the salt content of soil by measuring the EC values using the EC meter (inoLab® Cond 730 with TetraCon® 325 conductivity measuring cell.

3.4.2. Analysis of plant tissue samples:

3.4.2.1. Determination of mineral composition of plant tissue using microwave digestion:

Plant samples were dried and grinded to powder using liquid nitrogen. Around 0.5 g (weight was determined exactly) of the dried and grinded plant sample was obtained and 8.0 ml of nitric acid (69%) were added to each sample. Following that, 4 ml of hydrogen peroxide (H_2O_2) solution (30%) were added (few drops of 1-Octanol were added also to prevent foaming). Following that, the mixtures were placed in Teflon digestion vessels and closed. Vessels were placed in the microwave (according to the standard program to operate the device) and digested for 60 minutes. After microwave digestion, the digested extract was transferred to 50-ml falcons, and the column was completed with deionized water to 50 ml. The extract was then used for nutrients analysis using ICP-OES spectrophotometer.

3.4.2.2. Determination of total nitrogen in plant tissues:

Around 20 mg (weight was taken exactly) of the air-dried and grinded plant tissue sample were compressed into capsule and inserted into the nitrogen/protein analyser from Leco Corporation (Moenchengladbach- Germany).

3.5. Documentation of farms information:

During the three visits to the farms (the three stages of collecting samples), all available information about the fertilization programs and practices was documented through interviews with farmers. These visits were followed by a fourth visit after finishing the chemical analyses of samples. During this visit farmer's opinions and suggestions about the mistakes that chemical analysis showed were documented.

3.6. Data analysis and interpretation of results:

The obtained results were analyzed by calculating the mean and standard deviation of each farm; farms of each region were grouped together for each date. The results were presented as a comparison between regions and sampling. The obtained results were compared to standard plant nutrition programs that were adopted in developed countries.

Chapter Four: Results

The results that will be shown in the following figures reflect the analysis of soil samples and plant tissue samples for bell pepper cultivated in greenhouses in Jenin, Qalqilya and Tulkarm and Jericho regions. It is important to mention that during the course of this study, the minimum acceptable levels are our reference points; such approach is the preferred one for environmentally-sound agricultural production systems.

4.1. Soil pH

Soil pH is one of the most important factors that affects the availability of nutritional elements for cultivated plants. Figure (1) shows that the soil pH just before planting (T1) of all the selected farms exceeded 7.2. This value is considered high and affects negatively the availability of few elements needed by plants, of particular importance is the availability of iron (Fe). On the other hand, the results showed that the use of chemical fertilizers caused a clear increase in soil pH in most regions, especially in Tulkarm and Qalqilya and Jericho regions.

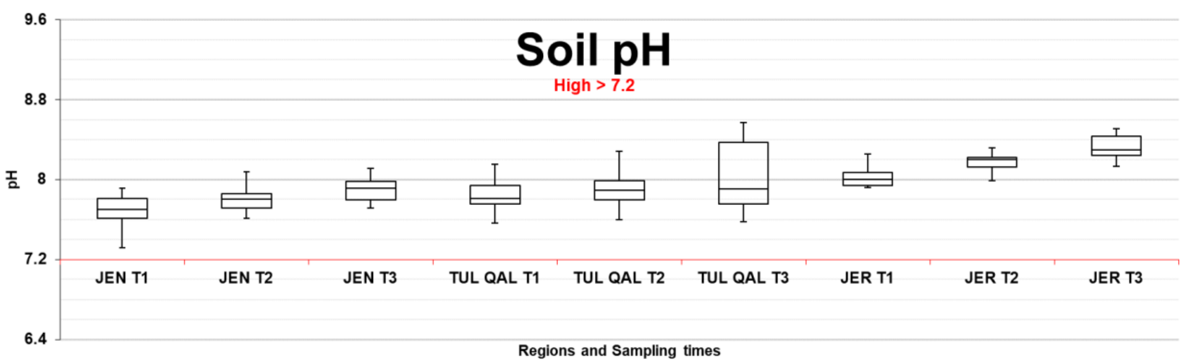

Figure 1: pH values of soil samples collected from greenhouses cultivated with sweet peppers at three collection times (T1: before planting; T2: at the peak of growing season: T3: by the end of the growing season) and from three regions (Jenin= JEN; Tulkarm and Qalqilya= TUL&QAL; and Jericho= JER).

4.2. Salt level

Figure (2) shows the salt levels in soils. It is obvious that the salt level in all regions exceeded the accepted level (75 $mg.100g^{-1}$), and in most regions the salt level exceeded even the toxic level of 200 $mg.100g^{-1}$. The highest soil salt level was in Tulkarm and Qalqilya region, and the lowest was in Jenin. It can be said that the effect of chemical fertilization on the soil salt level is limited, and it is difficult to find general change among the regions.

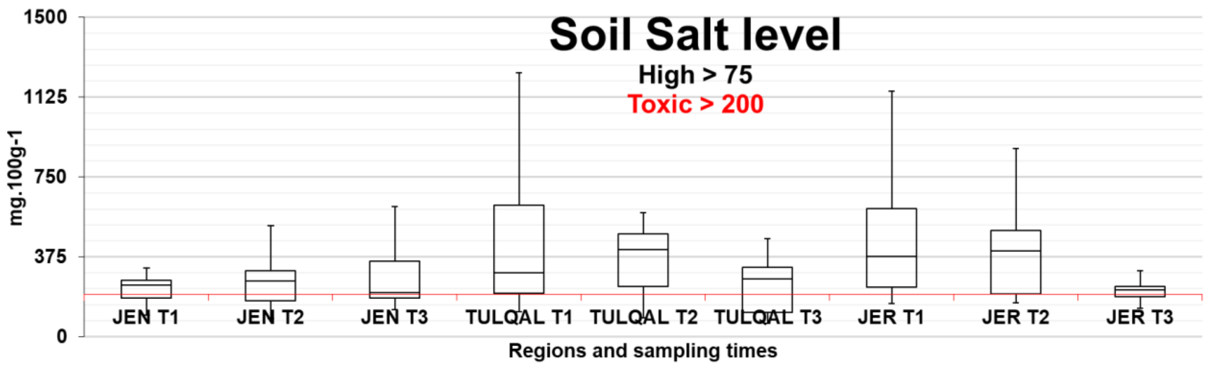

Figure 2: salt level ($mg.100g^{-1}$) of soils collected from greenhouses cultivated with sweet peppers at three collection times (T1: before planting; T2: at the peak of growing season: T3: by the end of the growing season) and from three regions (Jenin= JEN; Tulkarm and Qalqilya= TUL&QAL; and Jericho= JER).

4.3. Phosphorus

Figure (3) shows the phosphorus level in soil samples. In all regions the phosphorus level exceeded the maximum accepted level, with the highest levels for Jenin and Tulkarm and Qalqilya regions, and the lowest for Jericho, although it is still too high. The levels varied widely in Jenin and Tulkarm and Qalqilya regions, where the variance within Jericho region wasn't that much.

In contrast, Figure (4) shows the phosphorus level in the plant tissue from the same regions, where the phosphorus level in plant tissue in Tulkarm and Qalqilya and Jericho regions were within the sufficient level (0.20-0.40 %), whereas in Jenin region it was lower than the minimum sufficient level in plant tissues, although soils contain almost 10 times more P than needed.

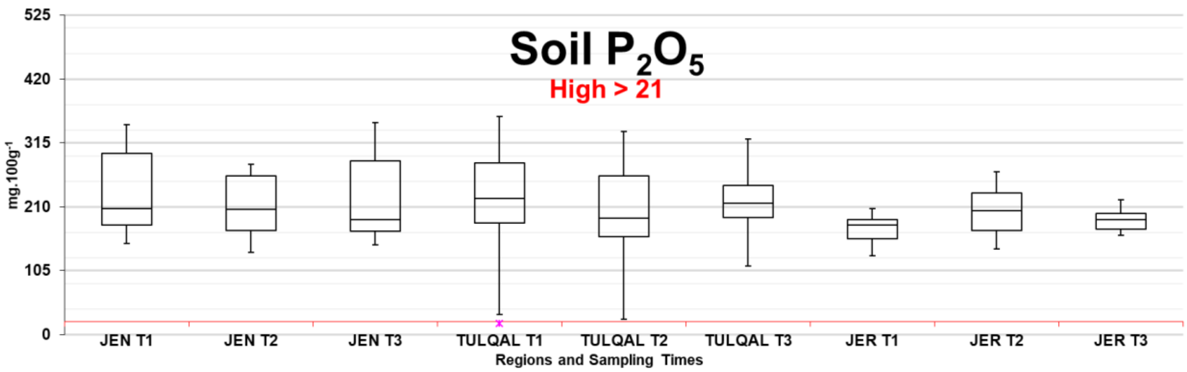

Figure 3: Phosphorus level (mg.100g^{-1}) of soils collected from greenhouses cultivated with sweet peppers at three collection times (T1: before planting; T2: at the peak of growing season: T3: by the end of the growing season) and from three regions (Jenin= JEN; Tulkarm and Qalqilya= TUL&QAL; and Jericho= JER).

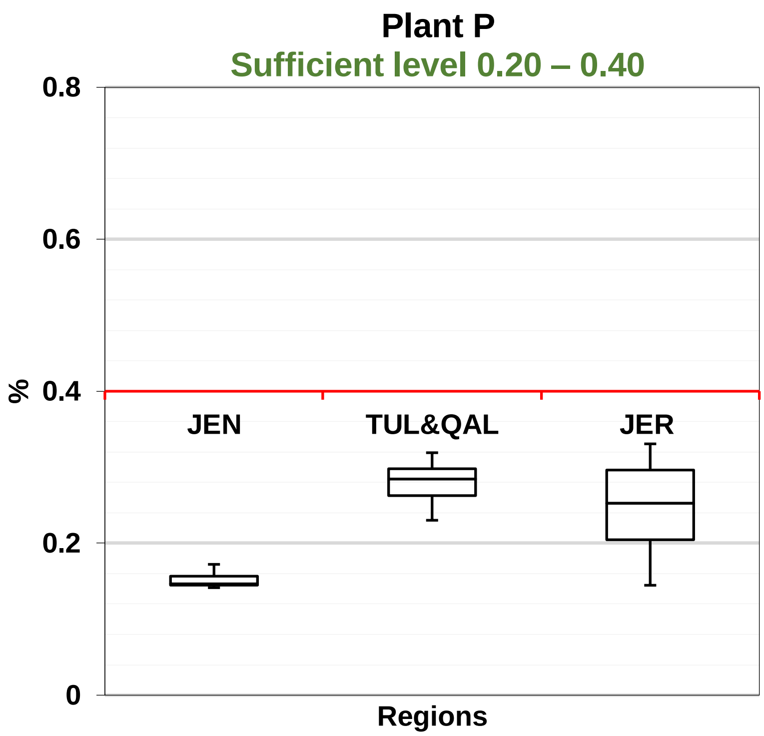

Figure 4: Phosphorus level (%) of mature leaves of sweet peppers collected from Jenin, Tulkarm and Qalqilya and Jericho regions.

