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Enhancing Yield Components and Chemical Constituents of Hot Pepper Plants Grown Under Hydroponic System Using NPK And Fe, Zn and Cu Fertilizers

Ziad Badr A. M., Mahmoud M. El- Hamady, E. H. Abou El-Salehein and Mohamed El Nagy Mohamed

Plant Production Department. (Horticulture –Vegetables), Faculty of Technology and Development, Zagazig University, Egypt.

***Corresponding author: Ziad Badr Abdelmageid Elbhrawy**

E-mail: Ziadbadr2026@gmail.com

ABSTRACT:

This study was established for evaluating the influence of some macro (NPK) and micro-nutrients (Fe, Zn and Cu) in individual or combination on yield and fruit nutritional content of hot pepper (*Capsicum annuum* L.) Super Nar cultivar. to obtain the highest fruits yield characters and the best nutritional values of hot pepper, soilless culture method (Nutrient Film Technique) under open hydroponic conditions in Faculty of Technology and Development Zagazig University, Egypt, during summer seasons of 2023 and 2024. The current study was simple experiment in randomized complete block design with three replicates. Eight treatments were applied as NPK at 2g/l, Iron (EDDTA), Zinc (EDDTA) and copper rates each at 2ml/l, NPK 2g/l + iron 2 $ml l^{-1}$, NPK 2g/l + Zinc (EDDTA) and NPK 2g/l + copper 2 $ml l^{-1}$ besides the control treatment without any addition. These treatments were added within irrigation water (fertigation) after 30, 45, and 60 days from transplanting date, any fertilizer sources were added three times per season. The obtained results indicated that applied hot pepper plants with NPK 2g/l and Zinc at 2 ml/l gave the highest values of yield components (average weight of fruit, fruits number per plant and total yield per feddan) and fruit quality (nitrogen, phosphorus, potassium and total soluble sugars contents) in the two consecutive seasons. Generally, it could be recommended that, for enhancing yield and nutritional values of fruits of hot pepper plant cv. Super Nar, it could be added plants with 2g/l of NPK and 2 ml/l of Zinc on the soil under open hydroponic system.

Key words: *Capsicum annuum*, NPK, Iron, Zinc, Copper, yield, nutritional values.

INTRODUCTION:

Hot pepper (*Capsicum annuum* L.) plants are among the numerous significant plants in the Solanaceae family. It is a commonly grown plant in Egypt that has been used for culinary flavoring and human health since ancient times (**Milla, 2006**). It is one of the most significant, well-liked, and popular vegetable crops grown in Egypt (**El-Sayed *et al.*, 2018**). Hot pepper dried fruit is used as a condiments and spice (**Dagnoko *et al.*, 2013**). Hot peppers are a significant horticultural crop in the Mediterranean region due to their economic relevance and nutritional value as a source of vitamin C and capsaicin. Additionally, it has a great monetary value and is much sought in Egypt and many other nations (**Flores *et al.*, 2004**). Hot pepper can be grown in greenhouse conditions or in open fields, either as a perennial or annual crop (**Bosland and Votava, 2012**). It is a good source of natural colors like carotenoids, as well as antioxidant chemicals and vitamin C. Antioxidants, vitamin C, pro-vitamin A, P (citrin), E, B1 (thiamine), B3 (niacin), and B2 (riboflavin) are all numerous in hot pepper (**Shao *et al.*, 2008**).

Approximately 2 million hectares of land were used for pepper cultivation globally in 2017, producing over 36 million tons (**FAO Stat, 2018**). Egypt's total area under pepper cultivation was 61,210 feddan (30,049 fed. on newly reclaimed land and 31.161 fed. in historic agricultural land). With an average of 7,880 tons per fed. (8,738 tons per feddan in old agricultural land and 6,990 tons per feddan in new reclaimed land), this production resulted in 482,325 tons of pepper (272,290 tons from ancient agricultural land and 210,035 tons from new reclaimed land), as reported by **Statistics of the Ministry of Agriculture (2023/2024)**.

