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EFFECT OF NANO-FERTILIZERS ON CUCUMBER PLANT GROWTH, FRUIT YIELD AND IT' S QUALITY

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Abstract

Using of mineral fertilizers has resulted in many serious environmental problems. Therefore, products obtained from different sources can be used. Nano fertilizers recently has been used in agriculture. This experiment was carried out at plastic green house, in the farm of faculty of Agriculture Cairo University, Giza, Egypt during winter season of 2017-2018 and 2018-2019 to determine the effects of nanofertilizer on cucumber growth and fruit yield. Different concentrations (3, 4.5, 6 and 9 ml) of liquid nano NPK were used. The mineral fertilizer was used as control. The results showed that the nanofertilizer treatments significantly improved the growth and yield of cucumber compared with control treatment. All treatments of nanofirtilizer led to increase plant height, number of leaves / plant, Chlorophyll content, yield and NPK % in leaves and fruits. The treatment of 6 ml NPK increase the yield by 4.84% and 53.42% in the first and second seasons, respectively. The treatment of 6 ml NPK recorded the lowest weight loss and decay% and the highest general appearance after 21 of storage at 5 C. While, the treatment of control NPK recorded the highest value of firmness and TSS. It can be concluded that nanofertilizer improved the plant growth, yield and fruit quality of cucumber and it can be used as an alternative to mineral fertilizers.

Key words: *Cucumis sativus*, Nano NPK, Growth, Production and Shelf-life

Introduction

Cucumber (*Cucumis sativus L.*) is one of the most important vegetable crops. It is one of the most nutritive vegetables rich in Vitamins (vit. C) and minerals such as calcium, potassium, silica, phosphorus, iron and magnesium (Sumathi *et al*., 2008). It is a tropical and subtropical crop belonging to family cucurbitaceae. The cultivated area of cucumber in Egypt was 95328.151 feddan in 2017, while the production was 488723 tones (FAO statistics division, 2019). Chemical fertilizer used in crop fertilization contains a small number of minerals that dissolve rapidly in wet soils and given the plants large doses of minerals (Vernon, 1999). The plants during growth stages need to chemical compounds to enhance its growth. These chemical compounds are named mineral fertilizers. Artificial fertilizers are inorganic fertilizers prepared in ideal concentrations of macro and micro nutrients. Nitrogen is an important nutrient element which is essential for plant growth. The most widely used water soluble source of nitrogen is Urea (46 % N). The nitrogen concentration of soil gets decreased because of leaching. Consequently, NUE (Nitrogen utilization efficiency) is low. Urea modified hydroxyapatite particles have been used to agriculture; because of it's higher NUE and slow release of the nitrogen to the soil and lead to maximize NUE by plants and minimize the adverse effects to the environment (Subbaiya *et al*., 2012). Phosphorus has an important role in several physiological processes in the plant, such as energy storage photosynthesis, transfer and respiration, cell enlargement and cell division. Also, Phosphorus is an important structural component of many biochemical's such as nucleic acids (DNA, RNA) co-enzymes, nucleotides, sugar phosphate and phospholipids. It stimulates root growth, fruit setting blooming and seed formation (Memon, 1996). Potassium is considered essential in photosynthesis, nitrogen metabolism, sugar translocation, enzyme activation, water relation, stomatal opening and growth of meristematic tissues, it acts as chemical traffic policeman, root booster, stalk strengthener, breathing regulator, protein builder and retard the diseases, but it is not effective without its co-efficient such as N and P (Chandra, 1989). The recent use of chemical fertilizers has resulted in many serious environmental problems such as accumulation of heavy metals in soil and plant system (Abdel Wahab *et al*., 2017). Therefore it is necessary to use modern ideas for fertilizing the vegetable crops to increase food production. Nanotechnology has been defined as relating to materials, systems and processes which operate at a scale of 100 nanometers (nm) or less. Nanotechnology used in all stages of the production of agricultural products such as processing, packaging, transport and storage. It is used in the detection diseases and control it. One of the most important uses of nanotechnology is nanofertilizer, which improves the ability of plants to absorb nutrients (Mousavi and Rezai 2011, Srilatha 2011 and Ditta 2012).The present research was aimed to study the effect of liquid nano NPK on cucumber growth, yield and quality, reducing the recommended dose of chemical fertilizer which aims to preserve the environment and reduce the cost of the plant production.

Materials And Methods

This study was carried out to study the effect of liquid nonfertilizer (NPK) on the growth, production and quality of cucumber plants.

