

## Enhancing Growth, Yield Components and Chemical Constituents of Chilli (*Capsicum annuum* L.) Plants by Using Different NPK Fertilization Levels and Nano-Micronutrients Rates

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### Authors' contributions

This work was carried out in collaboration between both authors. Authors MAA and MAIA designed the study and wrote the protocol. Author MAA wrote the first draft of the manuscript, managed the analyses of initial soil analysis and element analysis in the plant after the experiment and managed the literature searches. Author MAIA performed the statistical analysis and managed the analyses of the other analyses. Both authors read and approved the final manuscript.

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### ABSTRACT

The application of Nano micronutrient fertilizers could improve nutrient use efficiency that reduces the dosage of NPK fertilizers. This study aims to find out the best combination of NPK and Nano micronutrients fertilizers on growth, yield and quality of red hot chilli pepper. A field study was conducted on chilli (*Capsicum annuum* L.) fertilized by different NPK fertilization levels (0.0, 50, 75 and 100% of recommended levels) and sprayed by different Nano micronutrients rates (0.0, 0.25 and 0.50 g/l) during the two summer consecutive seasons of 2017 and 2018 at Agriculture Research. Farm (Ghazala Farm), Faculty of Agriculture., Zagazig University., Egypt, The recommended dosage was 218. N+ 36 P +142 K kg/ha and Nano-micronutrient fertilizer that was

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used contained (6% Fe, 6% Zn, % B, 5% Mn, 1% Cu and 0.1% Mo). The experimental design was a split-plot arranged in a three replicates. The main plots were assigned for four NPK fertilization levels and sub plot were devoted for three Nano-micronutrients rates. The results pointed out that the vegetative growth significantly increased by NPK fertilization at 100 or 75% RLs as well as Nano-micronutrients at 0.5 g/l rate and in combination compared to control (0NPK, 0 Nano-micronutrients). Yield components and chemical constituents were increased gradually by increased NPK fertilizers levels during the two seasons. The best combination treatment in this connection was 100% RLs of NPK fertilizers combined with 0.5 g/l of Nano-micronutrients compared to the other ones under study that increased the yield and capsaicin by 75% of NPK and 0.5 g/l of Nano than control, respectively.

**Keywords:** Chilli; NPK fertilization; nano-micronutrients; growth; fruit yield; chlorophyll; capsaicin.

## 1. INTRODUCTION

Chilli (*Capsicum annum* L.) is a vegetable and medicinal perennial plant belonging to the Solanaceae family was grown for their fruits, which are consumed, either fresh or dried [1]. Chilli contains proteins, vitamins including vitamin A and C and rich source of various minerals i.e phosphorous and irons [2]. Chilli fruits have been utilized as spice, food and household medicine for various common problems such as high blood pressure, cholesterol, skin problem, joint pain and used as stomachic, carminative, relief of pain in neuropathy, appetizer, beverages and counter irritant in treatment of lumbago and rheumatism [3].

To support chilli growth, the crops need essential nutrients, nitrogen, phosphorus and potassium in a sufficient amount. Nitrogen a macro nutrient that has a vital role—in the crop growth [4]. Nitrogen has a role on the synthesis of amino acids, enzymes, porphyrins, proteins, cytochrome and some plant hormones such as indole acetic acid [5]. Phosphorus is a part of the structure of phospholipids, nucleic acids (DNA and RNA), nuclear proteins [6], energy component, enzymatic correlations and the formation of esters with hydroxyl groups of alcohols and sugars. Furthermore, potassium plays an important role in settle cytoplasmic pH the mechanism of opening and closing the stomata regulating the plant's osmotic potential that enhances the efficiency of the plant to resist water stress and transmission of photosynthesis procedure [7].

Recent research on nano-particles in various plants has elucidated for enhanced each of physiological activities, plant growth, protein level and productivity signaling their potency use in crop improvement [8]. Furthermore, [9] demonstrated that foliar application by Nano iron

fertilizers had significant effects at 1% probability level on cover yield of fresh flower of *Crocus sativus*. Also, Studies reported that the utilize of Nano-fertilizers causes' enhancement in nutrients utilize efficiency (NUE), minimizes the frequency of the implementation and decreases the possible negative influences related with over dosage. So, nanotechnology has a high probability for gaining prospective agriculture, particularly in developing regions [10].

In the light of above mentioned facts, the current work was designed to enhancing the growth and productivity of Parbirian cultivar of chilli under different NPK fertilization levels and various Nano-micronutrients rates under Sharkia Governorate conditions.

## 2. MATERIALS AND METHODS

A field experiment was carried out in the two consecutive summer seasons of 2017 and 2018 at Agriculture Research. Farm (Ghazala Farm, Fig. 1), Faculty of Agriculture, Zagazig University, Egypt. The experiment aims the effect of four levels of NPK fertilization (0.0, 50, 75 and 100% of recommended levels and three rates of Nano-micronutrients (0, 0.25 and 0.50 g/l) on plant growth, yield components and some chemical constituents of chilli plant grown in clay soil. The recommended levels (RLs) of NPK were N at 218.38 + P<sub>2</sub>O<sub>5</sub> at 83.3 + K<sub>2</sub>O at 171.36 kg/ha (218. N+ 36 P +142 K kg/ha). The physical and chemical properties of the experimental soil site are shown in Table 1, according to [11].