4.4. Potassium

Figure (5) shows that potassium levels in soil samples in Tulkarm and Qalqilya and Jericho regions exceeded the high level, but Jenin recorded the highest level of potassium, even though some of the farms there were within the normal range. Further, the levels in Jenin varied clearly between farms; from normal potassium level to very high level. High levels of potassium also were recorded in plant tissue samples in all regions as shown in figure (6). As an example, it reached two times the needed level in Tulkarm and Qalqilya regions.

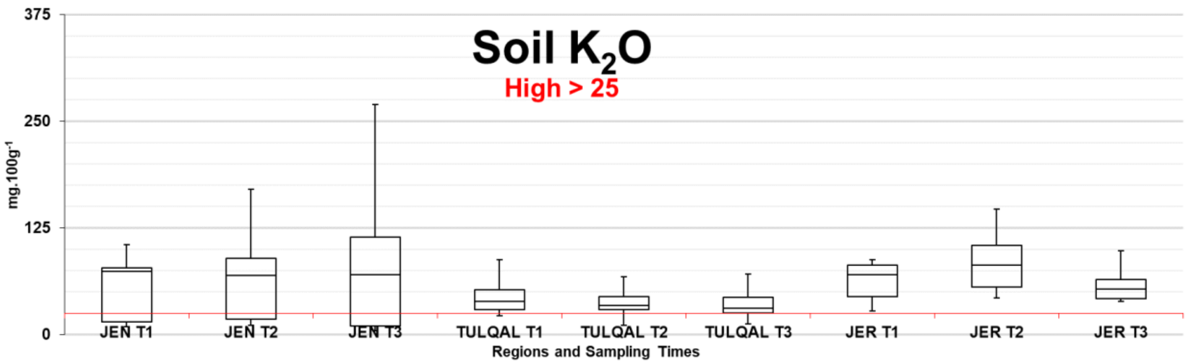

Figure 5: Potassium level (mg.100g^{-1}) of soils collected from greenhouses cultivated with sweet peppers at three collection times (T1: before planting; T2: at the peak of growing season: T3: by the end of the growing season) and from three regions (Jenin= JEN; Tulkarm and Qalqilya= TUL&QAL; and Jericho= JER).

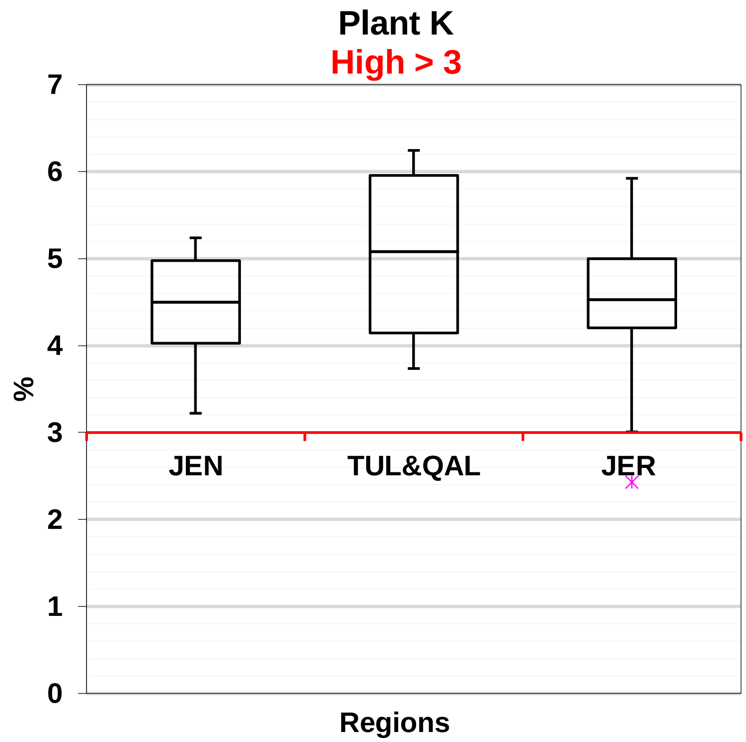

Figure 6: Potassium level (%) of mature leaves of sweet peppers collected from Jenin, Tulkarm and Qalqilya and Jericho regions.

4.5. Nitrogen

Figure (7) shows that the nitrogen levels in plant tissue in all regions exceeded the high level (3 %), which indicates that the added amount of nitrogen to the plant was much more than needed.

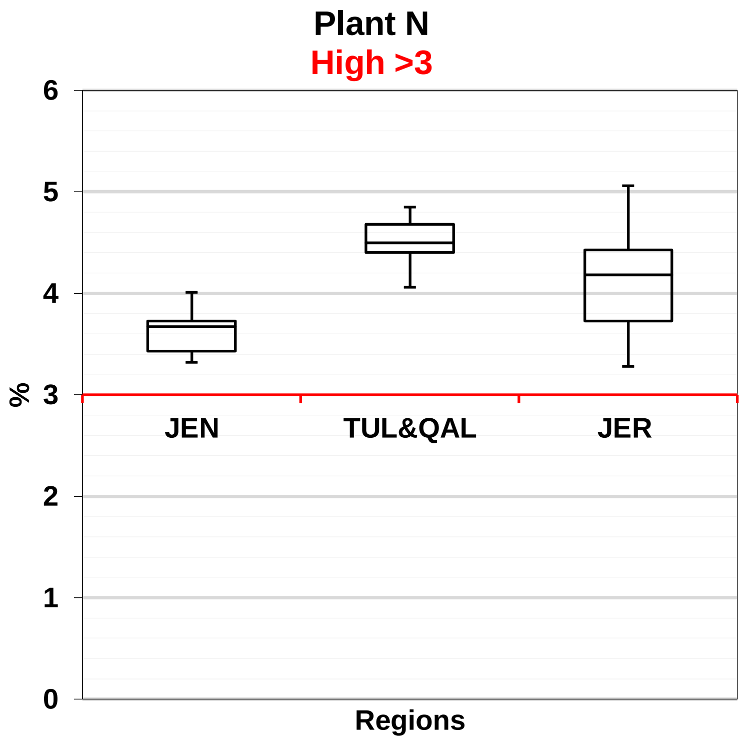

Figure 7: Nitrogen level (%) of mature leaves of sweet peppers collected from Jenin, Tulkarm and Qalqilya and Jericho regions.

4.6. Magnesium

Soil samples from all regions showed very high levels of magnesium; the level in Jericho reached 40 times the needed level. It is noted that Jericho, Tulkarm and Qalqilya regions have the highest magnesium level before planting (T1) and started to decline in at the peak of growing season (T2), and were lowest by the end of the growing season (T3). But it is exactly the opposite in Jenin region, where magnesium level was the highest by T3. Further, all regions showed high levels of magnesium in plant tissues as shown in figure (9). The highest levels were for Jenin, Tulkarm and Qalqilya regions with high variance in levels in Tulkarm and Qalqilya regions. Jericho had the lowest magnesium levels and were the nearest to the high acceptable level.

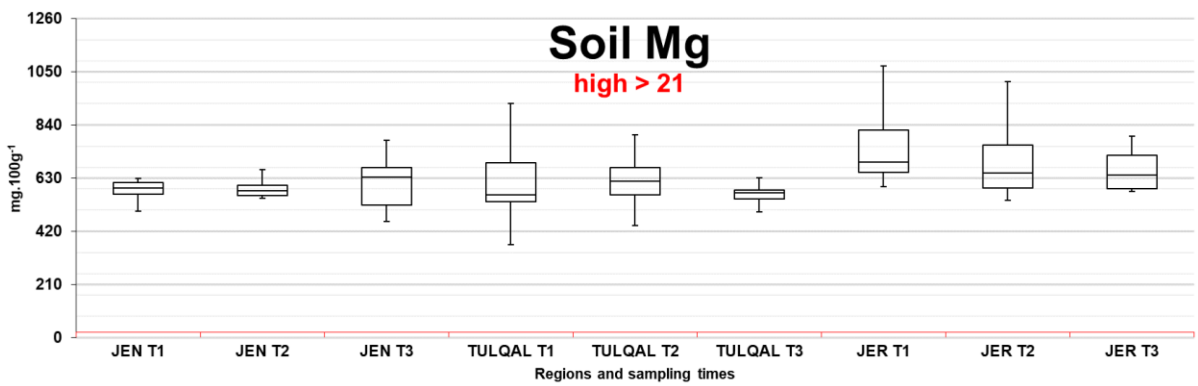

Figure 8: Magnesium level (mg.100g^{-1}) of soils collected from greenhouses cultivated with sweet peppers at three collection times (T1: before planting; T2: at the peak of growing season: T3: by the end of the growing season) and from three regions (Jenin= JEN; Tulkarm and Qalqilya= TUL&QAL; and Jericho= JER).

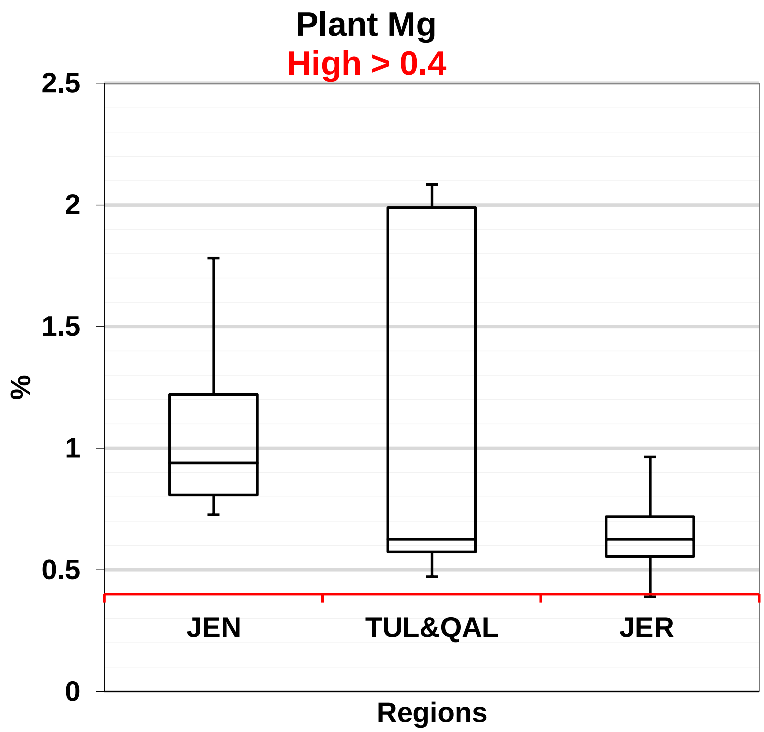

Figure 9: Magnesium level (%) of mature leaves of sweet peppers collected from Jenin, Tulkarm and Qalqilya and Jericho regions.

4.7. Calcium

Figure (10) shows that almost all regions are within the sufficient level of calcium in the soil, but it is the opposite in leaves tissues, as figure (11) shows; all regions had high levels of calcium in the plant tissues.