A simplified soilless technology may reduce hunger, according to **Bradley and Marulanda (2001)**. In agriculture, soilless culture is thought help control nutrients, increase water use efficiency, and cover underutilized areas. When growing plants hydroponically, an aggregate substrate or growing medium such as perlite, vermiculite, or coconut coir is used in addition to a water-based nutrition solution in place of soil. Hydroponic production systems are used by commercial enterprises, small farmers, and amateurs **(Saurabh *et al*., 2025)**.

In addition N, P, and K as macro-nutrients, vegetable plants now need added them as well as , micronutrients such as Fe, Mn, Cu, B, and Zn. The growth and yield of the capsicums are known to be influenced by the mineral nutrients N, P, and K. All growth and yield indicators were significantly impacted by the amount of N fertilizer used. So that, the yield of pepper increased when the level of nitrogen (N) increased (**Alkharpotly, 2018**).

Severe nitrogen overload caused necrotic lesions on leaves, which were followed by falling. N fertilizer was found to improved pepper fruit weight, yield, and quantity (**Ghoneim, 2005**; **Tumbare and Niikam, 2004; Getaneh *et al*., 2024**). Potassium is involved in a number of crucial regulatory functions in plants, such as the osmoregulation process, the control of plant water use and stomata, the sugars translocation and the carbohydrates formation, the plant's energy status, the enzyme activity control, protein synthesis and numerous other processes required to maintain plant growth and reproduction (**Hsiao and Lauchli, 1986**). Additionally, it is a highly mobile component of the plant and exhibits a particular phenomenon known as luxury consumption. Because of its significant impact on quality characteristics, potassium is frequently referred to as the quality nutrient (**Lester, 2006**). **Botella *et al.* (2017)** reported that the increase of K^+ in the nutrient solution improved pepper fruit quality by enhancing fruit soluble sugars, ascorbic acid and TSS contents. Additionally, phosphorus is essential for numerous biochemical and physiological activities in plants, such as energy conservation, photosynthesis, energy transfers and intercellular and intracellular coordination of metabolism of carbohydrate (**Abel *et al*., 2002**). Phosphorus fertilization significantly increased hot pepper growth, yield components parameters (fruit yield per plant as well as total yield per feddan) and chemical constituents (total nitrogen, total phosphorus and potassium % and total soluble solids) compared to control (**Helaly and EL-Bauome, 2020**).

Enzymes involved in hormone synthesis may be necessary for the physiological processes by which iron (Fe), Zinc (Zn), and copper (Cu) work. In addition to this Zinc is involved in synthesis of tryptophan which is a precursor of indole acetic acid (IAA) (**Spiegel-Roy and Goldschmidt, 2008**). Micronutrient stimulatory effects on photosynthesis, mitochondrial respiration, chlorophyll production and hormone biosynthesis—such as ethylene, gibberellic acid, and jasmonic acid-may also contribute to the increase of vegetative growth (**Hansch and Mendel, 2009**). Applied soil with nutrients can improve the absorption of those mineral nutrients, thereby increasing the growth and yield of vegetable plants. Moreover, according to **Hassan *et al.* (2011), Stojanova *et al.* (2018)** and **Hunde (2020)**, micro-nutrients in various forms and rates greatly increased the overall growth ,as well as yield of vegetable crops.

Thus, the main aim of this research was determined the influence of NPK individual or in combination with Fe, Zn and Cu to enhance yield and nutritional values of hot pepper plant through soilless culture under greenhouse conditions.

MATERIALS AND METHODS:

In order to investigate the effects of certain macro and micronutrients on hot pepper fruits fertilized under a hydroponic system of *Capsicum annuum* L. Super Nar cultivar, a greenhouse experiment was carried out in the summer of 2023 and 2024 at Faculty of Technology and Development , Zagazig University, Egypt.