The plot area was 16.80 m<sup>2</sup> (3.00 × 5.60 m) included eight ridges. Each ridge was 70 cm wide and three meters length. Chilli (*Capsicum annum* L.) cv. Parbirian seedlings age 40 days after sowing. were obtained from a privet Nursery called "Mustafa Abo Eisa Nursery" in Belbas District, Sharkia Governorate, Egypt Seedlings were transplanted in hills on one side of the ridge

on 15<sup>th</sup> of April during both seasons and immediately irrigated Nano-micronutrients was added as a foliar application which commercially known as Magro NanoMix, which consists of the following minerals: Fe (6%) – Zn (6%) – B (2%) – Mn (5%) – Cu (1%) and Mo (0.1%) as well as it consists of citric acid (4%) which obtained from Modern Agricide Company (MAC). Nano-micronutrients was applied as foliar application at 45, 60 and 75 days after transplanting. Each experimental unit received 5 letters solution using spreading agent (Super Film at a rate of 1 ml L<sup>-1</sup>). The untreated plants were sprayed with tap water with spreading agent (as control). The source of NPK fertilization was ammonium sulphate (21%N) calcium super phosphate (7%P) and potassium sulphate (40%K). Phosphorus fertilizer was added during soil preparation as a soil dressing application, while, nitrogen and potassium fertilizers were divided into three equal portions and were given at to the soil after 35, 55 and 75 days after planting time.

## 2.1 Experimental Design

The experiment was conducted using a split-plot design with three replication. The main plot was four NPK fertilization levels and sub plot was three Nano-micronutrients rates.

## 2.2 Recorded Data

### 2.2.1 Plant growth

After 98 days after planting of chilli, a sample of 3 plants were randomly taken from each

experimental unit and plant growth parameters were observed plant height (cm), number of branches/plant, number of leaves/plant, total fresh weight (g)/plant total dry weight/plant (g) and root length (cm).

### 2.2.2 Yield and its components

Fruits of chilli were harvested every 2 days intervals upon reaching 8-12 cm length. At harvesting stage the following data were recorded: fruit length (cm), fruit diameter (cm), average of fruit weight (g), number of fruits/plant, fruit yield/plant (kg) and yield/ton/ha.

### 2.2.3 Chemical constituents

Total nitrogen and total phosphorus as well potassium percentages in chill fruits were determined according to [11] at the end of experiment. Total chlorophyll content (SPAD unit) was determined in fresh leaves of chilli plant after 98 days from transplanting date by using SPAD- 502 meter [12]. Ascorbic acid (mg/100 g as fresh weight): It was determined by titration in the presence of 2, 6 dichlorophenol -indophenol dye as an indicator against 2% oxalic acid solution as substrate. Ascorbic acid was calculated as milligram L-ascorbic acid per 100 g of fresh fruits according to the method described by [13]. Total soluble solids (TSS) of juice (Brix°): It was determined by using a hand refract meter as Brix degree. However, total capsaicin content in chilli fruit (mg /100 g as dry weight) was determined by the method of [14].

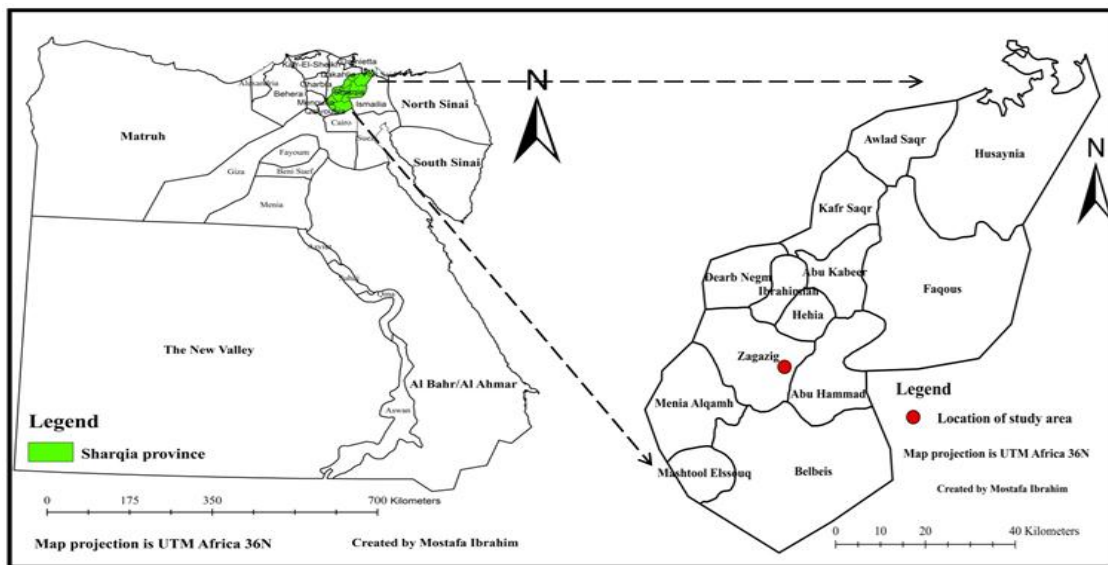


Fig. 1. Study location (Ghazala Farm) in Zagazig district, Sharkia Governorate, Egypt

