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The Action of Nutrients Deficiency on Growth Biometrics, Physiological Traits, Production Indicators, and Disease Development in Pepper (*Capsicum annuum* L.) Plant: A review

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ABSTRACT

BACKGROUND: Environmental factors affecting horticultural crops in quantity and quality. These factors are intertwined in influence in terms of cause and effect and what may lead to it. The environmental factors related to drought and salinity are very prominent and are of interest to researchers, especially academics. However, lack of nutrients is a significant factor at present. The lack of nutrients is affected by soil moisture, salinity, soil temperature, and air temperature surrounding the plant, and it may lead to the development of pathological factors so that the plant becomes vulnerable to immunodeficiency, insect, fungal, bacterial, and weed infections, as well as viruses. This review hypothesizes a link between environmental pressures on pepper and paprika plants, such as nutrient deficiency and drought, and the establishment of various pests, particularly fungal infections. **OBJECTIVES:** The goal of this study is to go over some of the past research on the impact of nutrient deprivation on pepper plant growth, yield, physiology, and disease development, the study also recommends using modern technology to schedule fertilization, irrigation, and following foliar fertilization as one of the methods of integrated pest control and one of the measures to reduce the impact of abiotic stresses on pepper. **RESULTS:** According to the article, calcium insufficiency is linked to the emergence of blossom end rot disease. In contrast, potassium deficit under dry conditions can contribute to the fungal disease gray leaf spot. **CONCLUSIONS:** One of the variables that cause environmental stress on pepper plants is a shortage of nutrients. According to the researchers, foliar nutrition is one of the most critical current ways for managing pests, nourishing plants, and enhancing their health and productivity.

KEYWORDS

Foliar Nutrition, Horticulture, Integrated Pest Management, Organic

INTRODUCTION

In horticulture and the environment, the effects of climatic factors on the growth and production of horticultural crops are superimposed. In addition to the heat, cold, drought, salinity and light. The effects of nutrient deficiency on production, both in quantity and quality, are evident. Reference has been made to the scientific and applied research efforts of the University of Debrecen, notably the Institute of Plant Protection, to explore

the use of digital electronic sensors to detect the health status of the plant and to study the scientific causes leading to the development of symptoms of nutritional deficiency as well as the relevance of the irrigation and fertilization plan.

The impact of macronutrients and micronutrients deficiency on pepper plants, the importance of soil chemistry and irrigation water, the link between nutrient deficiency and disease development, and the need for foliar nutrition technology as an integrated pest control method will all be investigated in this study.

1.1 Pepper Plant:

Pepper, its scientific name (*Capsicum annuum* L.), belongs to the Solanaceae family, which includes, in addition to pepper, tomatoes, potatoes, and eggplant. There are two types of pepper, bell pepper (paprika or sweet pepper) and hot pepper (chili peppers). The capsaicin ingredient, which creates a feeling of heat and is an exciting substance that causes a burning sensation when any tissue touches it, is one of its most vital components. Pepper cultivation and production is considered one of the main vegetable crops and performs an economic force that affects the income of many growers in the world. As a center for the domestication and genetic diversity of chili peppers, Mexico has a lot of cultivated species [1].

Pepper is a plant with morphology that differs from tomato in terms of growth patterns, where there are two types in tomatoes, the first is the indeterminate growth habit and the second is the determinate growth habit. However, research reports indicated that pepper (*Capsicum annuum* L.) is an indeterminate species with an infinite development of shoots [14]. Indeterminate plants grow continuously. The stem and branches continue to grow. Pepper plants have a shallow root system. There are typically a few major lateral roots that can reach a depth of 2 m to penetrate the soil. The white flowers are tiny and hermaphroditic primarily (both sexes in one flower).

From an ecological point of view, pepper is summer and tropical plant. Pepper does not withstand frost and is a tropical plant. Where the temperature drops below 12°C, it will not rise. Therefore, it is essential to have a mild winter climate. The soil pH is supposed to be (5.5- 6). Massimi and Al-Bdour [18] stated that pepper and sweet pepper are summers and warm-season crops. Kotuby-Amacher et al. [15] compare the salinity levels of the soil that are tolerated by peppers, bell peppers, and tomatoes. The researcher concluded that pepper and bell ones lose 25% yield when soil salinity is about 3.3 dS/m compared with the tomato, which loses the same percentage at higher salinity (5 dS/m) [15].

1.2 Nutrient Deficiency Vs. Salt Stress

Environmental stress factors, such as nutrient shortage, salt, heat, and drought, are the key environmental factors that limit the yield of any horticultural crop. It is logical and understood that a lack of nutrients required for plant critical processes and growth is one of the most critical environmental factors, which is considered the inverse of an increase in soil solution. (Figure 1). A cumulative, sequential relationship can illustrate the intertwined relationship between heat stress, drought, and soil salinization.

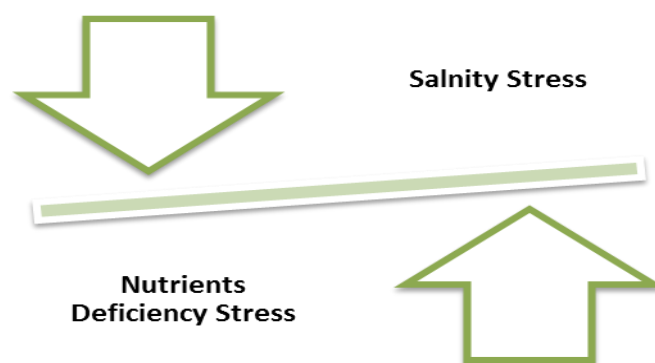


Figure 1. The inverse relationship between deficiency and excess of elements

Plant nutrition means that the plant gets the nutrients needed for plant growth and its biological, physiological, and chemical processes that guarantee production in quantity and quality. As is the case in other living things such as humans and animals, plants need the following elements: oxygen, carbon, hydrogen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and iron. The plant also needs zinc, boron, and manganese. The increase in temperature and the occurrence of drought may lead to the accumulation of one or more components in the nutrient soil solution, and here the salinity problem occurs. [15] Suggested that the important nutrients for soil salinization are nitrates, potassium, and gypsum. Other research on crops shows the effect of sodium chloride (NaCl) as a salinity agent on plants [30].

Since this research specializes in explaining the lack of nutrients and not increasing them, it is necessary to focus on the symptoms of the deficiency of the elements, not the symptoms of salinity and its increase. It is necessary to address the issue of chemical relationships in water and soil, where the presence of a certain element may increase (synergistic interaction) or decrease another element (antagonistic relation). Also, the readiness of the elements for uptake by the plant depends on the pH level. A relationship between soil acidity (pH) and nutrient absorption and preparation for plants has been demonstrated by modern science [12] (Figure 2).

Soil pH impacts the absorption of macronutrients and micronutrients. Via the Increased pH, micronutrient uptake capacity degrades, except for Molybdenum [7]. Conversely, if soil acidity increases, the absorption and uptake of major nutrients (macronutrients) will increase, including nitrogen, phosphorus, potassium, sulfur, calcium, and magnesium, to relatively different degrees and limits. As a result, trace elements (micronutrients) like iron, manganese, boron, copper, and zinc are absorbed less effectively (Figure 2).