Experiment site:

This study was carried out at plastic green house in the farm of faculty of Agriculture Cairo University, Giza, Egypt during the winter seasons of 2017 and 2018. Table 1 show the physical and chemical properties of the experiment soil. Seeds of cucumber cv. sonami F1 were purchased from Gaara company. The seeds were sowing in foam seedling trays (84 cells) contains a mixture of peat moss : vermiculite (1:1 V/V) on 24 September and 20 September in 2017 and

2018 respectively. The trays of seedling were kept under plastic sheet for 4 days until the beginning of seed germination and the seedling were irrigated, fertilized with liquid NPK (19:19:19) and treated with fungicide weekly. The seedlings were transplanted to plastic green house at 15 October and 10 October in 2017 and 2018 respectively, when it reached to 15 cm in length and 4 cm thickness and contain 3 true leaves. The distance between the rows was 150 cm with 50 cm space between the plants in the row. The experimental unit was 12m ^{2} (2m in width and 6 m in Length). The seedling were transplanted on one side of drip irrigation line in each row. The seedling were irrigated with water without any fertilizer during. The three days after transplanting then the treatment were done. The number of plots in the experiment were 18 (6 treatments × 3 replicates). The treatments were arranged in Randomise Complete Block Design with three replicates.

Experiment Layout:

Mineral fertilizer 100 kg of N, 100 kg of P_2O_4 and 150 kg of K_2O per feddan were used as control treatment as the recommended doses of ministry of agriculture and different concentrations of nano liquid fertilizer were used.

The number of treatments were 6 as follow:

1. NPK mineral fertilizer (control).
2. 1.0 ml N +1.0ml P +1.0 ml K /plant.
3. 1.5ml N +1.5ml P +1.5ml K /plant.
4. 2ml N +2ml P +2ml K /plant.
5. 3ml N +3ml P +3ml K /plant.
6. Untreated (with out fertilizer).

Nanofertilizers has been added 50 additives but mineral fertilizer were added according to the following fertilizer equations:

3N:2P:1K was used during the first 15 days after transplanting then the equation of 2N:2P:2K was used for 15 days and then 1N:2P:3K was used for 30 days during the flowering and fruiting stage.

Data Recorded

Vegetative Growth

Three plants were randomly chosen and labeled from each plot to measure the growth parameters after 40 and 60 days from transplanting date.

1. Plant height measure from the surface of soil until the maximum leaf lit.
2. Number of leaves / plant
3. Leaf area meter was measured by Cl-202 laser area meter (U.S.A).
4. Fresh and dry weight of leaves and fruits were measured by drying in forced oven at 70ºC until consent weight.

Leaves Chlorophylls Content:

Chlorophyll a, chlorophyll b, total Chlorophyll and carotenoids were extracted by N,N-dimethylformamide from green leaves after 6 weeks from transplanting date and determinate according to Moran, 1982 by Spectrophotometer model UV 2100. The samples were measured at 470, 647, 663 wave length.

Yield and its components

1. Early yield /plant calculated as the sum of three first picking
2. Total yield /plant

Fruit quality

1. Total Soluble Solid (TSS) was measured by using digital refractometer (PR 101, CO. Ltd. Tokyo, Japan) after 6 weeks of planting.
2. Firmness was measured by using Force Gauge model M4-200 made in USA.

Shelf-life experiment

The fruits from each treatment were harvested and stored at 5ºC for 21 days to evaluate the effect of nanofertilizer on shelf-life and decay % of cucumber. The fruits were packed in foam trays and covered by shrink wraps. The experiment was arranged in Complete Block design. The samples of each treatment were selected after 7, 14 and 21 days from storage to measure the following parameters.

1. General appearance : general appearance was measured by score of 1 : 5
   5 = excellent, 4 = very good , 3 = good , 2 = acceptable , 1 = poor
2. Weight loss % was determined according to the following equation

$$\text{Weight loss \%} = \frac{\text{initial weight} - \text{weight at sampling date}}{\text{initial weight}} \times 100$$

3. Decay % was determined according to the following equation

$$\text{Decay \%} = \frac{\text{weight of decay sample}}{\text{initial weight}} \times 100$$

4. Firmness (as described before) by Force Gauge
5. Total Soluble Solid (TSS) as described before by digital refractometer

Chemical Analysis:

NPK in leave and fruits were determined in dry material. 0.2 g of plant material (leave and fruits) were digested by sulphuric acid. 5 ml of concentrated sulphuric acid were added to each sample and the samples were heated for 10 min. then we added 0.5 ml of perchloric acid and the samples were heated again until were obtained a clear solution as described by Piper (1950). Total nitrogen was determined in digestive solution by micro-kjeldahl method as described by Helrich (1990).