**Table 1. Physical and chemical properties of experimental soil**

Physical analysis										Soil texture		
Clay (%)	Silt (%)	Fine sand (%)		Coarse sand (%)						Soil texture		
56.36	9.26	17.62		16.76						Clay		
Chemical analysis												
pH	E.C dS/m	Organic matter (%)	Soluble cations (meq./L)				Soluble anions (meq./L)			Available (mg kg <sup>-1</sup> soil)		
			Mg <sup>++</sup>	Ca <sup>++</sup>	Na <sup>+</sup>	K <sup>+</sup>	Cl <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>-</sup>	N	P	K
7.86	1.2	0.58	2.5	3.5	5.1	0.9	9.2	0.88	1.92	65	9	160

## 2.3 Statistical Analysis

Collected data were analyzed according to [15]. Least significance difference (L.S.D.) was used to differentiate means at the at 5% level of probability. The means were compared using computer program of Statistix version 9 [16].

## 3. RESULTS

### 3.1 Plant Growth

#### 3.1.1 Effect of NPK fertilization level

As shown in Tables 2 and 3 that, using 50, 75 and 100% recommended levels of NPK fertilization significantly increased chilli (*Capsicum annum*, L.) growth parameters compared to control. Generally, plant height,

branch and leaf number /plant, total fresh and dry weights/plant as well as root length increased with increasing NPK fertilization level during both seasons. The best treatment in this regard was that 100% RLs compared to the other ones under study.

#### 3.1.2 Effect of nano-micronutrients rate

The data illustrated in Tables 2 and 3 indicate that, plant height, branch and leaf number /plant, total fresh and dry weights/plant as well as root length of chilli were increased as Nano-micronutrients increased in both seasons. In addition, the highest rate of Nano-micronutrients (0.50 g/l) produced the highest values in vegetative growth parameters of chilli compared to control and the lowest one under study in the two consecutive seasons.

**Table 2. Impact of NPK fertilization level, micronutrients rate and their combinations on plant height, branch and leaf number per plant of chilli during the two seasons of 2017 and 2018**

Treatments	Plant height (cm)		Number of branches / plant		Number of leaves / plant		
	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	
<b>NPK fertilization level (as % of recommended levels*)</b>							
Control	69.89	75.85	23.56	24.70	441.29	449.04	
50	71.11	78.29	25.08	25.93	451.30	484.37	
75	74.67	80.26	26.67	27.74	472.00	490.78	
100	78.74	81.45	28.63	30.45	491.63	506.74	
LSD at 5%	1.01	0.40	0.76	0.87	3.68	6.55	
<b>Nano-micronutrients rate (as g/l)</b>							
Control	70.97	77.75	24.36	25.69	449.25	458.50	
0.25	74.78	78.28	26.31	27.19	464.92	489.14	
0.50	75.06	80.86	27.28	28.72	478.00	500.56	
LSD at 5%	1.05	0.91	0.50	0.72	1.97	3.70	
<b>Combination effect between NPK levels and nano-micronutrients</b>							
Control	Control	69.33	74.78	22.11	23.78	427.11	441.44
	0.25	69.78	75.89	23.78	24.78	443.44	449.78
	0.50	70.56	76.89	24.78	25.55	453.33	455.89
50	Control	70.11	77.33	23.89	24.33	444.11	449.34
	0.25	71.89	76.67	25.34	26.89	451.00	503.22
	0.50	71.34	80.89	26.00	26.56	458.78	500.56
75	Control	69.11	78.56	24.66	26.44	456.89	468.22
	0.25	77.44	78.78	27.22	26.78	476.78	491.44
	0.50	77.44	83.44	28.11	30.00	482.33	512.67
100	Control	75.33	80.34	26.78	28.22	468.89	475.00
	0.25	80.00	81.78	28.89	30.34	488.44	512.00
	0.50	80.89	82.22	30.22	32.78	517.55	533.00
LSD at 5%	1.99	1.54	1.11	1.46	4.87	8.89	

\*NPK fertilization levels (0.0, 50, 75 and 100 % of recommended levels) (0.0, 109.19, 163.79 and 218.38 Kg N / ha), (41.65, 62.48 and 83.3 Kg P<sub>2</sub>O<sub>5</sub> / ha), (85.68, 128.52 and 171.36 Kg K<sub>2</sub>O / ha)

### 3.1.3 Effect of combination between NPK fertilization and nano-micronutrients

From data recorded in Tables 2 and 3 it is obvious that, the best combination treatment in chilli growth parameters was that of 100% NPK RLs + 0.50 g/l of Nano-micronutrients compared to the other combinations, in most cases, during both seasons. Generally, under each NPK fertilization level plant height, branch and leaf number /plant, total fresh and dry weights/plant as well as root length of chilli increased by increasing Nano-micronutrients rates. Also, all combination treatments increased plant growth parameters compared to control (0.0 NPK % RLs + 0.0 g/l |Nano-micronutrients rate) during the first and second seasons.