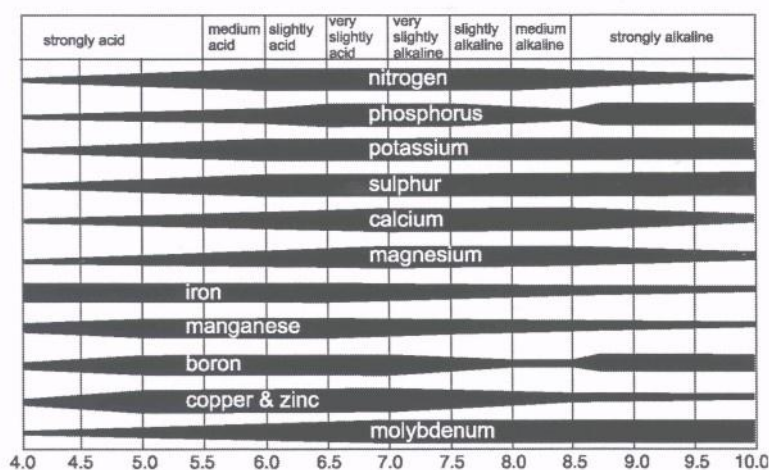


Figure 2. Graph of soil pH chart and nutrients availability [12]

1.3 Role of Macronutrients in Higher Plants

Nutrients are considered essential if they have a specific function and are included in the composition of the plant. Racz and Radocz (2019) [24] outlined macronutrients' role in plant cells. Nitrogen (N) and sulfur (S) are involved in the synthesis of amino acids, and phosphorous (P) is involved in the synthesis of nucleotides. Magnesium (Mg) is an essential component of the green plant pigment called chlorophyll, and calcium (Ca) is found in pectin compounds (Table 1). The plant absorbs large amounts of potassium (K), but its role in the plant is not completely clear. Potassium is required for water transportation and gas exchange with the atmosphere [28].

Table 1: Nutrients and essential roles to plant cells

Macronutrient	Symbol	Role
Nitrogen	N	Amino Acids
Sulfur	S	Amino Acids
Phosphorus	P	Nucleotides
Magnesium	Mg	Chlorophyll
Calcium	Ca	Pectin

In this regard, the mobile and non-mobile (or low mobile) nutrients are noted. The major and mobile nutrients in the plant are nitrogen, phosphorous, potassium, and magnesium. These elements' deficiency symptoms can be found in aged plant parts. On the other hand, calcium and sulfur are low-mobility elements that exhibit signs of insufficiency in modern plant parts [2] cited in [24].

It was reported that a close connection exists between nutrient mobility and the development of deficiency symptoms. Crops can mobilize nutrients from the older parts to the younger parts growing at, the older production stage [2] cited in [24]. This explains that the symptoms of nitrogen deficiency, phosphorous, potassium, and magnesium appear in old plant parts compared with calcium and sulfur. The major and essential nutrients of plant organic molecules are carbon (C), hydrogen (H), and oxygen (O).

1.4 Role of Micronutrients in Higher Plants

Setting a specific limit between the macronutrients and the micronutrients is challenging because some plants need large amounts of a particular nutrient, while others require the same element in small quantities. However, scientific opinions settled on considering the following elements of the micronutrients due to most plants need in quantities much less than the macronutrients; iron (Fe), sodium (Na), chlorine (Cl), boron (B), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), and cobalt (Co).

Iron, copper, and zinc are involved in the synthesis and action of plant enzymes [24]. All trace nutrients are essential for synthesizing enzymes and vitamins in the plant. On younger leaves, signs of micronutrient deficiency are observed, as most micronutrients cannot translocate. Nonetheless, molybdenum is an exception because the absence can often occur on the entire plant [7].

There may be many explanations for micronutrient deficiencies, such as the geological conditions of the soil, unfavourable pH value of the soil solution, availability of high-dose macronutrients, insufficient soil moisture and drought. As mentioned previously, it can be concluded that the absorption of micronutrients by plants depends on the acidity of the soil (Figure 2), Environmental factors such as drought and salinity, the interrelationships between promoting absorption (synergism) or inhibiting absorption (antagonism). [24] Outlined potential antagonistic relations between macronutrients and micronutrients about the excess presence of a specific nutrient in soil solution. In the next section, an explanation of these relationships is more straightforward.

1.5 Antagonistic Vs Synergistic Relations of Nutrients

Antagonism is defined as an excess of an element or nutrient that causes a reduction of uptake for another one. However, synergism is Increasing a specific nutrient increases the chance and absorption of another nutrient. Figure (3) shows 11 basic plant nutrients and micronutrients grouped around a circle while looking at Mulder's Chart. The nutrients are connected by solid and dotted lines, with arrows going in one direction or the other. Solid lines indicate an "antagonistic" relationship, indicating that elevated levels of one nutrient contribute to a nutrient absorption problem, whereas dotted lines indicate a "synergistic" relationship. This chart is one of the most prominent keys for soil and plant chemists. For example, from figure number 3, the following can be deduced:

- 1-Increasing the nitrogen nutrient in the soil reduces potassium absorption and reduces the absorption of boron and copper.
- 2-Increased potassium decreases the absorption of magnesium and boron.
- 3-Phosphorous nutrient presence reduces the absorption of potassium and calcium and a decrease in iron, copper, and zinc.
- 4-Calcium availability impacts potassium, magnesium, and phosphorus absorption. Its presence also affects the uptake of iron, boron, zinc, and manganese.

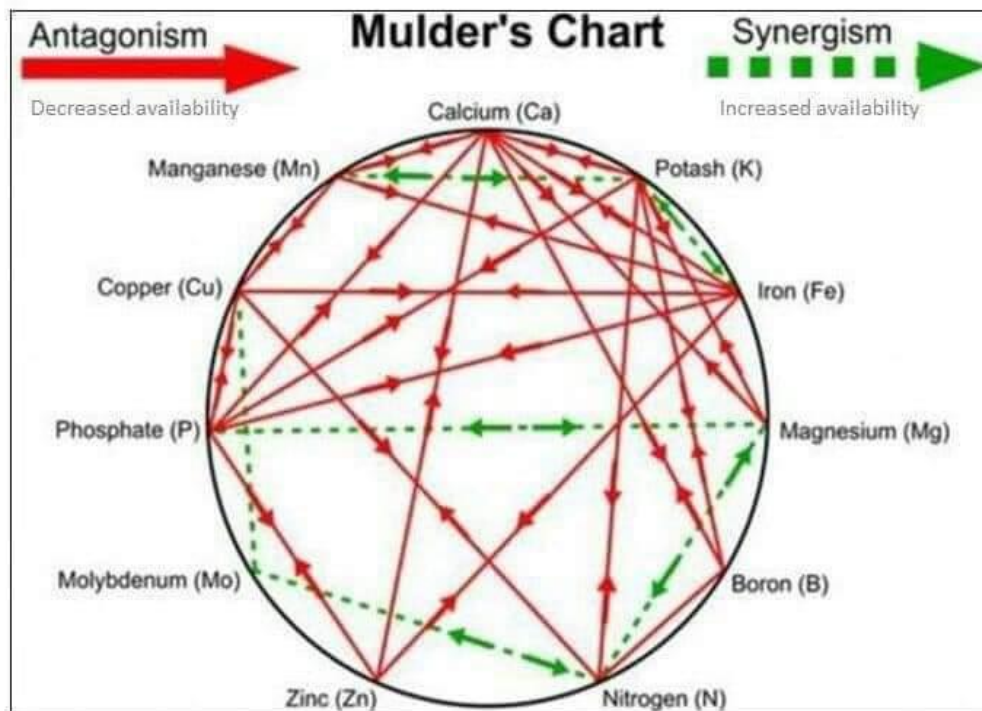


Figure 3. Nutrients antagonistic and synergistic relations in soil [24]

5-Increased magnesium decreases the absorption of potassium.