Seedlings source and cultivation:

The pepper "cv. Super Nar" seeds were bought from Go-ara Company, Egypt, then planted in speeding trays for thirty days in a private nursery in Qurien City, Sharkia Governorate, Egypt. The length of each hot pepper transplant was between 13 and 15 cm, and they all grew and developed similarly. Hot pepper seedlings were cultivated in 4- inch plastic pipes on March 14 and 18, respectively, with 20-cm gap between each plant. During the summers of 2023 and 2024, the pipes were slanted using the nutrient film method (NFT) at a rate of 3 cm every 10 meters. As advised for pepper plants, the fertilizer solution was made and replaced once a week.

Experimental Design:

A randomized complete block design with three replicates was used to set up the eight treatments in a simple experiment.

Minerals source and application:

Green Group for Agricultural Projects Company in Egypt was the source of the NPK (20-20-20), iron EDDT (13%) Zinc EDDT (13%), and copper (8%). Soil application of the mineral treatments were made 30, 45, and 60 days following the transplant date. The treatments of the current study were as follows: T1 was Control (without any addition), T2 (NPK at 2 g/l), T3 (Iron at 2 ml/l), T4 (Zinc at 2 ml /l), T5 (Copper at 2 ml /l), T6 (NPK at 2 g/l + Iron at 2 ml /l), T7 (NPK at 2 g/l + Zinc at 2 ml /l) and T8 (NPK at 2 g/l + Copper at 2 ml /l).

Data recorded:

A random sample of three hot pepper plants from each was taken at 80 and 152 days from planting date for determining fruit yield components during 1st and 2nd seasons, respectively.

Yield components: Average weight of fruit, fruits number per plant and fruits yield per feddan (ton) were determined.

Fruit nutritional values: Total nitrogen, total phosphorus and potassium percentages were determined in hot pepper fruits according to that reported by **(A.O.A.C., 1995)**. Also, total soluble solids (TSS) were determined in fruits as Brix° by using Refractometer (Model HR-010-Range 0- 10% Brix ± 0.1% Brix, Japan).

Statistical Analysis

Data was subjected to analysis of variance, and means were compared using the Duncan Multiple Range Test (**Duncan, 1955**). The **Analytical Software (2008)** computer software package was utilized to run all statistical analyses utilizing the analysis of variance technique.

RESULTS AND DISCUSSION:

Yield and its components:

As shown in Figures 1, 2 and 3 it is clear that added hot pepper plants with NPK at 2 g/l + 2 ml/l of Zn three times per season significantly increased fruits number per plant (14.88 and 16.88 fruits/plant), average of fruit (25.00 and 24.00 g) and total yield per feddan (8.32 and 9.32 ton /feddan) compared to control and the other fertilizer sources under study during 1st and 2nd seasons. In general, added hot pepper plant cultivar with NPK, Fe, Zn or Cu alone or in combination with NPK at 2 g/l + 2ml/l gave a significant increase in yield components compared to control.

Chemical fertilizers are known to promote plant growth because nitrogen is involved in the synthesis of nucleic acids and proteins, phosphorus is a necessary component of energy compounds (ATP and ADP) and phosphoprotein, potassium is an activator of numerous enzymes (**Helgi and Rolfe, 2005**) and Cu, Mn, and Zn are activators of particular enzymes (**Voss, 1998**). In addition, a number of vital cell processes, including gene expression, protein metabolism, the structural and functional integrity of bio-membranes, and photosynthetic carbon metabolism, depend on Zinc (**Cakmak, 2000**). However, excessive Zinc in plants can have a significant impact on normal ionic homeostatic systems by interfering with the transport, uptake and regulation and osmotic

of essential ions. This can disrupt metabolic processes like transpiration, photosynthesis, and metabolism-related enzyme activities (**Sainju *et al.*, 2003**).