Phosphorus was determined calorimetrically by using spectrophotometer model UV2100 as described by Jackson (1973). Flamephotometer (CORNING M 410, Germany) was used to determine the potassium content

Preparation of nano Fertilizers

Chitosan (MW 71.3 kDa, degree of deacetylation (89%) was purchased from Aldrich Company (Germany). All reagents were of analytical grade from precursor Potassium persulfate ($K_2S_2O_8$) and methacrylic acid was purchased from Aldrich (Germany). Calcium phosphate ($Ca(H_2PO_4)_2{\cdot}H_2O$), salt NH_4NO_3, urea ($CO(NH_2)^2$) and potassium chloride KCl were purchased from Sigma Chemical company (St. Louis, USA).

Nanoparticles were obtained by top to bottom molecular chemical approach method under pressure 2 Mpa. polymerizing methacrylic acid in chitosan solution as carrier coated in buffer solution for 5 hours at room temperature in two-steps processes. In the first step, 0.23 g chitosan was dissolved in methacrylic acid aqueous solution (0.5%, v/v) for 18 h under magnetic stirring. In the second step, with continued stirring, 0.2 mmol of $K_2S_2O_8$ was added to the solution, until the solution became clear. The polymerization was subsequently carried out at 75°C under magnetic stirring for 4 h which leads to the formation of nanoparticle solution, then centrifuged at 500 rpm for 30 minutes, which was thereafter cooled in an ice bath. Were used as sources of urea, salt NH_4NO_3, calcium phosphate, and potassium chloride, respectively. These substances were used separately. The loading of N fertilizers in chitosan nanoparticles was obtained by dissolving of 2M N into 100 ml of chitosan nanoparticle solution under magnetic stirring for 8 h at 25°C. Subsequently dried at 50 ºC for 72 h. The following concentrations: i) 1000 ppm of N; ii) 1000 ppm of P and iii) 1000 ppm of K were finally obtained in each solution. The resulting solutions had a pH of 5.5. The morphology and size of the nanoparticles were investigated using a JEOL 1010 transmission electron microscope at 80 kV (JEOL, Japan). One drop of the nanoparticle solution was spread onto a carbon-coated copper grid and was subsequently dried at room temperature for transmission electron microscopy (TEM) analysis. The sizes of the nanoparticles were determined directly from the figure using an Image-Pro Plus 4.5 software. The value is an average size of three parallels. The particles were uncontrolled in shape with a size range of (9.165) for Nitrogen, (8.254) for Phosphorous and (8.205) nm for potassium with crystal structure and 98.5% purity (Fig.1).