### 3.2 Yield Components

#### 3.2.1 Effect of NPK fertilization level

Data listed in Tables 4 and 5 suggest that, all NPK fertilization levels significantly increased fruit length (cm), fruit diameter (cm), average of fruit weight (g), number of fruits /plant as well as fruit yield per plant (kg) and per ha (ton) compared to control. Increasing NPK fertilization level from 50 to 100% gradually increased chili yield components during the two seasons. The highest values in this concern were obtained by the treatment of 100 NPK% RLs compared to the other ones under study.

**Table 3. Impact of NPK fertilization level, micronutrients rate and their combinations on total fresh weight/plant, total dry weight per plant and root length of chilli during the two seasons of 2017 and 2018**

Treatments	Total fresh weight/ plant (g)		Total dry weight/ plant (g)		Root length (cm)		
	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	
<b>NPK fertilization level (as % of recommended levels*)</b>							
Control	452.04	461.37	98.28	97.43	28.23	28.24	
50	472.11	535.73	100.90	121.38	30.48	32.20	
75	503.63	563.91	117.56	129.32	33.48	34.92	
100	532.36	594.48	130.16	142.72	34.84	36.52	
LSD at 5%	<b>11.08</b>	<b>12.84</b>	<b>2.06</b>	<b>3.14</b>	<b>0.96</b>	<b>1.11</b>	
<b>Nano-micronutrients rate (as g/l)</b>							
Control	441.63	496.01	101.80	116.05	30.03	31.28	
0.25	491.32	544.18	112.54	122.23	32.14	33.11	
0.50	537.16	576.42	120.83	129.86	33.10	34.52	
LSD at 5%	<b>7.00</b>	<b>9.40</b>	<b>1.27</b>	<b>2.20</b>	<b>0.62</b>	<b>0.54</b>	
<b>Combination effect between NPK levels and nano-micronutrients</b>							
Control	Control	390.07	378.72	90.87	89.02	28.04	27.18
	0.25	464.46	493.43	98.58	100.51	28.23	28.26
	0.50	501.61	511.95	105.39	102.76	28.44	29.28
50	Control	429.85	517.83	92.59	117.31	28.89	32.01
	0.25	465.14	535.20	99.48	120.50	31.02	31.74
	0.50	521.34	554.15	110.63	126.32	31.53	32.85
75	Control	464.06	533.44	100.65	119.93	31.69	32.45
	0.25	499.97	552.67	120.32	127.19	34.00	35.23
	0.50	546.87	605.60	131.70	140.85	34.74	37.07
100	Control	482.52	554.04	123.10	137.95	31.50	33.46
	0.25	535.72	595.43	131.79	140.73	35.33	37.22
	0.50	578.83	633.96	135.58	149.49	37.68	38.89
LSD at 5%	<b>15.88</b>	<b>19.97</b>	<b>2.91</b>	<b>4.76</b>	<b>1.39</b>	<b>1.41</b>	

\*NPK fertilization levels (0.0, 50, 75 and 100 % of recommended levels)  
(0.0, 109.19, 163.79 and 218.38 Kg N / ha), (41.65, 62.48 and 83.3 Kg P<sub>2</sub>O<sub>5</sub>/ ha),  
(85.68, 128.52 and 171.36 Kg K<sub>2</sub>O/ ha)

### 3.2.2 Effect of nano-micronutrients rate

Data of both seasons in Tables 4 and 5 show that, the two rates of Nano-micronutrients under study significantly increased chilli yield components compared to untreated plants in both seasons. Moreover, increasing Nano-micronutrients rates from 0.25 to 0.5 g/l gradually increased fruit dimension and yield parameters in the first and second seasons. Generally, the best treatment in increase chilli fruit length, fruit diameter, average of fruit weight, number of fruits /plant as well as chilli fruit yield per plant and per ha<sup>-1</sup> was that of 0.50 g/l of "Magro NanoMix" compared to the other one and control.

### 3.2.3 Effect of combination between NPK fertilization and nano-micronutrients

It is quite clear from the data in Tables 4 and 5 that, 100% RLs of NPK fertilization level plus 0.50 g/l of Nano-micronutrients rate gave the best values in chilli fruit measurements as well as fruit yield parameters compared to the other combinations during both seasons. Similarly, increasing NPK fertilization levels under each Nano-micronutrients rate increased chilli yield components (fruit dimension as well as fruit yield per plant and per ha<sup>-1</sup>). In other words, increasing Nano-micronutrients rates under each NPK fertilization level increased yield components of chilli.