In addition, **Ahmed and Abdelkader (2020)** on chilli showed that fruit yield per plant (kg) were gradually increased by increased NPK fertilizers levels. Moreover, **Elgezary *et al.* (2021)** investigated the effects NPK fertilization levels (0.0, 75, 100 and 125% of the recommended level) on the yield traits of the hot pepper plant cv. Chillina. According to the results, hot pepper fruit length and diameter, fruits number per plant and total yield per feddan were significantly increased by applying NPK fertilization at 125% RR in comparison to the control and other plants in the study. From the abovementioned results it could be noticed that, the superiority in hot pepper cv. SuperNar fruit yield by NPK +Zn fertilizer application is directly owing to the enhancing influence on growth parameters of plants (Tables 1, 2 and 3), which resulted in increments in metabolites syntheses to fruits and this in turn enhance average weight of fruit, fruits number per plant and total fruit yield of hot pepper. Likewise, **Singh *et al.* (2022)** pointed out that added plants with 50 ppm of Zn significantly recorded that highest values of fruit size and weight, fruits number /plant and total fruit yield per hectare compared to control.

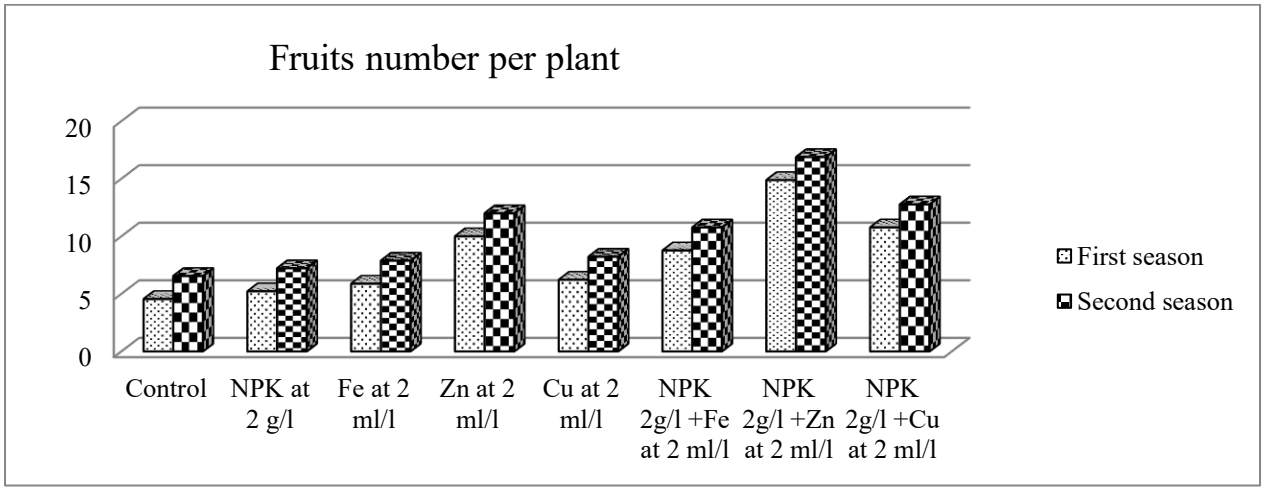

Figure 1. Influence of NPK, Fe, Zn and Cu fertilizers on fruits number per plant of hot pepper (*Capsicum annuum* L.) plants″Super Nar″ cultivar during 2023 and 2024 seasons