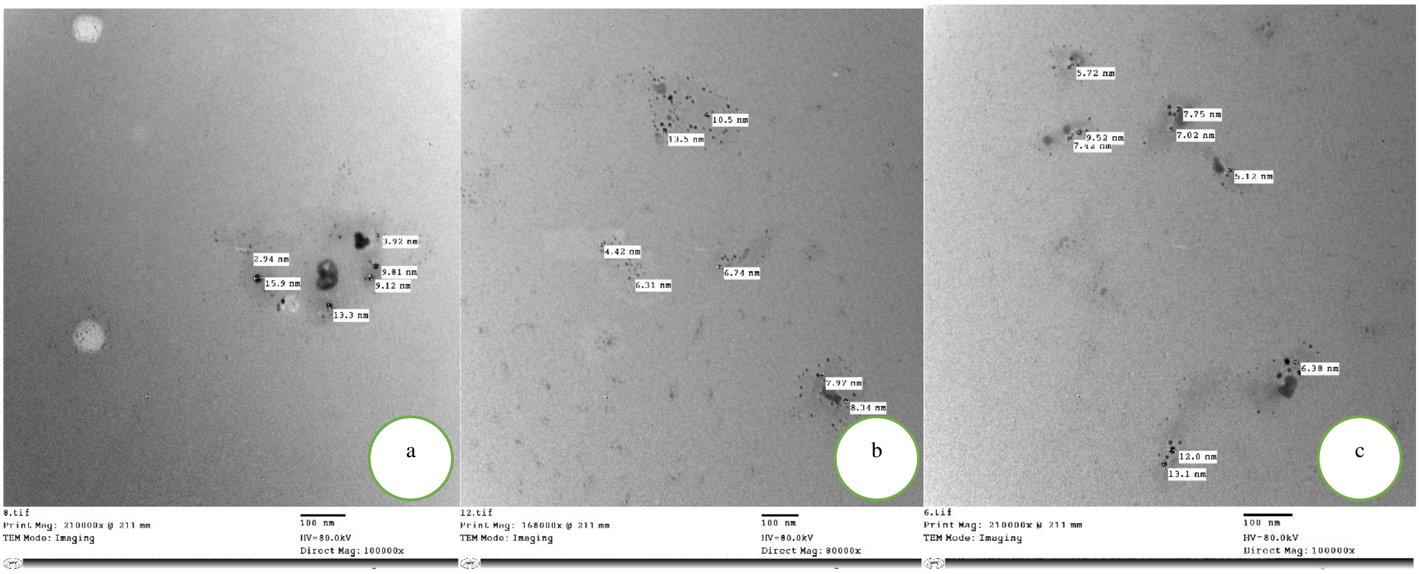

Fig 1. : TEM Images of a) Nitrogen ,b) Phosphorus and c) Potassium nano particles

Statistical Analysis

Data were statistically analyzed using analysis of variance (ANOVA) by using MSTAT-C program (1.2version).The means separated using L.S.D at p ≤ 0.05 between all treatments.

Results and Discussion

Analysis of variance showed that the tested treatments had a significant effect on morphological traits after 40 days of transplanting date (Table 2). Plant height and number of leaves significantly affected in both seasons, While the leaf area was affected in second season only. The highest plant height (102.6, 101.4 and 97.28 cm) were obtained from treatment with 9 ml NPK, 6 ml NPK and control NPK in the first season, without no significant differences between them. The control NPK achieved the highest value of plant height in the second season compared with all other treatments. The highest number of leaves (22.67, 20.67 and 20.33) were obtained from treatment with 6 ml NPK, 9 ml NPK and control NPK in the first season without no significant differences between them. The highest number of leaves (18.67, 15 and 15) were recorded form treatment with control NPK, 6 ml NPK and 9 ml NPK with no significant differences between them in the second season. There no significant differences between all tested treatments on leaf area in the first season. The highest value of leaf area (251.7 and 251.1 cm^2) were obtained from treatment with 6 ml NPK and 9 ml NPK in the second season. Regarding to the effect of tested treatment on plant height after 60 days of transplanting date, the data showed that the highest plant height (177.8, 172.2 and 166.8 cm) were obtained from treatment with 6 ml NPK, 9 ml NPK and 3 ml NPK in the first season. There were no significant differences between mineral NPK and all nano fertilizer treatments on plant height in the second season. The lowest value of plant height was recorded in untreated treatment compared to all other treatments in the both seasons. There were no significant differences among the treatments of mineral and nano fertilizers on number of leaves in the first season after 60 days from transplanting date. The treatment of 6 ml NPK achieved the highest value of number of leaves (22) followed by control NPK (21.67) and 9 ml NPK (18.67). The lowest value of number of leaves was recorded in untreated treatment compared to all other treatments. There are insufficient studies on nano fertilizers, although nowadays it is known to have a significant impact in agricultural production. The use of nano fertilizer has led to increased plant growth. These results were agreement with Abdel wahab *et al.*, 2019 on red radish. The impact of nano fertilizer on plant growth due to its role on improving seeds germination. Which, is reflected positively on morphological traits. (Subbaiya et al 2012) found Previous studies reported that K nano fertilizer and humic acid increased root growth and improve the root system effectiveness that lead to increase the plant height and the plant growth (Ghosh *et al.*, 1981). Also use of Ferbanat (nano micro humates, amino acids, natural biological substances, nano micro elements and soil microflora) has increased the growth of cucumber roots, the number of buds and weight of cucumber plant (Ferbanat 2013). Also, the growth of tomato plant was improved when added 3.0 L /ha of Nanonat and Ferbanat application (Ekinci *et al*., 2012). In another study it was shown that polymer trapping of urea fertilizers led to promote morphological traits of corn plant (Khaveh *et al*., 2015). A significant positive effect on these parameters in different concentrations nanoparticle could be due to highly positive responses of nanoparticle on various plant growth characteristics.