**Table 4. Impact of NPK fertilization level, micronutrients rate and their combinations on fruit length, fruit diameter and average of fruit weight of chilli during the two seasons of 2017 and 2018**

Treatments	Fruit length (cm)		Fruit diameter (cm)		Average of fruit weight		
	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	
<b>NPK fertilization level (as % of recommended levels*)</b>							
Control	8.60	8.83	1.94	2.22	26.74	29.78	
50	9.00	9.40	2.13	2.29	31.59	33.26	
75	9.53	9.73	2.32	2.73	33.41	36.55	
100	9.93	10.42	2.92	2.95	35.70	38.15	
LSD at 5%	<b>0.29</b>	<b>0.33</b>	<b>0.07</b>	<b>2.27</b>	<b>0.81</b>	<b>0.73</b>	
<b>Nano-micronutrients rate (as g/l)</b>							
Control	8.66	9.02	2.17	2.77	29.89	31.47	
0.25	9.37	9.57	2.36	2.02	31.95	34.55	
0.50	9.77	10.21	2.46	2.25	33.75	37.28	
LSD at 5%	<b>0.25</b>	<b>0.26</b>	<b>0.07</b>	<b>0.04</b>	<b>0.33</b>	<b>0.85</b>	
<b>Combination effect between NPK levels and nano-micronutrients</b>							
Control	Control	8.26	8.53	1.89	2.02	24.55	27.11
	0.25	8.52	8.55	1.94	2.25	27.44	29.66
	0.50	9.02	9.42	2.01	2.38	28.22	35.56
50	Control	8.42	8.77	2.01	2.08	29.78	30.56
	0.25	9.14	9.52	2.15	2.28	31.00	32.78
	0.50	9.45	9.92	2.24	2.52	34.00	36.44
75	Control	8.83	9.05	2.14	2.38	31.44	33.11
	0.25	9.75	9.86	2.27	2.89	33.33	37.00
	0.50	10.00	10.29	2.54	2.93	35.44	39.55
100	Control	9.12	9.71	2.65	2.59	33.78	35.11
	0.25	10.06	10.34	3.06	3.02	36.00	38.78
	0.50	10.62	11.22	3.06	3.25	37.33	40.55
LSD at 5%	<b>0.50</b>	<b>0.54</b>	<b>0.14</b>	<b>0.09</b>	<b>0.97</b>	<b>1.56</b>	

\*NPK fertilization levels (0.0, 50, 75 and 100 % of recommended levels)  
(0.0, 109.19, 163.79 and 218.38 Kg N / ha), (41.65, 62.48 and 83.3 Kg P<sub>2</sub>O<sub>5</sub> / ha),  
(85.68, 128.52 and 171.36 Kg K<sub>2</sub>O / ha)

**Table 5. Impact of NPK fertilization level, micronutrients rate and their combinations on number of fruits/plant, fruit yield/plant and yield /ha of chilli during the two seasons of 2017 and 2018**

Treatments	Number of fruits/ plant		Fruit yield/ plant (g)		Fruit yield/ ha (ton)		
	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	
<b>NPK fertilization level (as % of recommended levels*)</b>							
Control	12.77	13.11	341.72	391.16	12.21	13.97	
50	13.02	13.75	411.82	457.43	14.71	16.33	
75	13.51	14.16	452.01	518.39	16.14	18.52	
100	13.94	14.70	498.50	562.07	17.80	20.06	
LSD 5%	<b>0.16</b>	<b>0.44</b>	<b>9.65</b>	<b>17.05</b>	<b>0.357</b>	<b>0.62</b>	
<b>Nano-micronutrients rate (as g/l)</b>							
Control	12.97	13.50	388.51	426.31	13.88	15.21	
0.25	13.04	14.00	426.39	486.00	15.23	17.35	
0.50	13.67	14.29	463.13	534.48	16.54	19.09	
LSD 5%	<b>0.12</b>	<b>0.25</b>	<b>6.31</b>	<b>13.73</b>	<b>0.24</b>	<b>0.50</b>	
<b>Combination effect between NPK levels and nano-micronutrients</b>							
Control	Control	12.59	12.63	309.01	342.26	11.04	12.21
	0.25	12.80	13.20	351.29	391.93	12.54	13.99
	0.50	12.93	13.49	364.85	439.30	13.02	15.68
50	Control	12.74	13.54	379.45	413.42	13.54	14.76
	0.25	13.03	13.77	403.88	451.34	14.42	16.11
	0.50	13.30	13.93	452.11	507.52	16.14	18.11
75	Control	13.08	13.83	411.28	457.87	14.68	16.35
	0.25	13.59	14.20	453.12	525.64	16.18	18.75
	0.50	13.87	14.45	491.64	571.66	17.54	20.42
100	Control	13.45	14.00	454.30	491.68	16.21	17.56
	0.25	13.81	14.83	497.28	575.08	17.76	20.54
	0.50	14.57	15.27	543.92	619.44	19.42	22.11
LSD 5%	<b>0.25</b>	<b>0.60</b>	<b>14.08</b>	<b>28.10</b>	<b>0.50</b>	<b>0.99</b>	