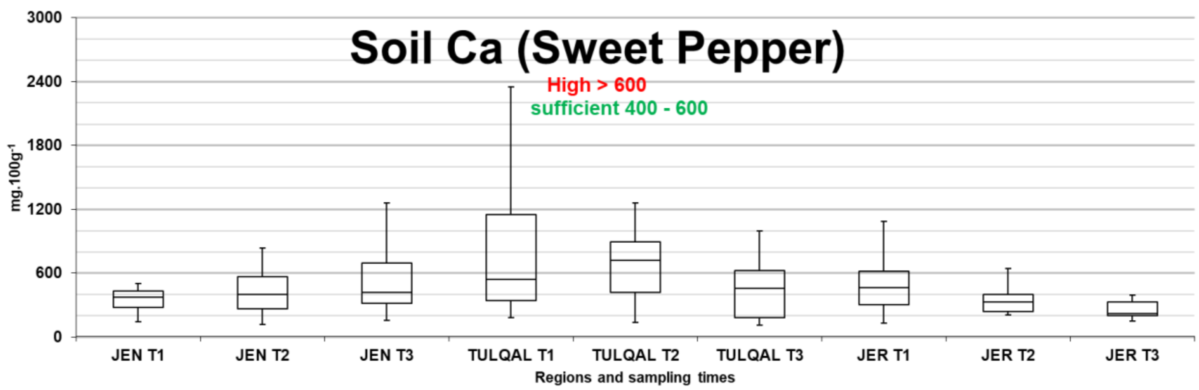

Figure 10: Calcium level (mg.100g^{-1}) of soils collected from greenhouses cultivated with sweet peppers at three collection times (T1: before planting; T2: at the peak of growing season: T3: by the end of the growing season) and from three regions (Jenin= JEN; Tulkarm and Qalqilya= TUL&QAL; and Jericho= JER).

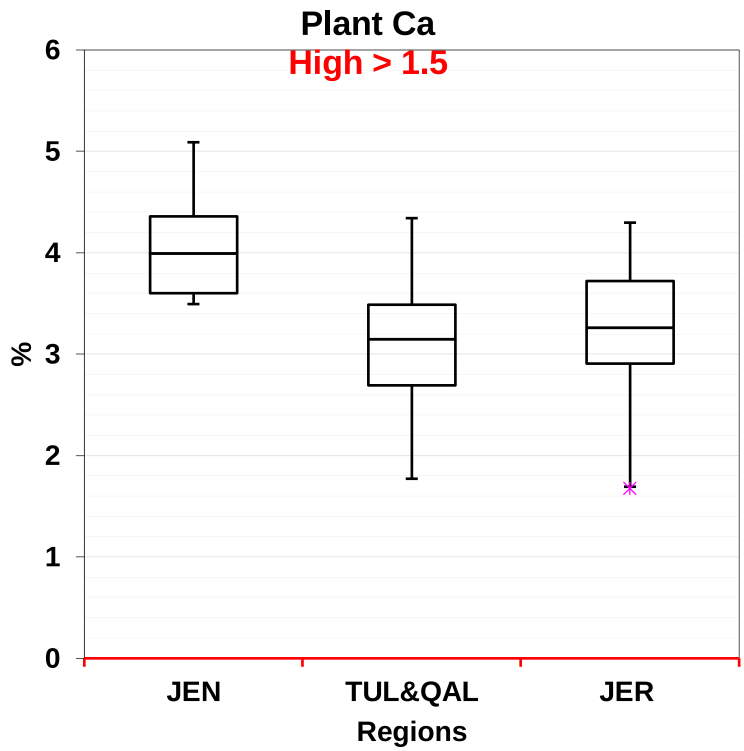

Figure 11: Calcium level (%) of mature leaves of sweet peppers collected from Jenin, Tulkarm and Qalqilya and Jericho regions.

4.8. Iron

Figure (12) shows that iron content of soil were below the minimum sufficient level in all regions. The highest was in Jenin even though it is still below the minimum sufficient level. In contrast, iron levels in plant tissues in Tulkarm, Qalqilya and Jenin regions exceeded the high acceptable level, almost twice the needed level with high variance in the same region, as shown in figure (13); in Jericho the iron level was less than the other regions and didn't exceed the maximum acceptable level.

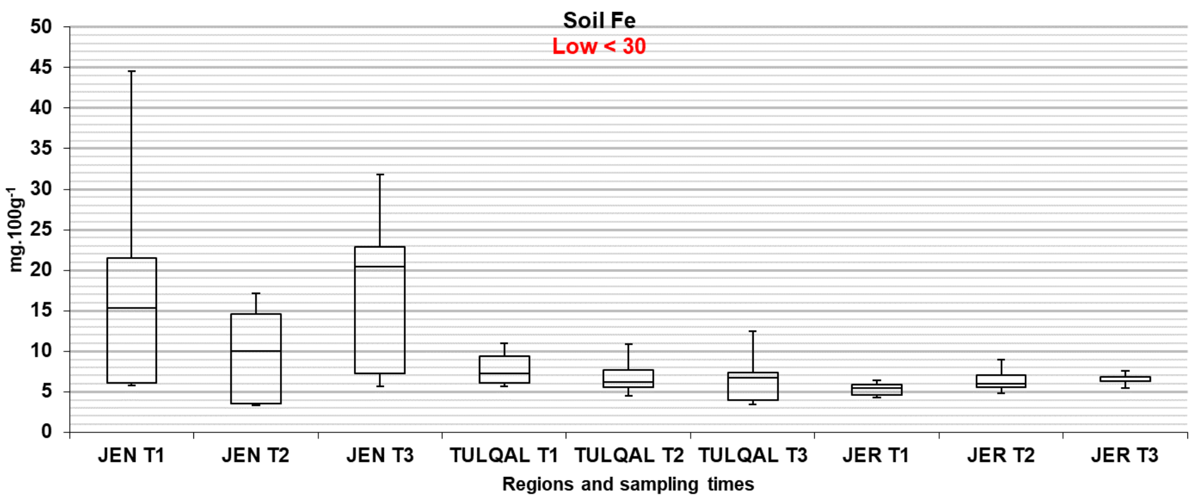

Figure 12: Iron level (mg.100g^{-1}) of soils collected from greenhouses cultivated with sweet peppers at three collection times (T1: before planting; T2: at the peak of growing season: T3: by the end of the growing season) and from three regions (Jenin= JEN; Tulkarm and Qalqilya= TUL&QAL; and Jericho= JER).

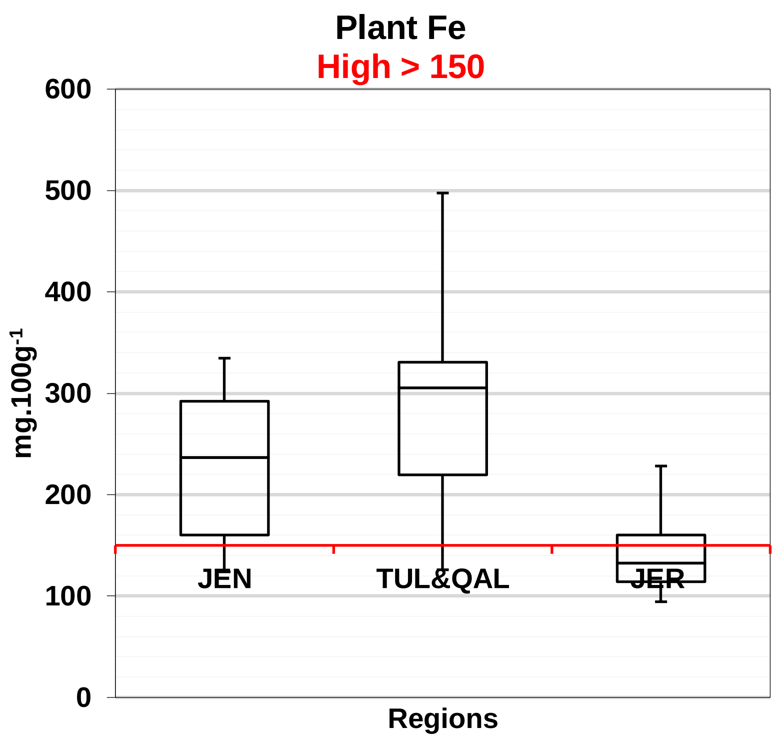

Figure 13: Iron level (mg.100g^{-1}) of mature leaves of sweet peppers collected from Jenin, Tulkarm and Qalqilya and Jericho regions.

4.9. Manganese

Figure (14) shows that manganese levels of soil samples from Jenin farms exceeded the acceptable level. In contrast, most of Jericho region farms were below the minimum acceptable level; most farms in Tulkarm and Qalqilya regions were below the high acceptable level.

Figure (15) shows that plant tissue samples for most of the regions were below the maximum acceptable level, but some farms in Jenin region farms exceeded that level.

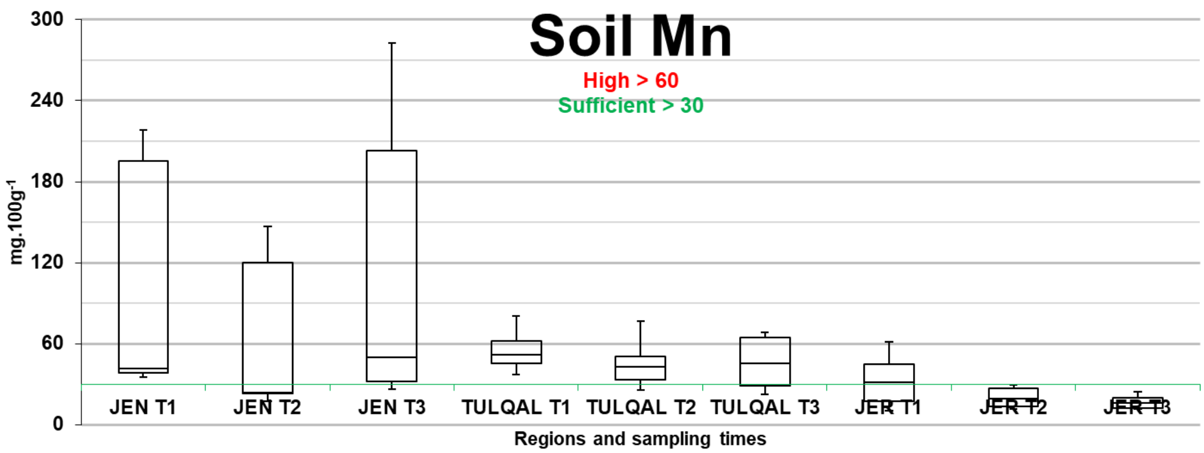

Figure 14: Manganese level (mg.100g^{-1}) of soils collected from greenhouses cultivated with sweet peppers at three collection times (T1: before planting; T2: at the peak of growing season: T3: by the end of the growing season) and from three regions (Jenin= JEN; Tulkarm and Qalqilya= TUL&QAL; and Jericho= JER).