Data recorded in table 3 indicate that the chlorophyll a was affected by tested treatment in the first season. The treatment of control NPK and 4.5 ml NPK recorded the highest chlorophyll content. In the second season the treatment of 9 ml NPK produced the highest value of chlorophyll a compared to all other tested treatments. The highest chlorophyll b content was recorded in 9 ml NPK followed by control NPK in the first season. In the second season there were significant difference between the treatments on chlorophyll b. The highest value was recorded by 4.5 ml NPK. The treatment of 9 ml NPK achieved the total chlorophyll content in the both seasons. There were a little significant differences between all the treatments on total carotenoids in the first season, the highest value (0.43 mg/100gm) was recorded in untreated treatment. While, in the second season the highest value of total carotenoids (0.37 and 0.26 mg/100gm) were recorded from treatment with 9ml NPK and 6ml NPK, respectively. The chlorophyll increased by increasing the concentration of nano fertilizer. N and K are considered essential mineral in photosynthesis and growth of meristematic tissues (Chandra, 1989). The incensement of chlorophyll due to the role of nano particle in improvement of leaves photosynthesis and decreasing the respiration rate (Abdel Wahab *et al*., 2019).

The effect of nano fertilizers on total yield /plant, Early yield and yield increase are shown in table 4. The highest yield /plant (4.18, 3.99 and 3.57 kg) were obtained from treatment of 6 ml NPK, control NPK and 9 ml NPK at the same level of significant $p \leq 0.05$ in the first season. The highest yield / plant (3.94, 3.72 kg) were recorded from the treatment by 6 ml NPK and 9ml NPK in the second season. The highest early yield /plant 717.4 g was obtained from treatment with 4.5 ml NPK in the first season. While, in the second season, the highest value of early yield /plant (961 g) was recorded from treatment with 3 ml NPK. These results were agreement with Ferbanat 2013 who found that Ferbanat application increased yield of cabbages with 38–42% and in potatoes with 35–40% compared to control. Results highlighted the importance of the nanofertilizers (Fe, P and K) on improving saffron yield (Amirna *et al*., 2014). The high concentration of nano fertilizer led to increase yield of corn (Khaveh *et al*., 2015). Also, the treatment of seeds by HA (Urea modified hydroxyapatite particle) led to increase the yield (Subbaiya *et al*., 2012). Previous studies reported that nano-preparation coated nitrogen fertilizer increased the yield of rice (Wang *et al*., 2001). The increase in yield is due to increased morphological traits and chlorophyll content (Table 2 and 3). The treatment of 6 ml NPK, provided the yield by 4.84 % in the first season and by 53.12% in the second season compared to control. On the other hand, the treatment of 9 ml NPK induced increasing of yield by 44.86 % in the second season only. These results were agree with Zareabyanel *et al.,* 2015 who found that the treatments of nano-nitrogen chelate (NNC), sulfur-coated nano-nitrogen chelate (SNNC), sulfur-coated urea (SCU) fertilizers led to increased potato yield by 56.10, 59.61, and 49.76% respectively compared to Urea fertilizer application. This is because these treatments led to reduced nitrate leaching levels by 35.72, 41.56, and 9.94% compared to U fertilizer application.

As shown in table 4, the highest values of total soluble solids (TSS) 2.73, 2.7 and 2.6 were recorded from treatment with 9 ml NPK, 6 ml NPK and control NPK in the first season, While in the second season there were a little significant differences between all the tested treatments on TSS. The highest value was recorded in treatment with control NPK. The highest firmness (3.68) was recorded from treatment with control NPK, followed by 6 ml NPK and 3 ml NPK in the first season. While, the highest values (3.1, 2.8 and 2.7) were recorded from treatment with 4.5 ml NPK, 9 ml NPK and control NPK in the second season. Data recorded in table 4 indicate that the highest value of dry mater/fruits (3.75% and 4.77%) were obtained from treatment with 9 ml NPK in the both seasons. All the fertilizer treatments (mineral and nano) achieved the high dry matter value / plant compared to untreated treatment. The treatment of 6 ml NPK recorded the highest value of dry mater / plant. Dry mater% /plan didn't affect significantly by all tested treatments in the second season. These results were agreement with Abdelaziz and Emad A. Abdeldaym 2018 and Abdel wahab *et al*. 2019.