The above mentioned the role of the macronutrients in the relation of antagonism in soil chemistry with other macro and micronutrients. While the increase in micronutrients causes the following:

- 1-Excess iron inhibits phosphorus uptake.
- 2- Excess soil zinc impacts iron uptake.
- 3- Elevated level of the copper nutrient in the soils leads to problems of uptake for both iron and manganese.
- 4- Excess manganese of soil affects iron uptake.

Because of the multiplicity of views, it is necessary to document other opinions in this regard. [24] Outlined the following notes:

- 1-Excess nitrogen affects calcium availability.
- 2-Excess potassium impacts the uptake of nitrogen and calcium.
- 3-Magnesium availability affects calcium availability.
- 4-Excess iron inhibits manganese uptake.
- 5-Zinc availability impacts manganese availability.
- 6-Copper uptake inhibits the uptake of molybdenum and zinc.
- 7- More manganese in the soil impacts the availability of molybdenum and magnesium.

Concerning the relationship of stimulation or synergism, according to figure (3), the following things can be drawn:

- 1-Excess nitrogen causes more magnesium and vice versa.
- 2- Excess magnesium causes an increase in phosphorous and vice versa.
- 3-Excess nitrogen causes an increase in molybdenum and vice versa.
- 4- Excess potassium causes more iron and vice versa.
- 5- Excess potassium causes more manganese and vice versa.

This figure appeared documented in many forms and details, and all of the above explanation is identical to Figure (3) reported in this paper. There is a synergistic relationship between copper and molybdenum, but the figure is not understood in any direction.

[24] Concluded and reported further information in this regard (not mentioned in figure 3):

- 1-Sulfur uptake affects molybdenum availability.
- 2-Sodium availability affects the uptake of potassium, calcium, and magnesium.
- 3-Excess aluminum inhibits phosphorus availability.
- 4-Excess ammonium ion affects the uptake of both calcium and copper nutrients.

1.6 Salt Stress Impact on Pepper

This research aims to review and document the most important studies that clarify the effect of the deficiency of various nutrients on the pepper plant. Therefore, it is vital to present the rise in nutrient concentrations and the impact of salt on the plant before beginning.

[15] Stated that a calculation of the total amount of soluble salt in the soil is soil salinity. Plants draw water less readily from the soil as salinity levels rise, aggravating drought stress conditions. Salt-affected plants are stunted with dark green leaves that are thicker and more succulent than usual in some instances. The investigator concluded that when soil salinity is around 5.1 dS/m compared with tomato, pepper, and bell ones lose 50% of yield. Tomato loses the same percentage at higher salinity (7.6 dS/m), which indicates the sensitivity of pepper to soil salinity more than tomatoes.

[21] Stated and noticed that the salinity of NaCl leads to the number of marketable fruits has decreased significantly and fruit size reduced in pepper plant. [22] Generalized that a high salinity in the soil results in the poor establishment of stands, decreased planting development of many horticultural crops, such as peppers, and reduced yield. The latter research discovered no seedling emergence in irrigation treatment water has either 3 or 6 dS/m. However, seedlings' emergence recorded was between 45% and 80% when seedlings were sub-irrigated with reverse osmosis water (RO) with a zero salinity level. From the previous references, it can be concluded that the increase in salinity, whether occurred in soil or irrigation water, significantly above the level of 3 dS/m is critical in determining seedling emergence and establishment, growth and field performance, and thus the vegetative yield components, flowering and fruiting of pepper plants. In particular, seedling strength or vigor is usually measured by multiplying the percentage of germination (or emergence) with the dry weight of the plant.

1.7 Nitrogen Deficiency in Pepper

The electronic application (PLANTIX App 3.3.0) was prepared by Progressive Environmental & Agricultural Technologies (PEAT GMBH) in Germany [28]. According to the different growth stages, the tomato plant's shortage of nutrients has been addressed with this application. According to the application [28], nitrogen deficiency may occur during the three vegetative growth stages, flowering, and fruiting growth in the pepper plant (sweet and chili types).

[28] Described nitrogen deficiency in pepper during three growth stages by the following:

- 1-Decoloration (pale green) of the leaves, bright red petioles, and veins.
- 2-The stunted leaf growth and development.
- 3-The plant's appearance is long and slender.

Nitrogen deficiency in sandy, well-drained soils with little organic matter can be found because they are vulnerable to nutrient leaching. Regular rains, floods, or intensive irrigation can wash nitrogen into the soil, causing problems [28]. Dry stress cycles obstruct the absorption of water and nutrients, resulting in an unbalanced supply of nutrients. Lastly, the soil pH (acidity) plays a part in the pepper plant's nitrogen supply. The high or low pH of the soil influences the absorption of nitrogen by the plant negatively (Figure 2). Similar reasons were reported for all growth stages of pepper, especially the vegetative growth stage due to the importance of nitrogen in driving the vegetative growth of any plant in general. [4] Experimented the pepper plant of a specific type known as (Zlatan Medal) to examine and prove the link between nitrogen and pepper plant vegetative growth. Pepper seedlings of the aforementioned species, five days old, grown hydroponically using a nitrogen-free nutrient solution. The shortage of nitrogen in the medium resulted in a reduction in the leaf area and the accumulation of plant biomass and an increase in the dry weight ratio of the root shoot. Under nitrogen deprivation, photosynthetic activity and chlorophyll decreased significantly. Research findings have shown that nitrogen plays a vital role in developing the chloroplast structure and, thus, in pepper plants' photosynthetic strength and productivity. The aforementioned scientific research shows the close relationship between nitrogen and physiological properties related to photosynthesis, vegetative growth, and pepper plant

yield. The health of vegetative growth reflects the health of fruit, growth and production in general because the leaves are the kitchen that nourishes the growth of the fruits of pepper.