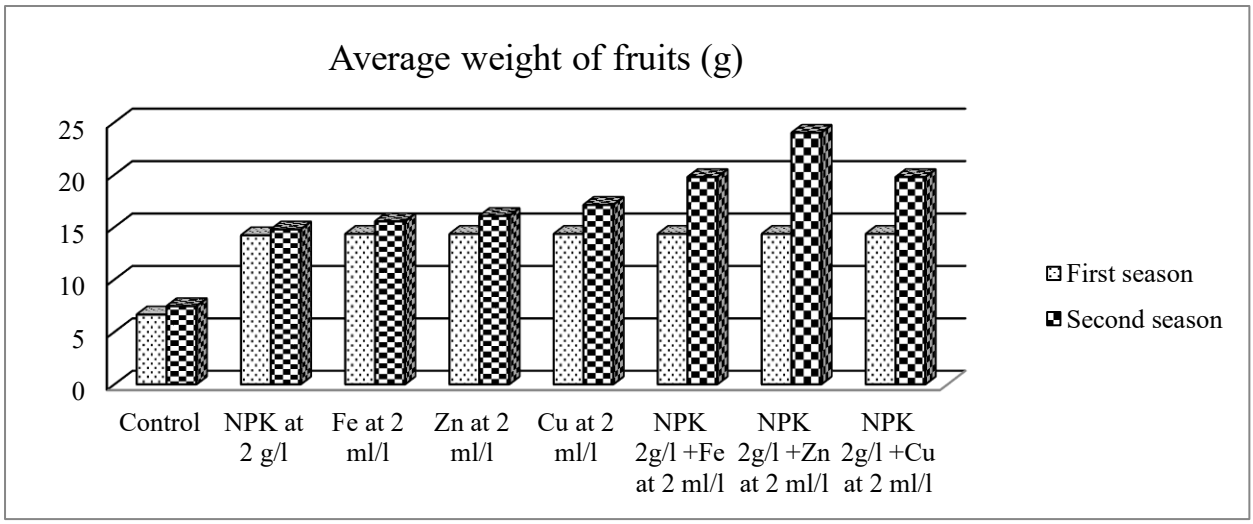

Figure 2. Influence of NPK, Fe, Zn and Cu fertilizers on average weight of fruit (g) of hot pepper (*Capsicum annuum* L.) plants″Super Nar″ cultivar during 2023 and 2024 seasons

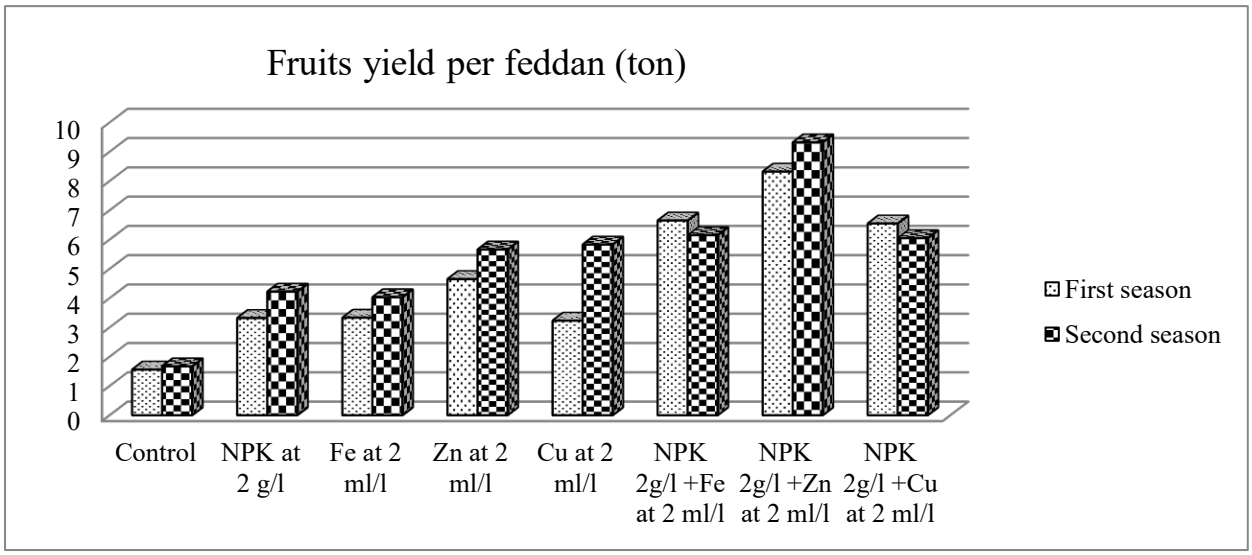

Figure 3. Influence of NPK, Fe, Zn and Cu fertilizers on fruits yield per feddan (ton) of hot pepper (*Capsicum annuum* L.) plants″Super Nar″ cultivar during 2023 and 2024 seasons