\*NPK fertilization levels (0.0, 50, 75 and 100% of recommended levels)  
(0.0, 109.19, 163.79 and 218.38 Kg N / ha), (41.65, 62.48 and 83.3 Kg P<sub>2</sub>O<sub>5</sub>/ ha),  
(85.68, 128.52 and 171.36 Kg K<sub>2</sub>O/ ha)

### 3.3 Chemical Constituents

#### 3.3.1 Effect of NPK fertilization level

Data recorded in Tables 6 and 7 reveal that, N, P and K fertilization levels significantly increased chilli fruits in nitrogen, phosphorus and potassium percentages as well as leaves total chlorophyll content (SPAD) and vitamin C, total soluble solids and total capsaicin content compared to control during both seasons. Mostly, the highest values in chemical constituents of chill leaves and fruits were achieved by 100% of NPK recommended levels compared to control and the other one under study.

#### 3.3.2 Effect of nano-micronutrients rate

Data given in Tables 6 and 7 pointed out that, abovementioned chemical constituents of chilli gradually increased with increasing Nano-

micronutrients rates in the two consecutive seasons. The highest values in this connection (NPK percentages, total chlorophyll content as well as vitamin C content, TSS and total capsaicin content) were obtained by the treatment of Nano-micronutrients at 0.50 g/l during both seasons.

#### 3.3.3 Effect of combination between NPK fertilization and nano-micronutrients

From data tabulated in Tables 6 and 7 it is clear that, in general, increasing NPK fertilization levels under each Nano-micronutrients rate increased chilli chemical constituents. These results hold true during the first and second seasons, in most cases. In addition, the best combination treatment in increase N, P and K percentages, total chlorophyll content as well as ascorbic acid, TSS and total capsaicin content, was that 100% RLs + 0.50 g/l Nano-



**Table 6. Impact of NPK fertilization level, micronutrients rate and their combinations on nitrogen %, phosphorus % and potassium % in fruits of chilli during the two seasons of 2017 and 2018**

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)		
	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	
<b>NPK fertilization level (as % of recommended levels*)</b>							
<b>Control</b>	1.447	1.528	0.463	0.494	2.470	2.477	
<b>50</b>	1.519	1.593	0.472	0.537	2.584	2.642	
<b>75</b>	1.543	1.751	0.485	0.594	2.662	2.658	
<b>100</b>	1.599	1.791	0.507	0.592	2.710	2.683	
<b>LSD 5%</b>	<b>0.016</b>	<b>0.018</b>	<b>0.005</b>	<b>0.006</b>	<b>0.017</b>	<b>0.022</b>	
<b>Nano-micronutrients rate (as g/l)</b>							
<b>Control</b>	1.482	1.627	0.478	0.534	2.573	2.550	
<b>0.25</b>	1.518	1.664	0.476	0.556	2.604	2.638	
<b>0.50</b>	1.581	1.707	0.501	0.573	2.643	2.657	
<b>LSD 5%</b>	<b>0.011</b>	<b>0.015</b>	<b>0.006</b>	<b>0.006</b>	<b>0.009</b>	<b>0.011</b>	
<b>Combination effect between NPK levels and nano-micronutrients</b>							
<b>Control</b>	<b>Control</b>	1.430	1.507	0.466	0.476	2.463	2.413
	<b>0.25</b>	1.447	1.540	0.446	0.497	2.470	2.487
	<b>0.50</b>	1.463	1.537	0.476	0.507	2.477	2.530
<b>50</b>	<b>Control</b>	1.493	1.583	0.457	0.505	2.550	2.587
	<b>0.25</b>	1.517	1.610	0.472	0.544	2.577	2.663
	<b>0.50</b>	1.547	1.587	0.488	0.563	2.627	2.677
<b>75</b>	<b>Control</b>	1.487	1.673	0.459	0.582	2.597	2.580
	<b>0.25</b>	1.523	1.727	0.481	0.595	2.650	2.700
	<b>0.50</b>	1.620	1.853	0.516	0.608	2.740	2.693
<b>100</b>	<b>Control</b>	1.517	1.743	0.490	0.574	2.680	2.620
	<b>0.25</b>	1.587	1.780	0.507	0.588	2.720	2.703
	<b>0.50</b>	1.693	1.850	0.524	0.612	2.730	2.727
<b>LSD 5%</b>	<b>0.023</b>	<b>0.031</b>	<b>0.011</b>	<b>0.011</b>	<b>0.022</b>	<b>0.028</b>	

\*NPK fertilization levels (0.0, 50, 75 and 100 % of recommended levels)  
(0.0, 109.19, 163.79 and 218.38 Kg N / ha), (41.65, 62.48 and 83.3 Kg P<sub>2</sub>O<sub>5</sub>/ ha),  
(85.68, 128.52 and 171.36 Kg K<sub>2</sub>O/ ha)

micronutrients compared to the other combination treatments under study compared to the other combination treatments under study. The percentage increase for the two seasons for N% (11.60% and 6.14%), P% (6.9% and 6.6%), K% (1.8% and 4%), total chlorophyll content (10% and 6.6%), ascorbic acid (0.87% and 3.2%), TSS (2.9% and 8.9%) and total capsaicin content (1.7% and 1.8%) respectively for the two seasons.