Agricultural extension experts usually recommend farmers to pay attention to fermented organic fertilization (either compost or manure) and balanced irrigation during periods of drought, with the need to prevent flooding and to ensure good soil drainage, and to maintain a moderate level of soil acidity and irrigation water within the limit that allows nitrogen to be absorbed. Figure (2) shows that the optimal range of soil acidity (pH) to absorb nitrogen is (6-7). Adding lime (contains calcium carbonate and magnesium carbonates naturally) to raise the level of acidity towards alkalinity (above 7) or adding sulfur to reduce the level of acidity towards acidity (under 7) are alternative practical ways to ensure that the level is reached.

1.8 Phosphorus Deficiency in Pepper

As with nitrogen, phosphorous deficiency can occur in the three main stages during the growth of chili and sweet peppers. These three stages are vegetative growth, flowering, and fruiting [28]. Phosphorus deficiency can be inferred if the following symptoms appear: (1) Curled foliage, (2) Plant development that has stunted, (3) Starting from the margins, purple leaves.

If the symptoms of phosphorous deficiency appear, the researcher must pay attention to the following scientific facts;

1-Phosphate ions are absorbed by plant roots only when they are dissolved in soil moisture. Therefore, the supply of this nutrient is limited because it has adhered to soil particles and the plant does not take it.

2-Calcareous soils with high calcium concentrations may be low in phosphorus. Both alkaline soils and acidic soils may have low phosphorous availability. Iron-rich soils and low organic matter soils can also be troublesome.

3-Abiotic stresses such as drought conditions or diseases that restrict the roots' absorption of water and nutrients may cause symptoms of phosphorus deficiency. In exchange, soil moisture absorbs the absorption of this nutrient and results in substantially higher yields.

Low temperature and cold weather conditions inhibit proper development, and root function may also contribute to this disorder.

Strey, 2021 [28] was indicated the importance of phosphorus in the growth, strength (vigor), and health of the roots of the pepper plant. It can be concluded that root strength is closely related to the readiness and absorption of phosphorous in the plant. Phosphorus deficiency is a complex issue involving both ecological and physiological factors. The health of the root system reflects the strength and health of the shoots. Therefore, phosphorus and nitrogen are essential nutrients for plant nutrition. [5] Reported findings of field experiment regarding phosphorus fertilization on a chili pepper, plant variety called (Long Slim Cayenne). The results indicate an increase in chili pepper vegetative growth, yield, and yield components because of phosphorus application which was attributed to the role of phosphorus nutrient in raising plant biomass accumulation by increasing photo-synthetically active radiation interception and promoting root growth, and thus increasing plant mineral nutrient uptake. That at the end of the study, chili pepper at the transplanting stage should be fertilized at a rate of 40 kg of pure phosphorus nutrient per hectare, especially under sandy loam soils. The results of this research study show another confirmation of the cross-linking role of phosphorus in improving and strengthening the root and thus increasing the absorption of water and nutrients.

The results showed that a phosphorus usage dose of 40 Kg/ha increased plant height, leaf area, shoot, and root dry matter, and fruit production per plant significantly compared with other treatments of phosphorus application (0, 20, and 60 Kg/ha). In this regard, farmers are advised to conduct a soil analysis before fertilization and before the beginning of the cropping season to maximize crop productivity by ensuring balanced fertilization that combines mineral (like diammonium phosphate DAP, and single superphosphate SSP) fertilizers and organic amendments (such as farmyard manure, organic mulch, compost, and after harvest cropping residues). In addition, maintaining the appropriate soil acidity (pH) to absorb the available phosphorus in the soil by adding lime or sulfur as required. It is noticed from figure number (2) that the ideal soil acidity (pH) range to improve the readiness of the phosphorus nutrient is (6.5 - 7.5), with an average of 7 at the neutral point between acidity and alkalinity. To this end, the above two sections described the inevitable relationship between the readiness of nitrogen and phosphorous for pepper plants according to the pH and watery soil conditions.

1.9 Potassium Deficiency in Pepper

Based on the software (PLANTIX App 3.3.0) [28], potassium deficiency occurs in the pepper plant's flowering, fruiting, and harvesting stages. The symptoms of potassium deficiency can be distinguished by the following:

- 1-The leaves begin to yellow at the edges.
- 2- The main vein remains dark green.
- 3-Curled leaves and a slower rate of growth (dwarfing).

Potassium deficiency can occur when there aren't enough potassium reserves in the soil or when potassium isn't readily available to the plant. In addition, the low acidity of soils (pH) and sandy soils with little organic matter are susceptible to nutrients leaching and drought and thus can cause problems. Heavy irrigation and much rain can also contribute to nutrient deficiency by washing nutrients out of the root region, especially in sandy soils.

Heat stress and dry conditions prevent the transport of water and nutrients to plants. Potassium can be harmed by high calcium and magnesium levels in the soil (antagonistic effect). The nutrient potassium is essential and important in transporting water inside the plant [28]. It is wrong to say that potassium decreases with more iron in the soil. There is a motivational relationship (synergism) between the two elements (Figure 3). It is recommended to water the pepper plants regularly to prevent flooding, apply organic matter in the form of fertilizer or plant mulch (potassium is found in wood ash) to the soil, use industrial and chemical fertilizers in a balanced way to ensure adequate nutrient supply the plant and test the soil acidity (pH) and lime content to achieve the optimal range. In addition, by minimizing leaching, liming acidic soils may improve potassium retention. Figure (2) shows the optimal range of soil potassium availability (6-10), with an average value of 8. It was reported that potassium is one of the most abundant elements in the earth's crust. However, while it is abundant in the earth's crust, it is present in relatively low concentrations in soil solutions. As a result, its availability to plants is typically reduced, resulting in a substantial reduction in plant growth and yield [8].

There are not many studies that examine the relationship between potassium deficiency and its effect on the growth, development, and production of the pepper plant. Despite this, some research deals with the importance of potassium nutrition and its positive effect on the pepper plant. In pepper plants, potassium nutrition had a greater impact on fruit yield parameters than on vegetative biomass [3]. By increasing fruit firmness, total soluble solids (TSS) content, soluble sugars, and ascorbic acid concentration, potassium cations (K^+) in the nutrient solution improved pepper fruit efficiency. As a result of the improved fruit quality obtained with adequate potassium nutrition, nutritionally enriched fruits were grown. [3] Stated that potassium stands out among the many plant mineral nutrients as the cation with the most significant effect on quality attributes that decide fruit marketability and customer preference.

Compared with nutrients nitrogen and phosphorous, potassium indicates that symptoms of its deficiency in pepper may also appear during the harvest phase [28]. Thus, the importance and influence of the mentioned nutrient on the marketing properties of pepper fruits can be concluded. The essential function of potassium nutrients in water transport and tissue firmness was discussed previously. This explains and confirms findings of the prepared research entitled "Potassium fertilization enhances pepper fruit quality" published in the journal of plant nutrition [3]. It is imperative to follow the directions of a professional pepper plant advisor to ensure balanced fertilization. It is usually recommended to do a soil examination to ensure the need for potassium in the soil and plants. Then, natural fertilizers such as wood ash can be added, which is very rich in potassium, and chemical fertilizers containing potassium such as potassium nitrate (KNO_3).