TSS Increased due to increase the chlorophyll and photosynthesis as shown in table 3. Potassium has a main role in sugars accumulate in fruit tissues (Peel and Rogers 1982) leading to increase TSS in cucumber (Lester *et al*., 2010). Likewise, increasing firmness of cucumber fruit could be associated to superior accumulation of some osmoles and increase potassium concentrations in fruit cells (Lester *et al*., 2006). The highest dry matter in plants treated by nano fertilizer associated highly to leaf photosynthetic pigments and photosynthesis rates that increase total carbohydrate accumulation which consider the main component of dry matter (Abdel Wahab *et al*. 2019).

Date recorded in table 5 show clearly that the leaves N, P, K % increased by increasing the concentration of nano fertilizer. The highest leaves N% was 5.47% and 5.62 % in first and second seasons, respectively from the treatment of 9 ml NPK. In addition, the treatment of 6 ml NPK had 5.54 % N without any significant differences with 9 ml NPK in the second season. The highest concentration of P% in leaves (0.66% and 1.06 % were recorded from treatment with 9 ml NPK in the both seasons. The highest value concentration of K% in leaves (4.17%) was recorded from treatment with 6 ml NPK and 9 ml NPK in the first season. The highest value in the second season was 4.59% from treatment of 9 ml NPK .The highest fruits N% were 0.22% and 0.21 % in first and second seasons respectively from the treatment of 9 ml NPK. In addition, the treatment of 6 ml NPK had 0.19 % of fruits N% without any significant differences with 6 ml NPK in the first season. While, concentration of P % no significant differences between all treatments in both season. Concentration of K% in fruit was no significant difference between all treatments in the first season. But in the second season, the best treatment in concentration of K% in fruits was 0.17% recorded in treatment with 9ml NPK without no significant differences between all treatments. Nitrogen, which is one of the most important nutrients in agricultural production, might be given only very few parts to plant and soil need, although it has been reported that the use of very small nano fertilizer particles is more effective than this rate (DeRosa *et al*., 2010). The use of concentration of 1000mg/L of nano fertilizer help to increase concentration of these nutrient elements in roots and shoots of the lettuce plants. It is positively reflected of plant growth (Roosta *et al*., 2017).

As shown in table 6 weight loss increased by increasing the storage periods on contrast, the general appearance decreased by increasing the storage periods. There was no significant difference between all treatments on weight loss% until 14 days of storage. The highest value of weight loss (10.72) were obtained in the treatment of 9 ml NPK after 21 days of storage at 5°C the treatments of 6 and 9 ml NPK mention the highest general appearance until 14 days of storage. After 21 days of storage all the tested treatments lost its general appearance and the general appearance reach to 2 in all treatments except for 6 and 9 ml NPK which had 3.

Data recorded in table 7 indicate that firmness decreased by increasing the storage periods. The highest value of firmness (1.0 %) were obtained in the treatment of 6 and 9 ml NPK after 21 days of storage at 5°C. While, the highest value of TSS (3.0%) were recorded of treatment with control NPK after 14 days of storage at 5°C. There were no significant differences between all the tested treatments on TSS after 21 days of storage at 5 °C. There were no significant differences between all the tested treatments on decay after 7,14 days of storage at 5 °C. The highest value of decay (41.79 and 36.71) were obtained in the treatment of 3 and 4.5ml NPK after 21 days of storage at 5 °C. As a result of this study it can be expressed that the fertilizer used in this study showed this effect and becomes available for cucumber plants. These results were agreement with Shehata *et al*., 2019 and 2017).

Conclusion

The changing climate, sustainable use of natural resources, environmental factors, accumulation of pesticides and over use fertilizers are the most important problems of modern agriculture. New methods have been used in order to avoid the effects of these factors. The nanofertilizer is one of the new. It could be stated that high N concentration to 6 ml NPK per plant gave the highest growth characteristics and yield and fruit quality of cucumber.

Table 1: Some physical and chemical properties of experiment soil

Parameters	Value
Particle-size distribution (%)	
Sand	24
Silt	41
Clay	35
Texture class	Clay loam
CaCo3 %	1.58
Organic matter %	3.10
pH (saturated past)	7.65
EC (dS m^{-1})	1.35
Field Capacity	10.98
Permanent wilting Point	4.09
Available water capacity	6.89
Bulk density	1.7
Real density	1.33
P%	0.28
K%	0.35
N%	1.3
Soluble Cation (m L^{-1})	
Ca^{2+}	4.5
Mg^{2+}	3.25
Na^{+}	3.50
K^{+}	2.25
Soluble anions (m L-1)	
CO_3^{-2}	Tr
HCO_3^{-}	1.01
CL"	6.09
$SO_4^{"2}$	7.40

Table 2 : Effect of NPK nanofertilizers on growth characters of cucumber plants, after 40 days and after 60 days of sowing data 2017/2018 and 2018/2019 seasons.