#### 4. DISCUSSION

##### 4.1 Effect of Different NPK Fertilization Levels and Foliar Application with Nano-Micronutrients Rates as well as Their Combinations on Chilli Growth Parameters

Consulting the above mentioned results which demonstrated that applied NPK fertilization levels

especially at 100% recommended levels gave higher values of chilli vegetative growth parameters compared to control. These results were in agreement with those obtained by [17] on chilli, [18] on chilli and [19] on celery and chilli, However, [20] reported that N, P and K play a major role in many physiological and biochemical processes leading to taller, more branches and heaviest weight per chilli plant.

As the rates of Nano-micronutrients increased, all the above mentioned parameters increased throughout the range examined. These results could be attributed to Nano-fertilizers improve easiness of utilize of nutrient to the plants which promote rate of photosynthesis and production of dry material as well result get superior in the plant growth parameters [21]. In addition, [22] found that use of Nano-fertilizers recorded the greatest growth characters of chilli compared to control. Also, [23] reported that Nano-

**Table 7. Impact of NPK fertilization level, micronutrients rate and their combinations on total chlorophyll content (SPAD) in leaves as well as Vit. C content (mg/100 g as fresh weight), total soluble solids (Brix°) and total capsaicin content (mg/100 g as dry weight) in fruits of chilli during the two seasons of 2017 and 2018**

Treatments	Total chlorophyll content		Vitamin C content		Total soluble solids (TSS)		Total capsaicin content		
	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	
<b>NPK fertilization level (as % of recommended levels*)</b>									
<b>Control</b>	49.70	50.01	179.77	183.82	6.23	6.24	124.88	132.02	
<b>50</b>	49.81	50.80	184.08	183.91	6.28	6.28	133.55	134.23	
<b>75</b>	50.47	52.15	189.74	184.92	6.44	6.56	137.03	135.88	
<b>100</b>	53.65	52.86	186.38	188.39	6.82	6.81	136.85	136.12	
<b>LSD 5%</b>	<b>0.39</b>	<b>0.68</b>	<b>0.60</b>	<b>0.80</b>	<b>0.02</b>	<b>0.03</b>	<b>0.99</b>	<b>0.64</b>	
<b>Nano-micronutrients rate (as g/l)</b>									
<b>Control</b>	49.92	50.75	183.84	183.64	6.33	6.33	131.47	132.63	
<b>0.25</b>	51.22	51.71	184.90	185.68	6.43	6.39	133.20	135.32	
<b>0.50</b>	51.59	53.40	186.24	186.46	6.57	6.70	134.56	135.72	
<b>LSD 5%</b>	<b>0.25</b>	<b>0.58</b>	<b>0.80</b>	<b>0.44</b>	<b>0.01</b>	<b>0.02</b>	<b>0.41</b>	<b>0.54</b>	
<b>Combination effect between NPK levels and nano-micronutrients</b>									
<b>Control</b>	<b>Control</b>	49.55	49.81	179.42	183.16	6.19	6.23	124.73	129.73
	<b>0.25</b>	49.76	50.02	179.91	183.68	6.25	6.24	124.92	132.53
	<b>0.50</b>	49.79	50.19	179.99	184.62	6.27	6.24	125.00	133.79
<b>50</b>	<b>Control</b>	49.68	49.79	183.33	182.52	6.19	6.25	130.20	133.03
	<b>0.25</b>	49.85	50.34	184.29	185.19	6.30	6.28	133.71	134.88
	<b>0.50</b>	49.91	52.28	184.62	184.02	6.34	6.32	136.75	134.79
<b>75</b>	<b>Control</b>	49.93	50.23	187.30	183.63	6.24	6.27	135.31	133.48
	<b>0.25</b>	50.43	51.79	188.51	185.20	6.31	6.32	137.27	136.58
	<b>0.50</b>	51.07	54.43	193.41	185.93	6.77	7.09	138.52	137.57
<b>100</b>	<b>Control</b>	50.51	53.18	185.31	185.25	6.70	6.56	135.66	134.29
	<b>0.25</b>	54.84	54.69	186.90	188.66	6.87	6.71	136.90	137.30
	<b>0.50</b>	55.60	56.71	186.93	191.27	6.90	7.15	137.98	136.76
<b>LSD 5%</b>	<b>0.56</b>	<b>1.16</b>	<b>1.44</b>	<b>1.08</b>	<b>0.03</b>	<b>0.04</b>	<b>1.20</b>	<b>1.08</b>	

\*NPK fertilization levels (0.0, 50, 75 and 100% of recommended levels) (0.0, 109.19, 163.79 and 218.38 Kg N / ha), (41.65, 62.48 and 83.3 Kg P<sub>2</sub>O<sub>5</sub> / ha), (85.68, 128.52 and 171.36 Kg K<sub>2</sub>O / ha)

micronutrients concentration produce an increase in chilli plant height, number of branches and total dry weight per plant when compared to control.