1.10 Digital Sensing, and Nitrogen, Phosphorus, Potassium Deficiencies

Scientific, research, and technical institutions have begun manufacturing electronic sensors to check soil and irrigation water nitrogen, phosphorus, and potassium levels. In addition, many electronic sensors help measure the pH and the level of total dissolved salts in both soil and irrigation water ($\mu s/cm$, and or mg/L). The institute of plant protection and the plant pathology laboratory at the University of Debrecen is now working on using these probes and sensors to manage plant nutrients in the soil and irrigation water and determine the nutritional and water needs of the pepper plant. These records also assess plant health and the possibility of foliar nutrition as one of the practices for integrated control of pests or environmental stresses such as heat, drought, and salinity stresses (Figure 5).

Mohunnad Massimi, Laszlo Radocz., 2021. The Action of Nutrients Deficiency on Growth Biometrics, Physiological Traits, Production Indicators, and Disease Development in Pepper (*Capsicum annuum* L.) Plant: A review. 15(3): 1-19. DOI: 10.22587/aejsa.2021.15.3.1

One of the international institutions in this field called luster leaf has [17] manufactured electronic sensors in Figure 4 (a and b), digital sensor model number (1835), and traditional hand pointer model number (1818), respectively. Both are determined to have ideal nitrogen and potassium levels within (50-200 mg/L). But, the ideal level for phosphorus is (4-14 mg/L). Furthermore, according to the technical specifications of the devices stated, the ideal soil acidity for pepper is (5.5-7.0) While tomatoes bear the extent that falls within (6.5-7.5).



Figure 4 (a+b): Nitrogen, phosphorus, potassium, and acidity sensors.

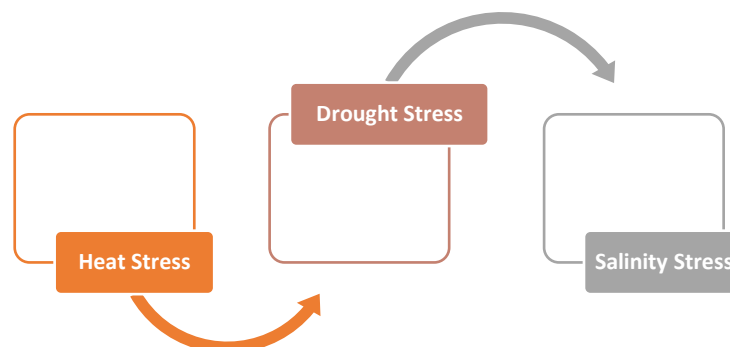


Figure 5. The Intertwined relationship of different abiotic stresses

To measure the acidity of irrigation water and soil, the researcher can use the electronic sensor shown in Figure 6. The usual method is to add an amount of soil (for example, 20 mm or cubic centimeters) to twice the equivalent amount of distilled water (40 mm). Distilled water does not contain hydrogen and hydroxyl ions, but de-ionized water contains both. Therefore, before use, the device must be calibrated using a buffer and distilled water solution, and it must be cleaned with distilled water after each use.



Figure 6: Soil and water acidity meter (pH) of Pancellent trade name

Researchers and field extension scholars also use the salinity sensor, soil, and irrigation water sensor Figure 7. Readings are given in (mg/L) or electrical conductivity units ($\mu\text{s}/\text{cm}$). Each 1 microsemin / centimeter equals 0.641 mg/L.



Figure 7: Soil and irrigation water salinity meter of Pancellent trade name

Below is an experiment from the Plant Pathology Laboratory at the University of Debrecen, specifically from doctoral research, as an example of the usage of electronic devices. Research entitled foliar nutrition and the Interrelationships of Plant Health status. Table (2) shows the results of using these electronic sensors which are improved varieties of pepper were planted under laboratory conditions and after full germination was achieved using distilled water, a transfer process was carried out from Petri dishes to organic soil containing biological humic acids. 30 mm (cc) of compost was applied with 60 mm distilled water and left until homogeneity (Photo 4).

Table 2: The readings obtained by the electronic sensors

Acidity	Fertility	Temperature	Total Dissolved Salts (ppm)	Electrical Conductivity $\mu\text{s}/\text{cm}$
pH	(N-P-K)	$^{\circ}\text{C}$		
7	3 (Ideal)	21.7	202	402.3

The acidity is ideal for the growth of peppers (pH equals 7). Soil fertility is also ideal as it indicates the minimum range of macronutrients which are equivalent to (50 mg/L of nitrogen, 4 mg/L of phosphorus, and 50

mg/L of potassium). The optimum temperature for transferring seedlings is appropriate (65 F equals 18.33°C). The Laboratory air temperature on the day of seedlings transfer was (22.1°C). About salinity, the level of salt is much lower than the critical limit for pepper plants.



Figure 8 Experiment with readings of an organic fertilizer solution



Figure 9: Using a sensor to monitor soil pH and moisture

1.11 Magnesium Deficiency in Pepper

Magnesium deficiency is typical in soils with low nutrients and water retention potentials, such as light, sandy, or acidic soils. Sandy soils may be more susceptible to nutrient leaching. Figure (2) explains that magnesium is more available when soil acidity (7-8). The strength of light affects the progression of symptoms. Magnesium deficiency is aggravated by bright sunlight. A fact stated in part (1.5) of this article is that increased potassium reduces magnesium absorption. Increased magnesium absorption would also reduce potassium supply, according to Figure (3). Based on the software (PLANTIX App 3.3.0) [28], ammonium and potassium applied in abundance negatively affect magnesium availability in the soil.

Magnesium is a component of chlorophyll molecules (Table 1) and is involved in sugar transport. If they don't get enough magnesium, the plants begin to degrade the chlorophyll in the older leaves to move it to the developing ones. Symptoms of magnesium deficiency in plants appear during the vegetative, flowering, and fruiting stages and are characterized by the following:

- 1-The key main veins of the leaves remain green. Chlorosis of the interveinal space appeared.
- 2-From the edges, light pale green spots or yellowing of leaves occur, followed by reddish or brown spots on the leaf.
- 3-Leaf tissues that are dry die off.

So it is clear that the direct role of the magnesium nutrient in the growth of leaves and the vegetative system appears. However, magnesium deficiency is not always negative for shoots. [26] Experimented to evaluate the effect of magnesium deficiency on the growth parameters of pepper. Pepper plants exhibited the following symptoms of magnesium deficiency:

- 1-A reduction in the plant's relative growth rate (RGR).
- 2-Reducing the total dry weight of the plant (DW).
- 3-Decreased stem mass fractions and root mass fractions (SMF, and RMF).
- 4- Total leaf area, the specific leaf area (SLA), and unit leaf rate reduction (ULR).
- 5-Leaf mass fraction increased.
- 6-Increasing the ratio of shoots to roots.