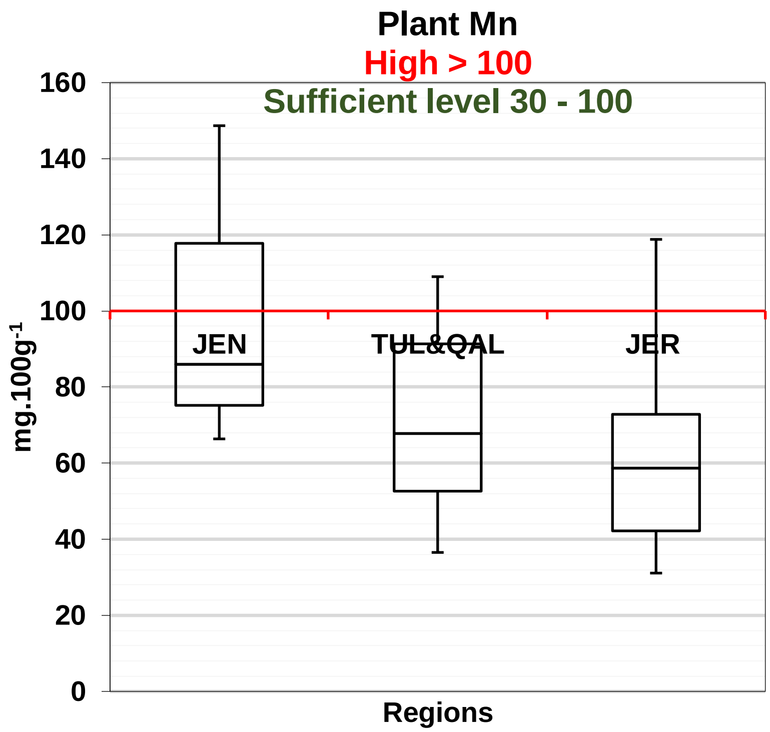

Figure 15: Manganese level (mg.100g^{-1}) of mature leaves of sweet peppers collected from Jenin, Tulkarm and Qalqilya and Jericho regions.

4.10. Copper

Figure (16) shows that soil copper content for most of the farms in Tulkarm, Qalqilya and Jericho regions didn't exceed the high acceptable level, but most of Jenin farms exceeded that level. In figure (17) the plant tissue's copper content of samples collected from most regions exceeded the high acceptable level, with high variance in levels in Tulkarm and Qalqilya regions; Jenin farms did not exceed that high acceptable level.

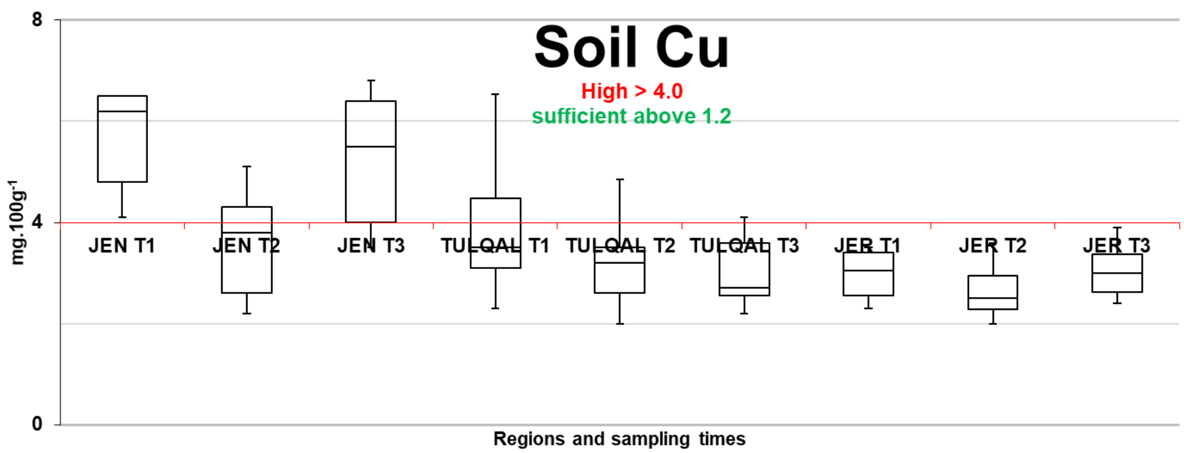

Figure 16: Copper level (mg.100g^{-1}) of soils collected from greenhouses cultivated with sweet peppers at three collection times (T1: before planting; T2: at the peak of growing season: T3: by the end of the growing season) and from three regions (Jenin= JEN; Tulkarm and Qalqilya= TUL&QAL; and Jericho= JER).

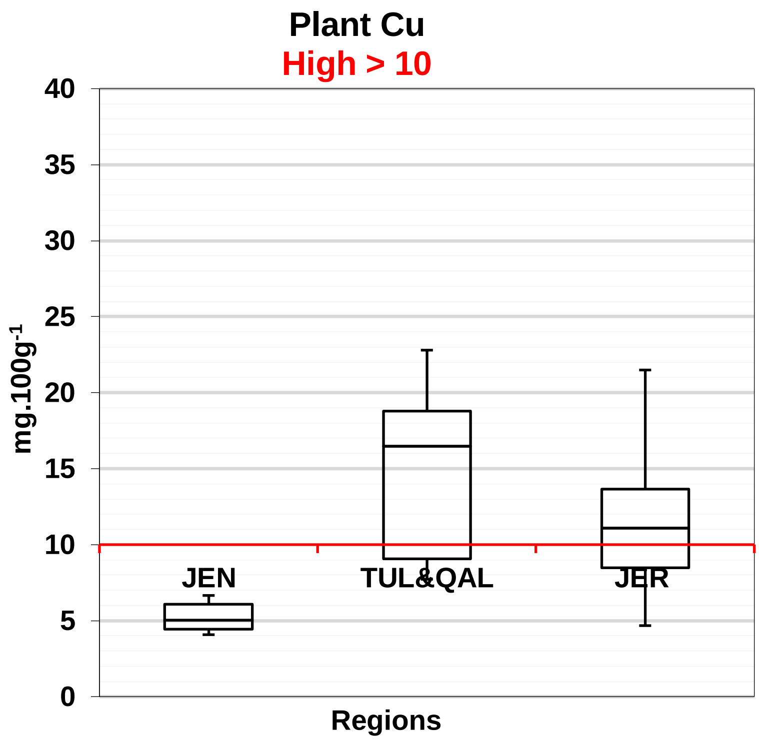

Figure 17: Copper level (mg.100g^{-1}) of mature leaves of sweet peppers collected from Jenin, Tulkarm and Qalqilya and Jericho regions.

4.11. Zinc

Figure (18) shows that zinc content of soil samples from all regions exceeded the high acceptable level. The highest levels were Jericho farms, as they exceeded the needed level by four times. However, results of plant tissue samples show that levels were below the high acceptable level, except for some farms from Tulkarm and Qalqilya region.

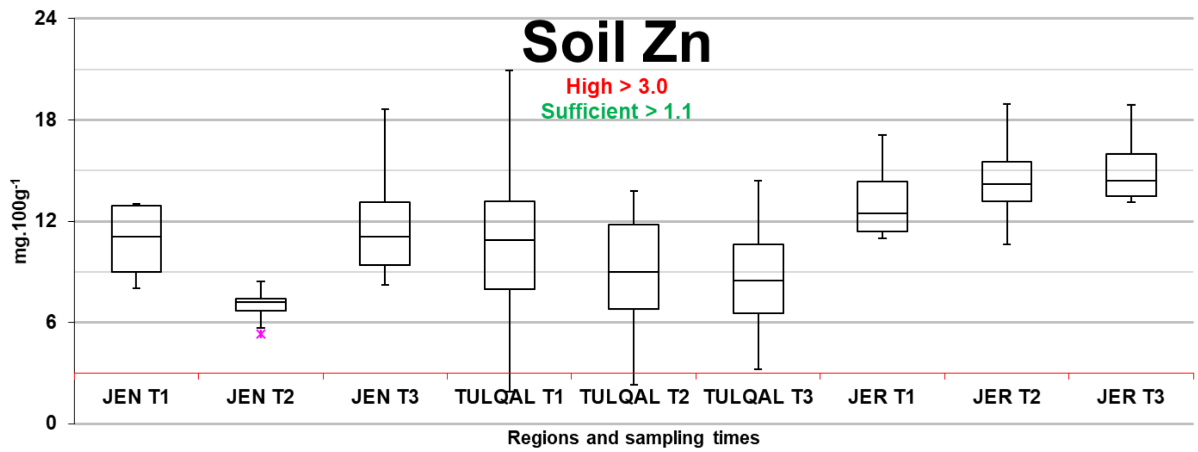

Figure 18: Zinc level (mg.100g^{-1}) of soils collected from greenhouses cultivated with sweet peppers at three collection times (T1: before planting; T2: at the peak of growing season: T3: by the end of the growing season) and from three regions (Jenin= JEN; Tulkarm and Qalqilya= TUL&QAL; and Jericho= JER).

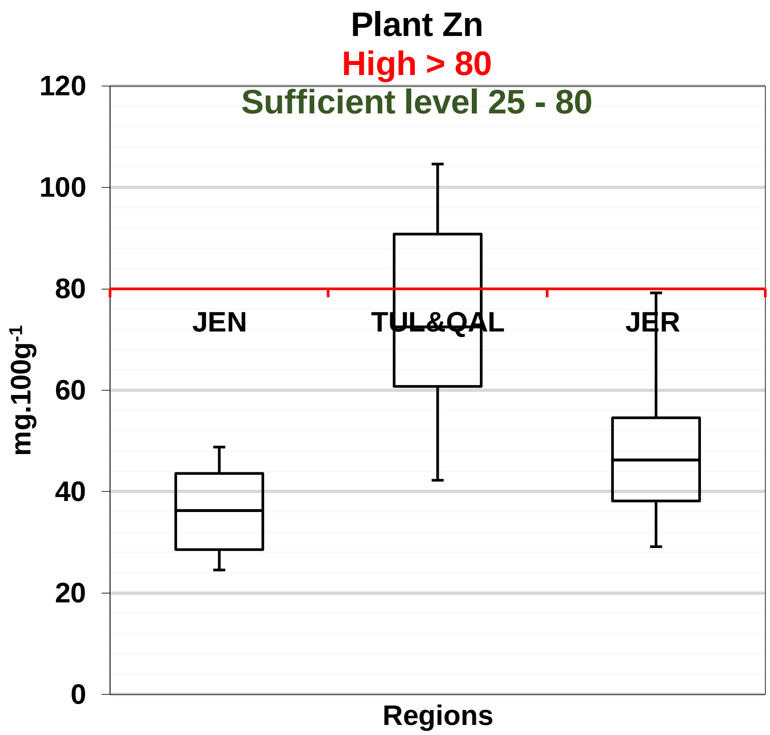

Figure 19: Zinc level (mg.100g^{-1}) of mature leaves of sweet peppers collected from Jenin, Tulkarm and Qalqilya and Jericho regions.

4.12. Boron

Figure (20) shows that boron levels for most farms exceeded the high acceptable level for boron. The highest levels were for Jericho region, whereas the lowest levels were for farms from Qalqilya and Tulkarm. Moreover, boron levels in that regions decreased in the second sampling time; the opposite happened in Jericho. As for plant tissues, farms of Tulkarm and Qalqilya regions had the highest boron levels, which exceeded the required limit by more than double, although their soils had the lowest boron level.