The combination between NPK fertilization levels and Nano-micronutrients rates proved that the highest values of plant height, branch number, leaves number, plant fresh weight, plant dry weight and root length were obtained when the highest NPK fertilization level (100% RLs) combined with the highest rates of Nano-micronutrients. These results were in accordance with those found by [19] on chilli and [24] on chilli (*Capsicum annum* L.) NPK fertilization as well as [25] on chilli plants regarding nano-micronutrients. Moreover, as mentioned above, both NPK fertilization levels and Nano-micronutrients (each alone) increased growth

parameters of chilli plant, in turn; they together might maximize their effects leading to taller, more branches and leaves and heaviest plants.

#### **4.2 Effect of Different NPK Fertilization Levels and Foliar Application with Nano-Micronutrients Rates as well as Their Combinations on Chilli Yield Components**

Concerning fruit dimensions (length and diameter) and fruit yields (average of fruit weight, fruit number and yield /plant as well as fruit yield /ha) it was observed that the highest levels of NPK fertilization (100% of RLs) gave the maximum values in this connection. The increasing by the treatment of NPK fertilization could be due to increasing in plant dry weight due to increasing uptake of N, P and K which

resulted in increased, The percentage increase to the two seasons for weight of fresh is (17.8% and 28.8%) and dry plants (32.4% and 46.5%) respectively for the two seasons (Table 3). The better chlorophyll builds up (Table 7) improved by chilli plants growth which increased the plant fruit yield and its components. In this respect many investigators found that increasing application of NPK fertilization level increased the yields of chilli [26] and chilli [27].

Nano-micronutrients fertilization increased chilli fruit yield per plant and per ha when compared to control (unsprayed plants). From the abovementioned results it could be suggested that, the superiority in chilli fruit yield by Nano-micronutrients application is directly owing to the improving effect on plant growth of chilli plants, which resulted in increments in metabolites syntheses to fruits and this in turn increase total fruit yield per ha. These results are agreed with the findings of [28] on chilli plants and [29] on chilli plants. The importance of the micronutrients comes from its influence of stimulating the process of photosynthesis and thus its positive effect on the yield components [30].

Obtained results revealed that the highest values in fruit length and diameter as well as fruit number per plant and fruit yield per plant and per ha were recorded in this study for chilli plant when plants were fertilized by 100% NPK of RLs level and sprayed by 0.50 g/l of Nano-micronutrient rate compared to the other combination treatments under study. These results are in accordance with those indicated by [9] on q chilli plant and [22] on chilli plant.

#### **4.3 Effect of Different NPK Fertilization Levels and Foliar Application with Nano-micronutrients Rates as well as Their Combinations on Chilli Chemical Constituents**

In the present study, it was found that the highest values of N, P and K percentages in chilli fruits as well as total chlorophyll content in chilli leaves, vitamin C content, TSS and total capsaicin content in chilli fruits were achieved with the highest level of NPK fertilization compared to the lowest levels (50 and 75% of RLs). These results are in agreement with those found by [31] on chilli plant.

Obtained data in this research pointed out that as Nano-micronutrient rates are increased gradually chilli chemical constituents are increased. The

accumulation of N, P and K as well as total chlorophyll content, vitamin C content, TSS and total capsaicin content by Nano-micronutrients foliar application may be due to the positive effect of micronutrients on uptake minerals and accumulation in leaves. These results are in accordance with those stated by [32] on chilli plants.

Moreover, the highest minerals percentages (N, P and K) in fruits and pigments contents in leaves of chilli plant as well as Vitamin C content, TSS and total capsaicin content in fruits were achieved when the highest NPK fertilization level was applied with the highest Nano-micronutrient rate the same resulted,. Furthermore, [23] suggested that 107.1 kg P<sub>2</sub>O<sub>5</sub>/ha + 500 or 1000 mg/l of Nano-micronutrients as foliar spray had significant effects in total phosphorus and total carbohydrates percentage and total chlorophyll "a + b" content of chilli plant compared to the other combination treatments under study.

## **5. CONCLUSION**

It can be concluded that using 75 and 100% of RLs (218.96 kg N/ha + 83 kg P<sub>2</sub>O<sub>5</sub> /ha and 171.36 kg P<sub>2</sub>O<sub>5</sub>/ha.) from NPK fertilization and foliar application of Nano-micronutrients three times/season at 0.50 g/l rate enhancing growth, yield components, capsaicin content of chilli cv. Barbarian under Sharkia Governorate condition.

## **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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