Generally, magnesium is essential for maintaining good growth and high yields by increasing photosynthetic activity. Therefore, necrotic patches appear on the leaf margins of peppers with magnesium deficiency and spread toward the leaf center. The yellowing (chlorosis) may also occur due to manganese and iron elements deficiency. However, magnesium deficiency occurs in old leaves, while the deficiency of trace elements of iron and manganese occurs in young leaves. More precisely, because both manganese and iron are immobile nutrients inside the plant, symptoms appear first in younger leaves near the top of the plant, while the symptoms of magnesium deficiency appear in older leaves near the bottom of the plant. In both cases, whether a deficiency of magnesium or a deficiency of manganese or iron, then the leaves begin to yellow and show signs of interveinal chlorosis. Therefore, the magnesium deficiency in pepper can be remedied by the following:

- 1-Magnesium may be sprayed on the leaves or added directly to the soil.
- 2-Adding magnesium-containing chemical fertilizers, such as magnesium sulfate (MgSO₄), can be used.

1.12 Calcium Deficiency in Pepper

The symptoms of calcium insufficiency in peppers are caused by the availability of this nutrient to the plant rather than a lack of soil supply. Alkaline soil contains calcium in abundance, especially at the level of acidity (7-8.5). Symptoms of calcium deficiency usually appear on new young leaves because it is an immobile nutrient of the plant. Therefore, heavy clay and irrigated soils can dissolve calcium and make it available to the plant. Deficiency symptoms appear in sandy soils, droughts, acidic soils, or very salty soils. Also, phosphorus nutrients decrease calcium absorption; excess nitrogen reduces the supply of calcium. Magnesium availability has an impact on calcium availability. The sodium supply regulates the calcium uptake, as seen in Figure (3). Excess ammonium ions interfere with the absorption of calcium nutrients. Calcium deficiency signs are:

- 1-Yellow spots on leaves.
- 2-Curled leaves.
- 3- Young shoots, roots, and fruits that aren't fully grown.
- 4-Growth retardation.
- 5-Plant Wilting.

(PLANTIX App 3.3.0) [28] stated that calcium deficiency can be observed in pepper in the vegetative, flowering, and/or fruiting growth stages. This explains the symptoms listed in point 3 above, as symptoms are likely to appear in the vegetative, flowering, and fruiting stages of pepper plants' growth. Calcium is involved in the formation of pectin. Therefore, the deficiency of this element will lead to the collapse of the cell walls. The cell walls of plants are made up of pectin, which has an acidic sugar backbone and neutral sugar side chains. It is involved in cell adhesion and cell wall formation. [16] Found that the relative air humidity in the plastic-covered growing facility increased due to the high temperature, affecting transpiration and nutrient transport. Ca²⁺ ion uptake was hampered by a long-term root zone temperature of 29 °C. Young cells in the fruit setting stage of pepper plants need more calcium. This explains why blossom end rot begins to form during this time. Blossom end rot is a severe pepper and tomato disease caused by an environmental problem (not a fungal infection) that is most commonly caused by uneven watering or calcium deficiency.



Figure 10: Peak rot of Paprika [25]

Blossom end rot affects both green and ripe fruits, with water-soaked areas on the bottom end eventually widening and maturing into sunken, brown, leathery spots. Secondary pathogens, which appear as a black, fuzzy-like development, often invade the infected area and cause the fruit to rot completely. Blossom end rot is not infectious and does not spread from plant to plant.

1.13 Macronutrients Deficiency Symptoms in Pepper

This paragraph will present a set of pictures showing symptoms of the deficiency of macronutrients on the pepper plant. Some of the images are available on the website of Haifa company [9]. Figure 11 shows pale leaf color, which indicates nitrogen deficiency. As for Figure 12 is a symptom of phosphorus deficiency in peppers, represented by stunting and leaf curl (the plant to the left).



Figure 11: Nitrogen deficiency in pepper [9]



Figure 12: Phosphorus deficiency in pepper [28]

Figure 13 (a) shows the symptoms of potassium deficiency on the pepper plant, represented by curling the leaves and a decrease in the speed of leaf growth (stunting) [9]. Figure 13 (b) shows the yellowing of the leaves starting from the edges (margins) with the main veins remaining green [28].





Figure 13 (a [9], and b [28]): Potassium deficiency symptoms in pepper

Figure 14 taken from the same source [28] shows clear symptoms of magnesium deficiency on the pepper plant, yellowing between the veins (interveinal chlorosis). Symptoms progress to pale, green, and yellow spots, followed by reddish-brown leaves.



Figure 14: Symptoms of magnesium deficiency in pepper plant [28]

1.14 Micronutrients Deficiency in Pepper (Zn, Mn, B, and Fe)

Zinc (Zn), manganese (Mn), boron (B), and iron (Fe) are the essential trace elements that can display symptoms of insufficiency in the pepper plant, according to Plantix application (3.3.0). This is especially true during the vegetative growth period. During the blossoming stage, the deficit in iron, boron, and zinc can also arise. In addition, zinc and iron deficiencies might occur during the fruiting period [28]. Close findings confirmed by the Haifa company website [9], deficiency of manganese and iron may show symptoms in pepper plants. Toxicity may also appear from excess boron.

Soil pH plays a major role in the availability of these elements. Returning to figure (2), the following is noted:

- 1-Iron availability increases in soils with a pH level of (4-6.5)
- 2-Manganese availability increases in the soil with a pH level of (5-6.5).
- 3-At the pH level of (5-7), boron and zinc are increased.
- 4-Copper needs the same level of acidity as zinc.

Molybdenum differs from the rest of the aforementioned trace elements in that it needs a basic or alkaline soil with a pH level of (7-10) for it to be available to plants in general.

Strey (2021) application [28] reported soils that are poor in organic matter, sandy, and have a high pH level are characterized by a deficiency of zinc. Increased calcium and phosphorous affect zinc absorption in the soil. Zinc

deficiency can occur in cool, damp soil as well. Pepper plants that are deficient in zinc are characterized by the following:

- 1-Yellowing of the leaves, beginning at the margins.
- 2-The main leaf veins remain green.
- 3-Deformed leaves clump together along the stem.
- 4-Stunted growth.

Manganese deficiency occurs in tropical regions where sandy soils suffer from a pH level higher than 6. Also, Excess calcium, copper, zinc, and iron impacts the availability of manganese in soils for plants. Manganese is an immobile nutrient in plants, so its deficiency symptoms first appear in modern leaves, accumulating in old leaves. The main symptoms of manganese deficiency in the pepper plant are:

- 1-Young leaves are mottled, light green, and have interveinal chlorosis.
- 2-On chlorotic areas, small necrotic lesions form.
- 3-Brown necrotic spots appear on the leaf surface, and the infected leaves turn brown.

On the other hand, boron deficiency is usually diagnosed in soils with high acidity, low organic matter soils, and highly leaching sandy soils. The excess nitrogen, potassium, and calcium affect boron uptake by plants. Pepper plant with boron deficiency has the following symptoms:

- 1-Brittleness of leaves and stems.
- 2-Yellowing and thickening of the leaves.