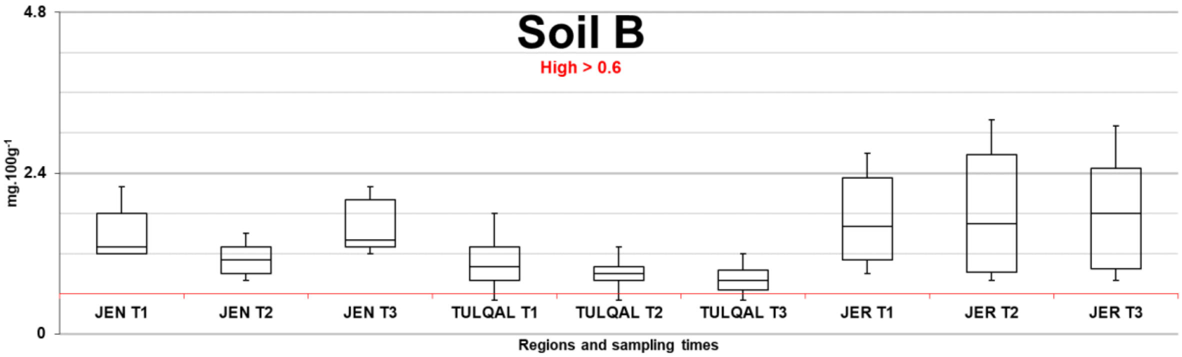

Figure 20: Boron level (mg.100g^{-1}) of soils collected from greenhouses cultivated with sweet peppers at three collection times (T1: before planting; T2: at the peak of growing season: T3: by the end of the growing season) and from three regions (Jenin= JEN; Tulkarm and Qalqilya= TUL&QAL; and Jericho= JER).

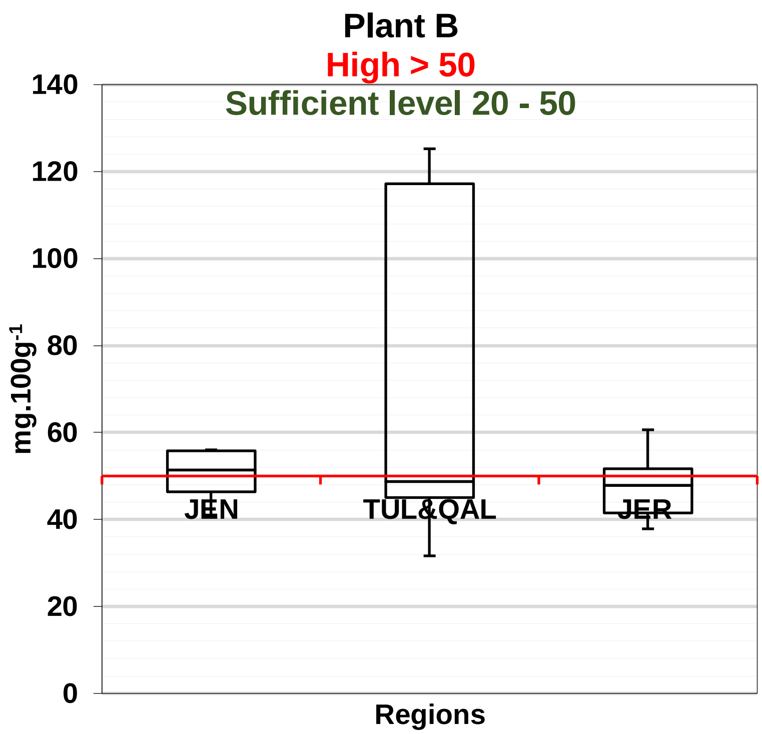

Figure 21: Boron level (mg.100g^{-1}) of mature leaves of sweet peppers collected from Jenin, Tulkarm and Qalqilya and Jericho regions.

4.13. Molybdenum

Figure (22) shows that all plant tissue samples have very high levels of molybdenum, which exceeded the high acceptable level. The highest values were recorded for Jericho region farms; they exceeded the needed level by ten times with high variance between farms.

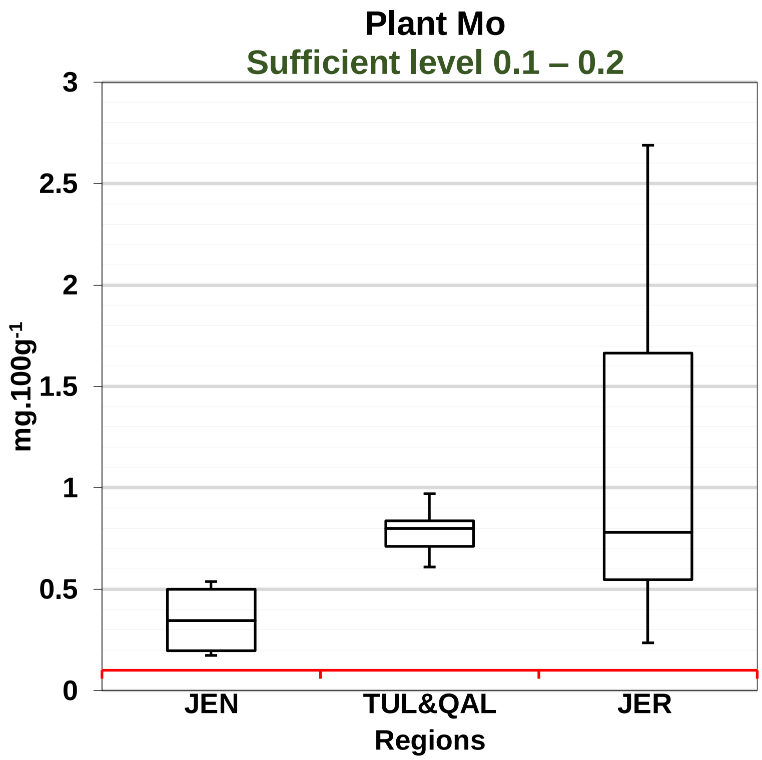

Figure 22: Molybdenum level (mg.100g^{-1}) of mature leaves of sweet peppers collected from Jenin, Tulkarm and Qalqilya and Jericho regions.

4.14. Sulfur

Figure (23) shows that the sulfur levels of plant tissues samples from all region's plants were high and exceeded the high acceptable level. Some of Jenin region farms were near that limit, whereas farms from Tulkarm and Qalqilya regions had the highest sulfur levels.

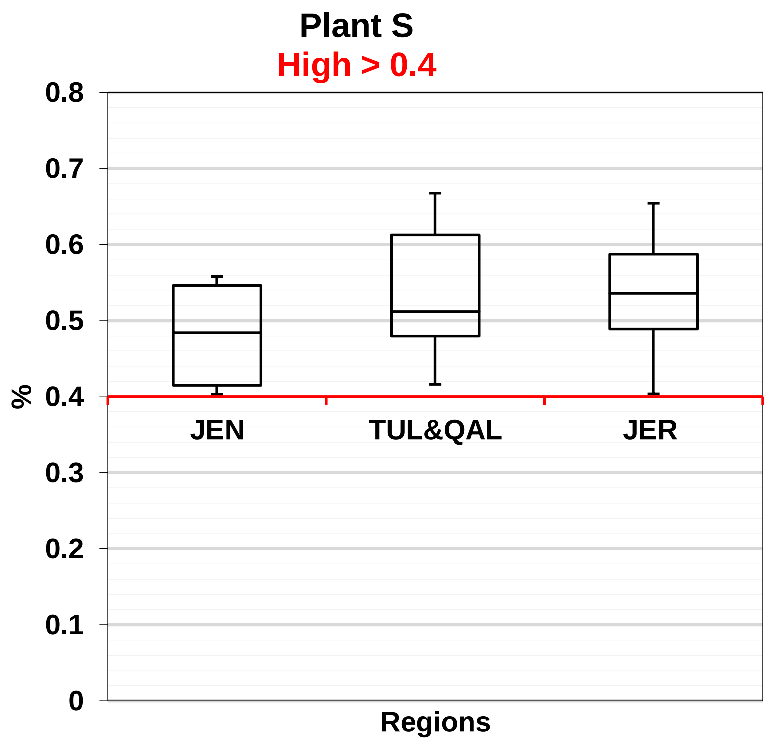

Figure 23: Sulfur level (%) of mature leaves of sweet peppers collected from Jenin, Tulkarm and Qalqilya and Jericho regions.

Chapter Five: Discussion

The results showed that the current fertilizing programs, as shown in table (1) below, caused a huge increase in the main nutritional elements (N, P, and K). In addition, high increases were reported also with magnesium levels in plant tissues and soil samples. This increase had a huge negative impact on soil structure and properties (physical and chemical properties). Table (2) showed the ratios between potassium and magnesium (K/Mg) and calcium and magnesium (Ca/Mg), where there was a huge increase in magnesium. This, in turn, would affect human health and cause real economic losses. Farmers usually do not pay attention to these losses that are caused by the intensive use of fertilizers, which may reach thousands of dollars yearly for each farm.

Table (1): Quantities and sources of the three essential nutrients (nitrogen, phosphorus, potassium) compared to the recommendations.

Category	*Fertilizer type*	*N*	*P_2O_5*	*K_2o*
Actual; AVG (kg per dunum)	*Organic sources*	*42.91*	*56.13*	*42.43*
SD		*35.25*	*63.47*	*38.56*
Actual; AVG (kg per dunum)	*Inorganic sources*	*34.86*	*32.98*	*41.64*
SD		*23.78*	*13.24*	*48.28*
Actual; AVG (kg per dunum)	*Totals*	*77.77*	*89.11*	*84.07*
SD		*41.95*	*68.51*	*75.13*
Recommended (Haifa Chemicals) (Kg per dunum)		*30.70*	*19.20*	*58.40*
Actual - recommended (kg per dunum)		*47.07*	*69.91*	*25.67*
% increase/decrease (Haifa Chemicals)		*153.31*	*364.09*	*43.96*

AVG: Average; SD: Standard deviation

Table (2) The ratios between calcium and magnesium (Ca/Mg), and potassium and magnesium (K/Mg) based on soil analysis results.

Farm	Location	K/Mg	Ca/Mg
1	Jenin	0.065	0.920
2	Jenin	0.087	0.660
3	Jenin	0.175	0.722
4	Jericho	0.253	0.997
5	Jericho	0.051	0.293
6	Qalqilya	0.176	0.351
7	Tulkarm	0.239	0.682
8	Tulkarm	0.195	0.794
9	Tulkarm	0.216	0.671
10	Tulkarm	0.203	0.505
11	Tulkarm	0.171	0.658
12	Tulkarm	0.230	0.652

5.1. High soil pH

Soil pH value is an important factor for plant nutrition, and it is affected mainly by nitrogen (Guan, 2016). Nitrogen is consumed by plants in two forms: Ammonium-N $(NH_4)^+$ or nitrate-N $(NO_3)^-$. Upon plants uptake of NH_4^+, there will be a release of H^+ ions, which might decrease rhizosphere soil pH. On the other hand, the uptake of NO_3^- nitrogen will results in the release of OH^- ions leading to an increase in rhizosphere soil pH (Guan, 2016).