		After 40 day				**after 60 day**
Year	**Treatments**	**Plant height (cm)**	**N. of leaves**	**Leaf area(cm^2)**	**Plant height (cm)**	N. of leaves
2017	Control NPK	97.28 ab	20.33 ab	171.3	162.3 b	22.67 a
	3ml NPK	90.65 b	19.67 b	177.4	166.8 ab	21.33 a
	4.5ml NPK	92.44 b	18.67 b	183.2	161.8 b	21.67 a
	6ml NPK	101.4 a	22.67 a	188.2	177.8 a	24.33 a
	9ml NPK	102.6 a	20.67 ab	188.1	172.2 ab	23.67 a
	Untreated	63.68 c	15.67 c	168.3	123.3 c	17.33 b
	LSD at 0.05	7.49	2.69	N.S	12.44	3.2
2018	Control NPK	102.8 a	18.67 a	200.4 b	132.2 ab	21.67 ab
	3ml NPK	69 d	14.33 b	176.7 b	121.7 ab	16.67 bc
	4.5ml NPK	78.11 c	14.51 b	187 b	123.1 ab	17 abc
	6ml NPK	87.11 b	15 ab	251.7 a	143.3 a	22 a
	9ml NPK	69.11 d	15 ab	251.1 a	126.7 ab	18.67 abc
	Untreated	49.56 e	13.67 b	175 b	116.7 b	15.67 c
	LSD at 0.05	8.81	3.76	43.24	25.66	5.23

Table 3 : Effect of NPK nanofertilizers on chlorophyll and carotnoids contents of leaves cucumber plants, during 2017/2018and 2018/2019 seasons.

	2017				2018			
Treatments	Chl a	Chl b	Total chl	Total carotnoids	Chl a	Chl b	Total chl	Total carotnoids
Control (NPK)	1.58a	0.54ab	2.1ab	0.36ab	1.34 b	0.52ab	1.86b	0.23b
3ml NPK	1.34ab	0.43bc	1.77bc	0.3ab	1.23 b	0.47ab	1.71b	0.22bc
4.5ml NPK	1.59a	0.26c	1.85abc	0.47a	1.15 b	0.66 a	1.8b	0.12c
6ml NPK	1.4ab	0.37bc	1.77bc	0.28ab	1.32 b	0.46ab	1.77b	0.26ab
9ml NPK	1.48ab	0.69a	2.17a	0.23b	1.97 a	0.37b	2.34a	0.37a
Untreated	1.24b	0.34bc	1.58c	0.43a	1.13 b	0.44ab	1.57b	0.21bc
LSD at 0.05	0.26	0.24	0.34	0.21	0.41	0.24	0.36	0.12

Table 4 : Effect of nanofertilizers on yield, TSS, Firmness and Dry mater of cucumber plants, during 2017/2018 and 2018/2019 seasons.

Year	**Treatments**	Yield/Plant (kg)	Early yield/Plant (gm)	Incensement of Yield (%)	TSS (%)	Firmness	Dry Mater/ fruits(%)	Dry mater/ plant (%)
2017	Control NPK	3.99 a	217.2 e	0	2.6 ab	3.68 a	2.04 b	11.34 a
	3ml NPK	2.33 b	436.7 c	-41.48	2.43 b	3.21 ab	2.19 b	12.15 a
	4.5ml NPK	2.38 b	717.4 a	-40.38	2.37 b	3.37 bc	2.06 b	11.91 a
	6ml NPK	4.18 a	449.5 c	4.84	2.7 a	3.51 ab	2.06 b	13.09 a
	9ml NPK	3.57 a	549.1 b	-10.46	2.73 a	3.12 c	3.75 a	12.51 a
	Untreated	1.65 b	392.3 d	-58.62	2.4 b	1.47 d	2.24 b	7.60 b
	LSD at 0.05	0.83	42.47		0.24	0.3	0.61	1.98
2018	Control NPK	2.57 b	391 c	0	2.83 a	2.7 ab	4.41 bc	12.49
	3ml NPK	1.82 bc	961 a	-29.07	2.77 ab	2.5 b	4.48 abc	12.01
	4.5ml NPK	1.46 c	373.6 c	-43.31	2.73 ab	3.1 a	4.72 ab	12.74
	6ml NPK	3.94 a	259.6 d	53.42	2.67 b	2.4 b	4.48 abc	12.74
	9ml NPK	3.72 a	661.4 b	44.86	2.73 ab	2.8 ab	4.77 a	12.32
	Untreated	1.46 bc	610.5 b	-43.41	2.73 ab	2.5 b	4.39 c	11.55
	LSD at 0.05	1.08	80.98		0.14	0.3	0.32	N.S

Table 5 : Effect of nanofertilizers on NPK concentrations in cucumber dry leaves and fruits during 2017/2018and 2018/2019 seasons.