Iron deficiency can be a serious problem in tropical soils that have been leached or in soils that have been poorly drained, particularly in areas with cold damp springs. Plants are particularly susceptible to iron deficiency in calcareous, alkaline soils derived from limestone. Photosynthesis necessitates the presence of iron. Iron is more available in soils with acidic pH of (4-6.5) (Figure 2). It was discussed in figure (3) several issues regarded uptake of iron and other nutrients. The deficiency of iron increases the uptake of potassium and calcium. Also, copper, zinc, and manganese inhibit iron uptake. However, excess iron inhibits phosphorus and manganese uptake by plants. Pepper plant with iron deficiency has the following symptoms:

- 1-Yellowing of leaves begins at the margins.
- 2-The leaf veins remain green.
- 3-Leaves become whitish-yellow with brown spots.
- 4-Stunting growth.

Figure (15-19) shows trace nutrients deficiency symptoms in pepper taken from different sources. Figure 18 was taken from the Haifa company website [9]. Also, Figure (15, 16, 17, and 19) were taken from Plantix application (3.3.0) documented by (Strey, 2021) [28].



Figure 15: Zinc deficiency symptoms in pepper plant [28]



Figure 16: Manganese deficiency in pepper [28]



Figure 17: Boron deficiency symptoms of pepper [28]



Figure 18: Iron deficiency in pepper plant [9]



Figure 19: Iron deficiency on true leaves of the pepper plant [28]

1.15 Nutrients Deficiency and Diseases Development

In this section, the emergence and development of various diseases associated with the deficiency of nutrients in the pepper plant will be mentioned and outlined (Table 3).

Table 3: Pepper diseases related to nutrients deficiency

Disease	Scientific Name	Type	Nutrient Deficiency	Other Factors
Gray Leaf Spot	<i>Stemphylium solani</i>	Fungus	Potassium	Drought
Blossom End Rot	None	Physiological	Calcium	None

Blossom end rot is a physiological disorder caused by calcium deficiency and was explained in detail previously (section 1.12). A fungus (*Stemphylium solani*) harmful to pepper plants causes gray leaf spots [13]. According to the latter study, the best temperature for mycelial growth and germination was 25°C. Gray leaf spot disease development characterized by leaf spotting symptoms was observed at 15°C (night temperature), and 20°C (day temperature). Furthermore, temperatures between 20 and 30°C are optimum for the disease's growth [28]. This disease may be caused by a complex combination of potassium deficiency and drought stress (Figure 20).



Figure 20: Gray leaf spot symptoms of peppers [28]

1.16 Nutrients Deficiency and Foliar Application

In contrast to providing nutrients to plants via the soil, a new technique known as foliar nutrition has emerged [19]. Fertilizer application in the soil is primarily based on soil tests, while foliar nutrition is primarily based on visual foliar symptoms or plant tissue checks. For successful foliar nutrition, a correct diagnosis of nutrient deficiency is needed [6].

Foliar feeding is not intended to replace soil fertilization. Soil application is the most productive and cost-effective way to supply a plant's main nutrient needs (nitrogen, phosphorus, and potassium). On the other hand, Foliar treatment has proved to be an excellent method of providing secondary nutrients (calcium, magnesium, and sulfur) and micronutrients to plants (zinc, manganese, iron, copper, boron and molybdenum).

The benefits of foliar nutrition were reported by [10]. The method promotes rapid mineral nutrient absorption while avoiding soil interactions that reduce root uptake due to soil immobilization. It can help with nutrient deficiency-related physiological issues such as pepper blossom end rot.

According to Wittwer et al [29] cited in Singh et al. [27], Plant foliage resistance to foliar application varies from plant to plant. Pepper and tomato foliage resistance was similar (0.48-0.72 Kg of Urea sprays 100 l⁻¹ of water). The pepper plant requires sulfur spraying at the bud formation level, 10-14 days after the first spray, and 10-14 days after the second spray, at a rate of (0.11-0.23 Kg Acre⁻¹) per sulfur spray time.

For maximum product growth, yield, and quality, [20] recommended foliar spraying of magnesium sulfate hydrate (epsomite) in peppers and tomatoes.

The effects of potassium (K) foliar application on pepper plants grown under different irrigation salinity levels were investigated in a greenhouse experiment (3000 and 6000 mg/L as compared with tap water with a salinity level of 300 mg/L). Irrigation with high salinity water reduced plant height, biomass production, and fruit yield

compared with plants irrigated with tap water. However, plant growth, biomass production, and fruit yield were all improved by foliar application of potassium monophosphate (KMP) at a concentration of 200 mg/L. This showed that foliar application of KMP mitigated the negative effects of high salinity water irrigation on pepper plant growth and fruit yield to some extent [11].

The advantages of foliar application in some areas, according to [23], help in the rapid correction of nutrient deficiency:

- 1-It aids in the rapid correction of nutrient deficiencies.
- 2-Foliar spraying may be combined with other applications, including insecticides.
- 3-Foliar application is beneficial when the soil is deficient in nutrients.
- 4-Foliar applications may be sprayed when a rapid growth response is needed.
- 5-It can help in the fixation of high phosphorus and potassium.
- 6-Where there have been adverse conditions in the field, such as root rot, disease, dryness, etc. A foliar spray can be used.
- 7-If there isn't enough moisture in the topsoil to absorb nutrients from the plant's roots, a foliar spray may be used.
- 8-Just apply a small amount of fertilizer at a time.
- 9-Foliar nutrition increased yield and quality parameters.

LABEL CONCLUSIONS AND RECOMMENDATIONS:

- 1-The main environmental stressors for horticultural crops are heat, drought, cold, frost, salinity, air humidity, soil moisture, and light.
- 2- One of the non-traditional environmental factors that affect the growth of horticultural crops is the lack of nutrients or nutrient deficiencies.
- 3-Plant nutrition is a major factor added to irrigation scheduling to ensure optimum yield and quality.
- 4-Soil chemistry is one of the most important secondary sciences related to this field, which the researcher must delve into to understand the rationale for the problem.
- 5-Feeding plants through roots and soil are the main method, but foliar feeding is a modern scientific technique with many advantages.
- 6-The foliar feeding technique is considered one of the integrated pest control methods and it's a comparative advantage in resisting difficult environmental conditions.

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REFERENCES:

- [1] Ballina-Gomez, H., L. Latournerie-Moreno, E. Ruiz-Sánchez, A. Pérez-Gutiérrez, and G. Rosado-Lugo., 2013. Morphological Characterization of *Capsicum annuum* L. Accessions From Southern Mexico and Their Response to the Bemisia tabaci-Begomovirus Complex. Chilean Journal of Agricultural Research, 73(4): 329-338. DOI: 10.4067/S0718-58392013000400001.
- [2] Bergmann, W., 1979. Termesztett növények táplálkozási zavarainak előfordulása és felismerése. Budapest, Mezőgazdasági Kiadó.
- [3] Botella, M.A., L. Arevalo, T.C. Mester, F. Rubio, F. Garcia-Sanchez, R.M. Rivero, and V. Martinez., 2017. Potassium Fertilization Enhances Pepper Fruit Quality. Journal of Plant Nutrition, 40(2): 145-155. DOI: 10.1080/01904167.2016.1201501.
- [4] Doncheva, S., V. Vassileva, G. Ignatov, and S. Pandev., 2001. Influence of Nitrogen Deficiency on Photosynthesis and Chloroplast Ultrastructure of Pepper Plants. Agriculture and Food Science in Finland, 10: 59-64. DOI: 10.23986/afsci.5680.
- [5] Emongor, V.E., and O. Mabe., 2012. Effects of Phosphorus on Growth, Yield and Yield Components of Chilli Pepper (*Capsicum annuum* L.). Acta Horticulturae, 936. 327-334. 10.17660/Acta Horticulturae.2012.936.42. DOI:10.17660/ActaHortic.2012.936.42.
- [6] Fageria, N.K., M.P. Barbosa Filho, A. Moreira, and C.M. Guimares., 2009. Foliar Fertilization of Crop Plants. Journal of Plant Nutrition, 32, 1044-1064. DOI: 10.1080/01904160902872826.