In vegetable production in greenhouses farmers mainly use the nitrogen fertilizers in the form of nitrate (e.g. potassium nitrate and calcium nitrate), as shown in table (3) below. These fertilizers are highly soluble and provide other essential elements needed by crops (Ghosh & Bhat, 1998). The preference of farmers for nitrate fertilizers is understandable, although the soil pH in farms necessitates other fertilizers with acidic reactions, including ammonium and sulfate fertilizers. However, ammonium may be toxic to plants specially in cool weather, as bacteria in low temperature cannot do nitrification (converting ammonia to nitrate) (Guan, 2016). This situation (high ammonium levels in leaves) can be solved partially by increasing temperature or by using nitrate-N fertilizers. (Conesa et al,2008).

Table (3): Nitrogen chemical formula in the used fertilizers.

Fertilizer	Source of nitrogen
05:03:08	NO_3 (68 %) + NH_4 (32 %)
20:20:20	NO_3 (5.4 %) + NH_4 (3.4 %) + NH_2 (11.2%)
17:10:27	NO_3 (11.3 %) + NH_4 (5.7 %)
07:03:07	NO_3 (60 %) + NH_4 (40 %)
13:0:46	NO_3 (100 %)
0:30:40	No Nitrogen
06:06:06	NO_3 (55 %) + NH_4 (45%)
0:34:52	No Nitrogen
20:10:20	NO_3 (12 %) + NH_4 (8 %)
10:0:30	NH_4
Ammoniac	NH_4
Ammonium acid	NO_3 + NH_4

In the following; each nutritional element will be discussed separately, to show its effect on plant's growth and development.

5.2. Effect of nitrogen increase on plant growth and development

Nitrogen is the most nutritional element needed by plants (Aulakh & Malhi, 2005). The results indicated that leaves from all studied farms had a very high level of nitrogen, due to the intensive use of chemical fertilizers and organic fertilizers (animals' manure). Previous studies showed that high levels of nitrogen caused huge increase in the growth of the vegetative parts in the plant (Fumis & Cechin, 2014). This has been confirmed by a study carried by Liu and others on sunflower plants, where they noticed that the dry weight of the plant increased due to the increase of leaves number, as a result of the intensive use of nitrogen as fertilizer. One of the main reasons that caused increase in nitrogen levels is the addition of animal's manure (Liu et al., 2014).

The negative impact of high nitrogen levels mainly appeared on fruit's quality and quantity, as high levels will increase the incidence of diseases (Parisi et al., 2014; Raese & Drake, 1997). Furthermore, nitrogen can affect negatively the uptake of other elements upon high concentrations, such as the uptake of zinc, manganese and calcium. (Heidari & Mohammad, 2012). So, the balanced ratios between the nutritional elements is always important to ensure that plants get all the needed nutrients in the required quantity (Aulakh & Malhi, 2005). The most important ratio is the one between nitrogen and phosphorus, in addition to that the ratio between nitrogen and potassium during the fruiting phase; in which, this ratio should be increased to meet the high demand of potassium by the plant (Huett & Dettmann, 1988).

Based on the above mentioned studies, there is an urgent need to decrease the amounts of nitrogen applied, by decreasing the use of nitrogen fertilizers (Banger et al,. 2018) and also manure.

5.3. Effect of phosphorus increase on plant growth and development

As mentioned before, phosphorus is considered one of the most important nutritional elements for all kinds of plants. Its concentration in soil is usually less than the other two major nutritional elements (N and K), and it is the same in plant tissues (McGrathet al., 2014).

The process by which the organic compound dissociates to release phosphate or soluble organic P is called mineralization, and its rate is the main factor for determining the amount of organic P in soil (Menzies & Lucia, 2009). This process is affected by many environmental factors such as temperature, moisture and pH. (Dalai, 1977). Soil temperature controls the balance between mineralization and immobilization of P, since temperature has a direct relation with microorganisms' population and activity. In this sense, soil temperatures above 30 °C accelerate mineralization of organic P, but soil temperatures below 30 °C favor the immobilization (Menzies & Lucia, 2009). In addition, organic phosphorus is less stable in alkaline soil, thus adding acids to soil will help and increase plant uptake of phosphorus. Moreover, soil moisture level affects phosphorus and other elements like nitrogen (Gahoonia & Nielsen, 1994). As a result, it is important to define soil content of phosphorus and other nutritional elements in addition to the organic compounds especially pre-fertilization (Sheffield, 2008). In this regard, it was shown that the intensive use of organic fertilizers that contain phosphorus and nitrogen would affect the uptake of other elements (e.g. zinc and iron) (Mousavi et al., 2013), and may cause phosphorus accumulation in soil (Pizzeghello et al., 2011). When phosphorus level in soil reaches 150-300 ppm, it may take three to five years to get rid of it completely; exceeding this level will take more time (Sheffield, 2008).

So, it is important to measure the level of soluble phosphorus in soil before fertilizing in order to calculate the amount of phosphorus needed for the next season. In a study carried by Menzies & Lucia (2009) it was found that the plants didn't utilize all the available phosphorus in one season, and the remaining amount of phosphorus after one year was 60 % of the total phosphorus; after 3 years the remaining amount reached 20 %. In addition, the continues use of huge amounts of phosphorus fertilizers will lead the soil to a point where there would be no response for any addition of phosphorus (Menzies & Lucia, 2009). Depending on this, many strategies were suggested in order to decrease the high concentration of phosphorus in soil including the following: analysis of phosphorus level in soil (Provin & Pitt, 2008), determination of P level in water source (running water or artesian wells water), analysis of used fertilizers before usage (Sheffield, 2008), the use of low phosphorus fertilizers, cultivating crops that need high level of phosphorus, and maintain soil acidity within the range that makes phosphorus available and absorbable by the plant (Provin & Pitt, 2008).

5.4. Effect of potassium increase on plant growth and development

There are four different sources for potassium in soil, including: - soil minerals that are considered the largest source of potassium but the least available for plant uptake, - the exchangeable potassium source that is the readily available form of potassium and absorbed easily by plant roots, - the unexchangeable potassium that forms 1-10 % of total potassium and serves as a reserve source of potassium in soil, and - the potassium found in organic matter or in the microbial population in soil that supplies very little potassium (Prajapati & Modi, 2012).

In order to achieve all these multiple roles of potassium, the ratios between potassium and other essential elements (e.g. nitrogen, phosphorus, calcium and magnesium) must be taken into consideration as they may affect the uptake and the utilization of potassium by plants and thus affect crop quality and quantity (Daliparthy et al., 1994). As an example; there is a strong interaction between potassium and nitrogen during the crop growth, as it was noticed that when potassium in soil was below the optimal level, the response to nitrogen fertilizers decreased, since the adequate amount of potassium is the key role for producing proteins and enzymes (Malvi, 2011).

5.5. Effect of calcium increase on plant growth and development

Calcium abundance in alkaline soil in arid and semiarid region is related mainly to rainfall rate, which affects the chemical composition and levels of calcium in soil (Jodral-Segado, et al., 2006). Lower rates of precipitation render calcium more stable in soil. Accordingly, calcium levels tend to increase in the soil's upper layer (Ritchey, et al.,1980).

In our case, the calcium level in soil is normal, although levels are above the high sufficient level in plant tissue. However, farmers have to avoid calcium reduction in soil, and need to irrigate their crops frequently for efficient usage of available calcium and to avoid calcium deficiency in fruits (Grant & Racz, 1987).

5.6. Effect of magnesium increase on plant growth and development

Magnesium is common in many minerals, including primary minerals such as ferromagnesium minerals (e.g. olivine and pyroxene) and secondary minerals such as carbonates (e.g. dolomite and magnesite). Magnesium in soil can be found in several forms: water soluble, exchangeable and nonexchangeable form of magnesium. The nonexchangeable form of magnesium in soil is more than the exchangeable and water-soluble Mg; 4-20 % of total Mg are exchangeable Mg (Henriksen, 1972).

The availability of Mg in soil, despite its form, depends on many factors including rocks type, pH value, water type, cation exchange capacity, plant type and climate conditions (Jodral-segado et al., 2006). Plant uptake of magnesium is affected by the presence of the other exchangeable cations including ammonium, potassium, calcium, sulfur and manganese. Further, the high soil pH and the ratios between magnesium and the other exchangeable cations mentioned above, affect the uptake of magnesium (Henriksen, 1972), Moreover magnesium levels affect the uptake of other elements by plants, specially calcium and potassium, (Singh & Singh, 1970) since it has been found that the presence of magnesium and calcium in high concentration affects the uptake of potassium, as they are highly competitive (Grant & Racz, 1987). Accordingly, the ratios between magnesium and other nutritional elements, like calcium and potassium, can affect the quality of fruits; the ratio between calcium and magnesium (Ca/Mg) affects firmness, texture, storage capacity (Gerendás & Führs, 2013); in clay soil the ideal Ca/Mg ratio might be 7:1, whereas in sandy soil the ideal ratio might be 3:1(Nitri-Tech solutions, 2015). Since calcium has a major role in cell wall stabilization, and because the magnesium has the ability to replace calcium from the binding site, then the unbalanced ratio between Ca and Mg will negatively affect the product quality. (Gerendás & Führs, 2013). Otherwise, the ratio between potassium and magnesium (K/Mg) influences the organoleptic properties by regulating cellular cation/anion balance and initial pH, and also it can influence photosynthesis rate and the accumulation of sugars (specially in fruits and roots). (Gerendás & Führs, 2013). Accordingly, the increase in magnesium levels, more than the sufficient level needed by plants, might be detrimental to product quality (Gerendás & Führs, 2013).

Although toxicity with magnesium occurs rarely, the Ca/Mg ratio of less than one, as shown in this study, is too bad for cultivated plants and soils. The negative impact on soil structural properties is evident, as magnesium is a divalent cation that has greater hydration energy and radius than calcium, which will affect negatively the attraction force between soil particles leading to soil dispersion. Upon plowing soils with excessive Mg levels, massive soil blocks will form which will retard water flow resulting in poor water distribution (Vyshpolsky et al., 2007). As for plant metabolism, Mg may lead to phosphate precipitation and enzyme inhibition that could affect negatively photosynthesis rate (Roosta, 2011). In addition, blocking of potassium flow inside the plants may occurs as cellular Mg increases due to unbalanced ratio between Mg and other elements, including Ca. (Roosta, 2011). Furthermore, soil pH might increase upon increases in calcium carbonate content and Mg (McCauley et al., 2009). This in turn will affect the availability of other nutritional elements, specially iron (Fe), which is considered one of the main nutritional problem of plants cultivated in Palestine (Roosta. 2011); previous studies showed that soils in semi-arid zones have high concentrations of both Ca and Mg (Jodral-Segado, et al., 2006). Moreover, Mg-containing chemical fertilizers will add Mg to soil (Roosta, 2011), which will worsen the soil staus.

Chapter Six: Recommendations and conclusion

The results of this research reflect a very bad reality in the agricultural sector. That is related to the uncontrolled use of chemical fertilizers. Accordingly, many recommendations can be listed in order to decrease the environmental problems and economic losses attached to this problem. Some of these recommendations (short-term) can give quick positive results and can be applied within one to two seasons. However, to solve the problem drastically, long-term recommendations are urgently needed.