		Leaves			Fruits		
Year	**Treatments**	N %	P %	K %	N %	P %	K %
2017	Control NPK	3.62 d	0.27 e	3.6 b	0.14 b	0.02	0.15
	3ml NPK	3.79 cd	0.32 d	3.62 b	0.16 b	0.02	0.15
	4.5ml NPK	4.08 c	0.39 c	3.79 b	0.16 b	0.02	0.15
	6ml NPK	5.01 b	0.52 b	4.17 a	0.19 a	0.02	0.16
	9ml NPK	5.47 a	0.66 a	4.17 a	0.22 a	0.02	0.16
	Untreated	3.10 e	0.12 f	3 c	0.11 c	0.01	0.14
	LSD at 0.05	0.32	0.03	0.29	0.03	N.S	N.S
2018	Control NPK	3.52 d	0.24 e	3.38 d	0.12 c	0.02	0.15 ab
	3ml NPK	4.65 c	0.53 d	3.93 c	0.16 b	0.02	0.15 ab
	4.5ml NPK	5.27 b	0.72 c	4.12b c	0.18 b	0.02	0.16 ab
	6ml NPK	5.54 a	0.87 b	4.54a b	0.18 b	0.02	0.16 ab
	9ml NPK	5.62 a	1.06 a	4.59 a	0.21 a	0.02	0.17 a
	Untreated	3.59 d	0.22 e	3.35 d	0.11 c	0.02	0.15 b
	LSD at 0.05	0.25	0.058	0.42	0.25	N.S	0.02

Table 6 : Effect of nanofertilizers on weight loss % and appearance of cucumber fruits after 21 days storage at 5 ºC 2017 / 2018 season.

Storage Periods days		**Treatments**						
		Control NPK	**3ml NPK**	**4.5ml NPK**	**6ml NPK**	**9ml NPK**	**Untreated**	**L.S.D at 0.05**
Weight loss %	0	0	0	0	0	0	0	0
	7	2.56	1.52	1.44	1.43	1.31	1.31	N.S
	14	2.34	5.75	4.23	6.30	7.92	3.71	N.S
	21	7.75b	7.31b	6.35b	6.91b	10.72a	6.32b	2.03
General apperran	0	5	5	5	5	5	5	N.S
	7	5	5	5	5	5	5	N.S
	14	4 b	5 a	5 a	5 a	5 a	4 b	0.025
	21	2 b	2b	2b	3a	3a	2b	1.0

Table 7 : Effect of nanofertilizers on Firmness, TSS and decay of cucumber fruits after 21 days storage at 5 ºC 2017 / 2018 season.

Storage Periods		Treatments						
		Control NPK	3ml NPK	4.5ml NPK	6ml NPK	9ml NPK	Untreated	L.S.D at 0.05
Firmness	0	2.7 ab	2.5b	3.1a	2.4b	2.8ab	2.8ab	0.49
	7	2.1c	1.6a	1.8d	2.4a	2.3b	2.3b	0.03
	14	1.6ab	1.4ab	1.2ab	1.4b	2.0a	2.0a	0.78
	21	1.4a	0.89b	0.9b	0.9b	1.0b	1.0b	0.30
TSS	0	2.77 ab	2.77 ab	2.73 ab	2.67 b	2.73 ab	2.83 a	0.14
	7	3.05 ab	2.95 ab	2.75 b	2.90 ab	3.30 a	2.7 b	0.47
	14	3.0 a	2.4 c	2.5 bc	2.8 ab	2.4 c	3.0 a	0.42
	21	2.25	2.20	2.20	2.30	2.30	2.10	N.S
Decay	0 day	0	0	0	0	0	0	N.S
	7 day	0	0	0	0	0	0	N.S
	14 day	0	0	0	0	0	0	N.S
	21 day	0 b	41.79a	36.71a	6 b	0 b	0 b	19.79

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