- [7] Gupta, U.C., W.U. Kening, and L. Siyuan., 2008. Micronutrients in Soils, Crops, and Livestock. *Earth Science Frontiers*, 15(5):110–125. DOI: 10.1016/S1872-5791(09)60003-8.
- [8] Hafsi, C., A. Debez, and C. Abdelly., 2014. Potassium Deficiency in Plants: Effects and Signaling Cascades. *Acta Physiologiae Plantarum*, 36: 1055- 1070. DOI: 10.1007/s11738-014-1491-2.
- [9] Haifa., 2020. Pepper: Nutrient Deficiencies, Haifa (Pioneering the Future), Haifa, Israel, www.haifa-group.com.
- [10] Haytova, D., 2013. A Review of Foliar Fertilization of Some Vegetables Crops. *Annual Review & Research in Biology*, 3(4), 455-465.
- [11] Hussein, M.M., S.Y. EL-Faham, and A.K. Alva., 2012. Pepper Plants Growth, Yield, Photosynthetic Pigments, and Total Phenols as Affected by Foliar Application of Potassium Under Different Salinity Irrigation Water. *Agricultural Sciences*, 3(2), 241-248. DOI: 10.4236/as.2012.32028.
- [12] Ketterings, Q.M., G. Albrecht, and J. Beckman., 2005. Soil pH for Field Crops, *Agronomy Fact Sheet Series, Fact Sheet # 5*, Cornell University Cooperative Extension.
- [13] Kim, B.S., S.H. Yu, H.J. Cho, and H.S. Hwang., 2004. Gray Leaf Spot in Peppers Caused by *Stemphylium solani* and *S. lycopersici*. *The Plant Pathology Journal*, 20(2): 85-91. DOI: 10.5423/PPJ.2004.20.2.085.
- [14] Kim, D.H., M.S. Han, H.W. Cho, Y.D. Jo, M.C. Cho, and B.D. Kim., 2006. Molecular Cloning of a Pepper Gene that Is Homologous to SELF-PRUNING. *Molecules and Cells*, 22(1): 89-96.
- [15] Kotuby-Amacher, J.K., R. Koenig, and B. Kitchen., 2000. *Salinity and Plant Tolerance*, Archived USU Extension Publications, Utah State University.
- [16] Lantos, F., K. Mike, T. Monostori, and L. Helyes., 2012. Evaluation of Calcium Deficiency Symptoms in Sweet Pepper (*Capsicum annuum* L.) Fruits Via Visual Plant Diagnosis and Microscopic Examination. *Acta Horticulturae*, 938: 283-289. DOI: 10.17660/ActaHortic.2012.938.37.
- [17] Luster Leaf., 2021. *Luster Leaf Products for Successful Gardening Catalog*, Luster Leaf Products, Inc, Illinois, www.lusterleaf.com.
- [18] Massimi, M, and A. Al-Bdour., 2018. A Short Scientific Note on the Horticultural Crops Optimum Planting Dates in Jordan. *Egyptian Journal of Horticulture*, 45, 337-340., DOI:10.21608/ejoh.2018.6221.1085.
- [19] Massimi, M., and L. Radocz., 2020. A Brief Literature Investigations on Foliar Plant Nutrition and its Function in the Protection of Horticultural Crops. *Hungarian Agricultural Engineering Journal*, 38: 63-70. DOI: 10.17676/HAE.2020.38.63.
- [20] Nannette, R., 2011. Magnesium Sulphate Hydrate (Epsomite) Boosts Growth in Tomatoes, Peppers and Roses, How to Use Magnesium Sulphate in the Garden. <http://voices.yahoo.com/magnesium-sulphate-hydrate-epsomite-boostsgrowth-in-8638139.html?cat=6>.
- [21] Navarro, J.M., C. Garrido, P. Flores, and V. Martinez., 2010. The Effect of Salinity on Yield and Fruit Quality of Pepper Grown in Perlite. *Spanish Journal of Agricultural Research*, 8(1): 142-150. DOI:10.5424/sjar/2010081-1153.
- [22] Niu, G., and D.S. Rodriguez., 2010. Salinity and Soil Type Effects on Emergence and Growth of Pepper Seedlings. *HortScience*, 45(8): 1265-1269. DOI: 10.21273/HORTSCI.45.8.1265.
- [23] Patil, B., and H.T. Chetan., 2018. Foliar Fertilization of Nutrients. *MARUMEGH*, 3(1), 49-53.
- [24] Racz, D., and L. Radocz., 2019. Nutrient Deficiency and Effects of Various Nutrition Technologies on Crop Health. *Acta Agraria Debreceniensis*, 2: 109- 113. DOI: 10.34101/actaagrar/2/3687.
- [25] Radocz, L., 2020. *Integrated Pest Management (1) Course, Integrated Plant Protection IV*, Institute of Plant Protection, University of Debrecen.
- [26] Riga, P., and M. Anza., 2003. Effect of Magnesium Deficiency on Pepper Growth Parameters: Implications for Determination of Magnesium-Critical Value. *Journal of Plant Nutrition*, 26(8): 1581-1593. DOI:10.1081/PLN-120022367.
- [27] Singh, J., M. Singh, A. Jain, S. Bhardwaj, A. Singh, D.K. Singh, B. Bhushan, and S.K. Dubey., 2013. An Introduction of Plant Nutrients and Foliar Fertilization: A Review. Chapter 16. In *Book: Precision Farming: A New Approach*: Daya Publishing Company: New Delhi: India.
- [28] Strey, R., 2021. *PLANTIX Application, 3.3.0, 2021. Progressive Environmental & Agricultural Technologies (PEAT GMBH), Germany (Retrieved February 2021)*.
- [29] Wittwer, S.H., M.J. Bukovac, and H.B. Tukey., 1963. *Advances in Foliar Feeding of Plant Nutrients*. In *MHMcVickar, (Eds.), Fertilizer Technology and Usage*. Soil Science Society of America, Madison, WI, 429-455.
- [30] Zhou, J., H. Hu, X. Li, R. Zhao, G. Li, and P. Yang., 2010. Effects of Rootstock on Fruit Yields and Quality of Hydroponically Cultivated Grafted Cucumber under NaCl Stress. *Acta Horticulturae*, 871:63-70. DOI: 10.17660/ActaHortic.2010.871.6.