Short-term recommendations:

1. Reducing the amount of organic fertilizers (animals' manure), specially poultry manure.
2. Washing greenhouse soil by the end of each season using large amount of water, and/or growing a gluttonous plant for nutrients such as corn, spinach and cabbage without adding phosphorus or magnesium fertilizers. Further, reductions in the amounts of nitrogen and potassium fertilizers are needed.
3. Using fertilizers that have acidic effect which help to release tangible parts of phosphorus and potassium.
4. Using decomposed animal manures to maintain the survival of decomposing bacteria.

Long-term recommendations:

1. Build up high efficiency laboratories, in order to have the ability to analyze soil, plant tissue and water samples with affordable price, so that the farmers can control the addition of fertilizers by knowing the amount of nutrients in his farm before each season.
2. Future research is highly needed to achieve balanced fertilization program for each region.
3. Control the quality of the available fertilizers used by farmers. This requires the presence of modern laboratories to analyze the component of these fertilizers.
4. Provide training programs in "Plant nutrition" for agricultural extensionists, in order to be able to give the farmers the right advices about the appropriate fertilizers to use with the right quantity depending on the requirements of the farm.
5. Development of local chemical industries (chemical fertilizers) in Palestine with Arabic description for application timing and quantities.
6. Development of agricultural guides for the available agrochemicals.

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Appendix: (Farms information)

Location: Tulkarm **Farmer:1** Crop (when the sample was taken): Sweet Pepper

Results:

Plant samples	**Calcium**		**Potassium**	**Phosporus**	**Nitrogen**
	4.2		4.2	0.16	3.3
Magnesium	**Zinc**		**Iron**	**Sodium**	**Sulfur**
0.8	32.6		192	0.014	0.4
Copper			**Molybdenum**	**Boron**	**Manganese**
7.2			1.3	47.8	55.7
Soil Samples	**Calcium**		**Potassium**	**Phosporus**	**Nitrogen**
Time 1	369.9		26.6	166.4	
Time 2	698.6		25.9	162.8	
Soil samles	**Zinc**		**Iron**	**Sodium**	**Magnesium**
Time 1	8.2		8	222.8	534.2
Time 2	5		5.5	353.9	599.9
Soil samples	**pH**		**Salinity**	**Manganese**	**Copper**
Time 1	7.9		204.6	51.6	3.4
Time 2	7.9		365.3	36.4	2.1
Soil samples			**Chloride**	**Molybdenum**	**Boron**
Time 1					0.9
Time 2					0.7

Fertilization program:

Organic sources:

Type	Quantity	Times
Cow manure	20 (2-3 year)	Before planting

Chemical fertilizers:

Type	Quantity	Times
20:20:20	25kg	Whole season
13:13:13	25kg	
11:08:22	25kg	
11:08:27	25kg	
05:03:08	37.5L	
07:03:07	37.5L	
Ecostar, Humus		

Location: Tulkarm **Farmer: 2** Crop (when the sample was taken): Sweet pepper

Results

Plant samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
	3	5	0.2	4.6
Magnesium	**Zinc**	**Iron**	**Sodium**	**Sulfur**
0.6	79.8	99.9	0.009	0.5
Copper		Molybdenum	Boron	Manganese
8.3		0.8	39.8	413.3
Soil Samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
Time 1	702.1	46.6	212	
Time 2	935.5	44.1	206.4	
Time 3	723.8	41.3	196.4	
Soil samles	**Zinc**	**Iron**	**Sodium**	**Magnesium**
Time 1	11.3	10.4	370.4	538.2
Time 2	7.8	6.6	457.6	640
Time 3	6.6	6.4	318.8	604.7
Soil samples	**pH**	**Salinity**	**Manganese**	**Copper**
Time 1	7.7	386.6	78.1	6.8
Time 2	7.6	504	42.5	3.2
Time 3	7.7	356.6	50.6	2.9
Soil samples	**Boron**	**Chloride**	**Molybdenum**	
Time 1	1.3			
Time 2	0.8			
Time 3	0.8			

Fertilization program

Organic sources:

Type	Quantity	Times
cow + chicken manure	2 c	Once each year

Chemical fertilizers:

Type	Quantity	Times
Superphosphate + شيحيم	50Kg(superphosphate)+400kg for each 1000m^2(شيحيم)	
20:20:20	15kg/1000m^2	Twice
13:13:13	15kg/1000m^2	Once
10:0:30	15-20kg/1000m^2	4 times
Sheffer 07:03:07	20L/1000m^2	12 times (once each 2 weeks for 10 months)
Sheffer 05:03:08	20L/1000m^2	6 times during the season
20:10:30	20L	3 time during the season
Iron	5kg (when needed)	Whole season

Location: Tulkarm **Farmer: 3** Crop (when the sample was taken): Sweet Pepper

Results

Plant samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
	3.1	3.9	0.2	3.7
Magnesium	**Zinc**	**Iron**	**Sodium**	**Sulfur**
	37.5	158.3	0.007	0.4
Copper		**Molybdenum**	**Boron**	**Manganese**
		0.6	51.6	38
Soil Samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
Time 1	1281.4	35.2	248.8	
Time 2	491.8	35.7	272.6	
Time 3	551.1	27.7	239.6	
Soil samles	**Zinc**	**Iron**	**Sodium**	**Magnesium**
Time 1	7.3	6	674.6	690.5
Time 2	9.8	7.1	425.1	574.4
Time 3	10.7	8.4	403.8	565
Soil samples	**pH**	**Salinity**	**Manganese**	**Copper**
Time 1	7.7	663.6	56.4	2.9
Time 2	8	297.3	61.5	3.7
Time 3	7.9	319.6	66	4
	Boron	Chloride	Molybdenum	
Time 1	0.8			
Time 2	0.9			
Time 3	1.1			

Fertilization program

Organic sources:

Type	Quantity	Times
Chicken manrue	7 ton	

Chemical fertilizers:

Type	Quantity	Times
Superphosphate	100kg/1000m^2	Before planting
20:10:30(نبراس)	4kg/1000m^2	Each week for month
0:34:52	2kg/1000m^2	6 Times during the season
Ammoniac	125kg	
13:13:13	25kg/1000m^2	At the beginning of the season

Location: Qalqilya **Farmer: 4** Crop (when the sample was taken): Sweet pepper

Results

Plant samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
	2.9	5.3	0.3	4.6
Magnesium	**Zinc**	**Iron**	**Sodium**	**Sulfur**
0.6	45.3	130.7	0.02	0.5
Copper	**Molybdenum**	**Boron**	**Manganese**	
12.6	0.8	46.2	67.9	
Soil Samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
Time 1	378.1	37.9	27.1	
Time 2	1026.2	50.7	66.7	
Time 3	690.6	49.9	82.8	
Soil samles	**Zinc**	**Iron**	**Sodium**	**Magnesium**
Time 1	2.4	9.5	154.2	378.1
Time 2	5.2	16.6	194.4	621.1
Time 3	4.8	11.8	142.9	547.4
Soil samples	**pH**	**Salinity**	**Manganese**	**Copper**
Time 1	7.7	192.5	47.8	2.4
Time 2	7.6	439.3	66.4	3
Time 3	7.6	318.6	58.8	2.7
Soil samples	**Boron**	**Chloride**	**Molybdenum**	
Time 1	0.5			
Time 2	0.7			
Time 3	0.7			

Farm information:

Greenhouse in Jayoues, with a total area of 1000m^2 planted with Sweet Pepper (this greenhouse was planted for 2 years with different type of plants)

Fertilization program

Organic sources:

Type	Quantity	Times
Cow manure	10 ton	Before planting

Chemical fertilizers:

Type	Quantity	Times
20:20:20	25Kg	From planting to picking season (5Kg each 2 weeks)
27:10:17	25Kg	During the picking season (5 kg each week)
22:08:11	25Kg	During picking season
Ammoniac fertilizer	25Kg	At the beginning of transplanting
Phosphoric acid	15L	After picking season
Iron	2Kg	During the season

What are the main reasons for excessive use of chemical fertilizers?

The addition of fertilizers depends on the farmers, they assume adding more fertilizers will increase production and quality of fruits.

Location: Qalqilyia **Farmer: 5** Crop (when the sample was taken): Sweet pepper

Results				
Plant samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
	3.4	3.2	0.2	3.7
Magnesium	**Zinc**	**Iron**	**Sodium**	**Sulfur**
1.2	40.7	126.8	0.019	0.5
Copper		**Molybdenum**	**Boron**	**Manganese**
488.5		0.4	47.1	62.7
Soil Samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
Time 1	1922.1	86.3	300.2	
Time 2	787.4	27.6	214	
Soil samles	**Zinc**	**Iron**	**Sodium**	**Magnesium**
Time 1	16.5	6.9	1073.4	1152.8
Time 2	9.6	6.2	523.6	771.8
Soil samples	**pH**	**Salinity**	**Manganese**	**Copper**
Time 1	7.8	1095	57.9	3.7
Time 2	7.8	463.6	32.7	3
Soil samples	**Boron**	**Chloride**	**Molybdenum**	
Time 1	1.5		0	
Time 2	1		0	

Farm information

Greenhouse with total area of 1000 m^2 in Al Nabi Elyas village (Qalqilya), each season its planted sweet pepper or tomato, and this farm was recorded as global gab farm in 2008,2010,2011.

Fertilization program

Organic sources:

Type	Quantity	Times
Compost	50 bag (bag volume 20L)	Before planting and after the soil is prepared
Superphosphate	50 Kg	During soil preparation

Chemical fertilizers:

Type	Quantity	Times
Ammoniac fertilizer	25Kg	After planting or
08:03:05	50L	During picking season (5L each week)
22:08:11	25Kg	During picking season
Phosphoric acid	10L	During picking season
Iron	2Kg	During picking season
Mageisal(مغنيسال)	5Kg	During picking season
Calcium	1L	During picking season

What are the main reasons for excessive use of chemical fertilizers?
The addition of fertilizers depends on the farmer not on soil analysis results.

Location: Jenin **Farmer: 6** Crop (when the sample was taken): Sweet Pepper

Results

Plant samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
	2.8	5.7	0.2	4.5
Magnesium	**Zinc**	**Iron**	**Sodium**	**Sulfur**
	64.3	257.8	0.01	0.5
Copper		**Molybdenum**	**Boron**	**Manganese**
		0.7	97.3	79.8
Soil Samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
Time 1	402.7	78.2	319.1	
Time 2	370.6	70.3	272.9	
Time 3	626.9	85.2	256.9	
Soil samles	**Zinc**	**Iron**	**Sodium**	**Magnesium**
Time 1	12.9	6	107.5	610.7
Time 2	8.7	3.4	119	585.4
Time 3	13.1	6.5	178.3	687.6
Soil samples	**pH**	**Salinity**	**Manganese**	**Copper**
Time 1	7.5	227.6	36.7	6.3
Time 2	7.9	207.3	21.1	4.0
Time 3	7.8	332.2	36.1	5.8
Soil samples	**Boron**	**Chloride**	**Molybdenum**	
Time 1	1.2			
Time 2	0.8			
Time 3	1.3			

Farm information

This farm was planted on 15/03/2017 with sweet pepper, the season stayed until January, the soil was sterilized using metam sodium

Fertilization program

Organic sources:

Type	Quantity	Times
Turkey manure	4 cubic meter/1000m^2	Before 45 day of planting

Chemical fertilizers:

Type	Quantity	Times
13:13:13	5kg/1000m^2	First week of planting
13:13:13	5kg/1000m^2/week	For 60 day
07:03:07	5L/1000m^2/week	From 60 day to 100 day
11:08:20	5kg/1000m^2/week	From 120 day to 170 day
Iron	2kg/1000m^2	During the season
Micronutrient	2L/1000m^2/week	During the season
0:30:40	2L/1000m^2/week	During the season
Sulfatepostasuim	106kg	From day 18 until the end of the season

What are the main reasons for excessive use of chemical fertilizers?