Nutritional values of fruits:

Data listed in Tables 1 and 2 suggest that all foliar spray treatments macro or/and micro-nutrients significantly increased total nitrogen, total phosphorus and potassium percentages as well as TSS of hot pepper compared to control in 2023 and 2024 seasons. The best treatment in chemical constituents in fruits was NPK at 2 g/l + 2 ml/l of Zn in comparison with the other treatments under study in both seasons. Concerning individual effect of micro-nutrients, soil applied hot pepper plants three times per season with Zn significantly recorded the highest values in this concern compared to Fe or Cu alone in both seasons. In most cases, utilizing any nutrient source (macro or/ and micro-nutrients under study) significantly enhanced fruit quality of hot pepper plant compared to control.

Sarg *et al.* (2007) pointed out that the highest level of macro-nutrients had superior influences on all the studied pepper parameters (TSS and NPK contents in fruits). Also, the highest average contents of calcium (1.42%), nitrogen (1.37%), potassium (2.25%), and phosphorus (0.53%) were also determined in the pepper cv. Variant 2 by using NPK + Oligomix (1.20 %B, 4 % Fe, 0.10 % Cu, 2 % Zn, 0.10 % Mo and 1.50 % Mn) fertilizers (**Stojanova *et al.*, 2028**).

Table 1. Effect of some macro and micro- nutrients on total nitrogen and phosphorus percentages of *Capsicum annuum* L. ″Super Nar″ cultivar during 2023 and 2024 seasons

Treatments	Total nitrogen (%)		Total phosphorus (%)	
	2023	2024	2023	2024
Control	1.10 c	1.08 c	0.200 c	0.120 d
NPK at 2 g/l	2.00 b	2.09b	0.207 b	0.200 c
Fe at 2 ml/l	2.07b	2.05b	0.210b	0.200 c
Zn at 2 ml/l	2.11 b	2.08 b	0.220 b	0.200 c
Cu at 2 ml/l	2.07b	2.04b	0.207 b	0.210 b
NPK 2g/l +Fe at 2 ml/l	2.55a	2.61a	0.263a	0.293 a
NPK 2g/l +Zn at 2 ml/l	2.09b	2.06 b	0.206 b	0.210 b
NPK 2g/l +Cu at 2 ml/l	1.10 c	1.08 c	0.200 c	0.120 d

Means within a row followed by different letter (s) are statistically different using the Duncan Multiple Range Test at 0.05 level of probability.

Table 2. Effect of some macro and micro- nutrients on potassium percentage and TSS content (Brix°) of *Capsicum annuum* L. ″Super Nar″ cultivar during 2023 and 2024 seasons

Treatments	Potassium (%)		TSS content (Brix°)	
	2023	2024	2023	2024
Control	2.20 d	2.31 d	3.44 f	3.58 f
NPK at 2 g/l	3.25 c	3.02c	4.70 e	4.65e
Fe at 2 ml/l	3.30c	3.06c	5.53 d	5.20 d
Zn at 2 ml/l	3.06 c	3.19b	6.30 c	6.67c
Cu at 2 ml/l	3.08 c	3.05b	5.80 d	5.44d
NPK 2g/l +Fe at 2 ml/l	3.64 a	3.77a	10.01 a	10.75 a
NPK 2g/l +Zn at 2 ml/l	3.18 b	3.09 b	8.51 b	8.07 b
NPK 2g/l +Cu at 2 ml/l	2.20 d	2.31 d	3.44 f	3.58 f

Means within a row followed by different letter (s) are statistically different using the Duncan Multiple Range Test at a 0.05 level of probability.

Conclusion:

This study reveals that NPK + Zn should be utilized by greenhouse producers instead of each alone under soilless culture condition. The utilize of 2 NPK g/l rate combined with 2 Zn ml/l, resulted in increases in hot pepper SuperNar cultivar yield components and fruit nutritional values.

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