To increase the vegetative growth, production and the instructions of agricultural engineers.

Location: Jenin **Farmer: 7** Crop (when the sample was taken): Sweet Pepper

Results				
Plant samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
	3.8	5.0	0.14	3.5
Magnesium	**Zinc**	**Iron**	**Sodium**	**Sulfur**
0.8	44.9	299.9	0.01	0.4
Copper		**Molybdenum**	**Boron**	**Manganese**
6.1		0.5	55.7	88.7
Soil Samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
Time 1	351.2	87.2	194.6	
Time 2	450.8	130.8	211.9	
Time 3	714.7	234.9	236.1	
Soil samles	**Zinc**	**Iron**	**Sodium**	**Magnesium**
Time 1	9.4	29.8	441.1	602.1
Time 2	6.5	9.6	645.5	645
Time 3	13.2	26.2	750.3	681.2
Soil samples	**pH**	**Salinity**	**Manganese**	**Copper**
Time 1	7.8	275.6	41.9	4.4
Time 2	7.9	382.6	24.3	2.4
Time 3	8.0	441.3	39.5	3.8
Soil samples		**Chloride**	**Molybdenum**	**Boron**
Time 1			0	1.2
Time 2			0	1.1
Time 3			0.03	1.9

Farm information

This farm was planted on 10/02/2017 with sweet pepper, the soil was sterilized using metam sodium

Fertilization program

Organic sources:

Type	Quantity	Times
Cow manure	15 cubic meter/1000m^2	Before 45 day of planting

Chemical fertilizers:

Type	Quantity	Times
Phosphoric acid	5L/1000m^2	First week
Phosphoric acid	5L/1000m^2	Second week
Aluminum sulfate	7kg/1000m^2	Third week
13:13:13	7kg/1000m^2	From the fourth week to the sixth week
Urea fertilizer	5kg/1000m^2	Week seventeen
11:08:22	7kg/1000^2	From day 70-120
0:52:34	3kg/1000m^2	
Organic fertilizer (Ecostar)	20L	During the season
11:08:22	7kg/1000m^2	From week 20 to the end of the season

What are the main reasons for excessive use of chemical fertilizers?
Improve the quality of fruits and the quantity of production and to kill all soil diseases and remove the grass

Location: Jenin **Farmer: 8** Crop (when the sample was taken): Sweet Pepper

Results

Plant samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
	4.3	3.7	0.15	3.7
Magnesium	**Zinc**	**Iron**	**Sodium**	**Sulfur**
1.3	27.7	159.2	0.006	0.5
Copper		**Molybdenum**	**Boron**	**Manganese**
4.3		0.19	44.8	106.8
Soil Samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
Time 1	304.2	11	194.2	
Time 2	457.3	14.5	161.9	
Time 3	218.9	6.3	158.3	
Soil samles	**Zinc**	**Iron**	**Sodium**	**Magnesium**
Time 1	9.7	23.3	204.3	521.4
Time 2	6.8	15.5	280.2	561.4
Time 3	9.3	20.7	274.3	498.9
Soil samples	**pH**	**Salinity**	**Manganese**	**Copper**
Time 1	7.7	174.3	203.9	6.4
Time 2	7.6	247.3	131.6	4.1
Time 3	7.8	159.3	238.5	6.4
Soil samples	**Boron**	**Chloride**	**Molybdenum**	
Time 1	1.9		0.03	
Time 2	1.4		0	
Time 3	2		0	

Farm information

Greenhouse with total area of 1000m^2

Fertilization program

Organic sources:

Type	Quantity	Time
Sweet pepper	1250 plant	15/03/2017
Sweet pepper	1250 plant	10/03/2017

Chemical fertilizers:

Type	Quantity	Time
Superphosphate	100kg	Before planting
Ammoniac	50kg	Before planting
20:20:20	7kg	10/04/2017
Ecostar	5L	17/04
20:20:20	8kg	25/04
Iron	0.5kg	25/04
20:10:20	8kg	05/05
Ecostar	5L	12/05
Ammoniac	8kg	12/05
Compound fertilizer	10kg	22/05
Compound fertilizer	10kg	02/6
Ammoniac	8kg	15/06
20:10:20	8kg	10/07
11:08:22	8kg	20/07
20:20:20	8kg	05/08

20:20:20	8kg	15/08
20:10:20	8kg	25/08
11:08:22	8kg	10/09
11:08:22	8kg	25/09
13:13:13	140kg	

What are the main reasons for excessive use of chemical fertilizers?
To increase production, quality and quantity of fruits.

Location: Jericho **Farmer: 9** Crop (when the sample was taken): Sweet Pepper

Results

Plant samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
	3.8	4	0.2	4.2
Magnesium	**Zinc**	**Iron**	**Sodium**	**Sulfur**
2	97.4	392.5	0.03	0.5
Copper		**Molybdenum**	**Boron**	**Manganese**
8.3		0.8	46.8	66
Soil Samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
Time 1	683.9	57.1	151.6	
Time 2	501	73.3	182.7	
Time 3	236.3	48.4	180.3	
Soil samles	**Zinc**	**Iron**	**Sodium**	**Magnesium**
Time 1	14.9	4.6	905.2	890.2
Time 2	17	5.4	762.2	822
Time 3	15.7	6	443.3	738.1
Soil samples	**pH**	**Salinity**	**Manganese**	**Copper**
Time 1	8.1	678.3	16.5	2.5
Time 2	8.1	562.3	13.9	2.6
Time 3	8.4	258.3	11.9	2.8
Soil samples	**Boron**	**Chloride**	**Molybdenum**	
Time 1	2.4		0	
Time 2	2.7		0	
Time 3	2.6		0	

Farm information

The green house was planted with sweet pepper at 20/10/2017, the soil was sterilized with metam sodium before two weeks of planting (15L/1000m^2)

Fertilization program

Organic sources:

Type	Quantity	Times
Cow + chicken manrue	2 cubic meter/1000^2	15/10

Chemical fertilizers:

Type	Quantity	Times
Humic acid	2L/1000m^2	First week of the season
Humic acid	3L/1000m^2	Second week
Ammonium sulfate	4kg/1000m^2	Once each 10 days
Phosphoric acid	2L/1000m^2	Once each mounth
Iron	1kg/1000m^2	Whole season

Location: Jericho **Farmer: 10** Crop (when the sample was taken): Sweet Pepper

Results

Soil Samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
Time 1	398	68.4	195	
Time 2	281.2	97	223.5	
Time 3	280	73.5	197.4	
Soil samles	**Zinc**	**Iron**	**Sodium**	**Magnesium**
Time 1	11.4	6	470	662
Time 2	13.1	7.4	417	591
Time 3	14.4	7.4	175	587
Soil samples	**pH**	**Salinity**	**Manganese**	**Copper**
Time 1	8	313	49	3.4
Time 2	8.2	274.7	26.4	2.7
Time 3	8.2	192.7	21.4	3.3
Soil samples	**Boron**	**Chloride**	**Molybdenum**	
Time 1	1		0.06	
Time 2	0.4		0.03	
Time 3	1		0	

Farm information

Sweet pepper was planted on 20/10/2017 in Jericho, the soil was sterilized using sodium metam before 2 months of the season.

Fertilization program

Organic sources:

Type	**Quantity**	**Times**
Cow manure	5 cubic meter/1000m^2	2 months before the season starts

Chemical fertilizers:

Type	**Quantity**	**Times**
Phosphoric acid	5L/1000m^2	First week of the season
Ammoniac	15kg/1000m^2 /weeks	Once each 2 weeks
13:13:13	7kg/1000^2/week	From the second week to the second month
11:08:20	7kg/1000m^2/week	At the beginning of the third month to the fifth month
Iron	2kg/week	Whole season
05:03:08	10L/1000m^2/week	During the first and the second month
0:30:40	3L/week/1000m^2	During the third and fourth month
Micronutrients	10L/1000m^2	Whole season
Humic acid	3L/1000m^2	Whole season

What are the main reasons for excessive use of chemical fertilizers?
To increase the quality and the production of fruits.

Location: Tulkarm **Farmer: 11** Crop (when the sample was taken): Sweet pepper

Results

Plant samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
	2.4	4.6	0.2	4.4
Magnesium	**Zinc**	**Iron**	**Sodium**	**Sulfur**
0.4	48.1	131.4	0.015	0.5
Copper		**Molybdenum**	**Boron**	**Manganese**
10.2		2.1	46	50.9
Soil Samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
Time 1	272.0	48.4	287.3	
Time 2	464.6	20.6	175.6	
Time 3	149.1	15	219.3	
Soil samles	**Zinc**	**Iron**	**Sodium**	**Magnesium**
Time 1	14.4	6.5	195.5	556.9
Time 2	11.7	6.5	325.4	576
Time 3	8.6	3.7	130.7	561
Soil samples	**pH**	**Salinity**	**Manganese**	**Copper**
Time 1	8	168.6	43.8	4.1
Time 2	8.1	271.3	39.3	3.4
Time 3	8.4	87.3	25.3	2.2
Soil samples	**Boron**	**Chloride**	**Molybdenum**	
Time 1	0.9			
Time 2	0.8			
Time 3	0.5			

Location: Tulkarm **Farmer: 12** Crop (when the sample was taken): Sweet Pepper

Results

Plant samples	Calcium	Potassium	Phosporus	Nitrogen
	3	4.3	0.3	4.2
Magnesium	**Zinc**	**Iron**	**Sodium**	**Sulfur**
0.7	50.8	169.7	0.01	0.5
Copper		**Molybdenum**	**Boron**	**Manganese**
12.8		2.2	40.6	44.1
Soil Samples	**Calcium**	**Potassium**	**Phosporus**	**Nitrogen**
Time 1	676.4	43.2	241.3	
Time 2	377.1	60.0	309.2	
Time 3	191.7	36.4	303.1	
Soil samles	**Zinc**	**Iron**	**Sodium**	**Magnesium**
Time 1	12.7	7.1	292.2	622.1
Time 2	12.4	5	286.6	598.3
Time 3	11.5	4.7	187.9	557.9
Soil samples	**pH**	**Salinity**	**Manganese**	**Copper**
Time 1	7.8	347.6	49.2	5.2
Time 2	8	248.3	34.3	3.1
Time 3	8.3	123.6	33.4	3
Soil samples	**Boron**	**Chloride**	**Molybdenum**	
Time 1	1.1			
Time 2	0.9			
Time 3	0.7			