Effect of soil application of nano NPK fertilizers on growth, productivity and quality of Lettuce (*Lactuca sativa*)

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ABSTRACT

This investigation was conducted during the two winter seasons of 2017 and 2018 to study the effect of soil application of nano NPK at rates of (0, 12.5, 25, 50 %) from the recommended dose of conventional NPK chemical fertilizers on growth, yield, and head quality of lettuce. The results showed that the high rate of nano nitrogen (50%) significantly increased the vegetative growth expressed as plant fresh weight, leaf area head fresh weight, head size, firmness, total yield and marketable yield. Moreover 50 % of nano potassium treatment produced the highest significant increment of ascorbic acid, TSS and head total sugars content. However, the highest significant total chlorophyll, carotenoids and dry matter content was recorded with nano nitrogen (50%), while head phosphorus, and potassium content were reached the highest values with 50% nano phosphorus and nano potassium respectively. Head nitrate content significantly increased with control NPK conventional over all nano treatments. It was concluded that vegetative growth, yield and marketable yield responded positively to the application of 50% nano nitrogen while head quality significantly increased with 50% nano potassium fertilization.

Keywords: Nano Fertilizers, NPK, lettuce, yield, ascorbic acid, No3.

INTRODUCTION

Lettuce is known to have been cultivated at least 4,500 years BP as long-leaved Cos type lettuce was depicted on the walls of Egyptian tombs (Lindqvist 1960). Heading lettuce (*Lactuca sativa*) cv. big bell is the most popular crop among leafy vegetables. It is one of the most important members of the Compositae family; it can prevent cancer due to phenolic compound, vitamin A, C and carotenoids content. These compounds have a function on nutrition and health care, which could enhance anti-oxidation ability of human body and suppression the inflammatory disease and cancer (Lin et al., 2014 and Pepe et al., 2015).

Nanotechnology science refers to manipulating and control of matter at nano scale (at range 1-100 nm), where a unique phenomenon enables novel applications (Bhushan, 2017). Nowadays nanotechnology is used in agriculture and related industries (Froggett, 2009). The important focus areas for nanotechnology in agricultural researches are agricultural diagnostics, nano biosensors, nano bio farming, nano pesticides, nano herbicides and controlled release of nano fertilizers and nano complexes (Agrawal and Rathore, 2014).

Fertilizers are chemical compounds applied to promote plant and fruit growth (Behera and Panada 2009). Excessive use recently of conventional chemical fertilizers has resulted in much serious environmental pollution such as heavy metals accumulation in soil, plant system and underground water contamination (Abdel Wahab et al., 2017). In addition, overdoses of mineral fertilizers are kind of energy wasting, reduces nutrient use efficiency (Kaushik and Djiwanti 2017). In general, about 50-70 % of the applied conventional chemical fertilizers get lost in the environment causing economic, agronomical, environmental concerns and health threats. So it is necessary to use new ideas in vegetable fertilization to increase food production. Therefore, new alternatives should be used for eco-friendly, economic and sustainable for agriculture system such as nano fertilizers as slow or controlled release fertilizers (El-Ramady et al., 2018). Soil application of N- P- K nano fertilizers have greater role in enhancing significant growth and yield of cotton such as total and open bolls per plant, boll weight and seed cotton yield besides reducing the cost of fertilizer and also minimizing the environmental pollution (Eleyan et al., 2018).

Many investigations were done on nano fertilizers as a controlled release agent for nitrogen, phosphorus, and potassium and evaluate their effects on French bean (Hasaneen and Abdel-Aziz 2016), wheat plants (Abdel-Aziz et al., 2016), and red bean (Biosci et al., 2014). A study conducted by (Chemistry, 2017) proved an active effect for nano fertilizers on vegetative growth, yield and quality of vegetables and other crops which open a new dimension for plant nutrition through nanotechnology. Therefore, the aim of

this study was to evaluate the effect of soil application of Nano NPK fertilizers on growth, and quality of lettuce plants.

MATERIALS AND METHODS

This investigation was carried out during the two successive seasons of 2017 and 2018, on lettuce, (*Lactuca sativa*) c.v big bell. The experiment was done in a private farm at Elmansouria village, Giza governorate, Egypt to study the effect of soil application of nano N P K fertilizers on vegetative growth, head chemical contents, yield and marketable yield of lettuce.

Lettuce seeds were obtained from Bakker brothers company – China and had sown in foam trays filled with mixture of Peat moss and vermiculite (1:1v/v) on 5 October during 2017 and 2018 seasons. Seedlings were kept under standard shaded green house as nursery. However, seedlings were transplanted into open field on 5th November in the two growing seasons. Every treatment included 3 replicates and each replicate consisted of 3 rows, each row was 3.5 m long and 70 cm width. The distance between rows was 70 cm apart and between plants was 25 cm. The area of each plot was 7 m^2 contains 42 plants. Surface irrigation was applied and other agricultural practices took place whenever it was necessary according to the recommendations of Ministry of agriculture Egypt (Hassan, 2011).

The soil type of this area was sandy loam. The physical and chemical analyses of the soil in the two seasons are shown in Table (1). A one way complete plot design was followed in this study. The recommended chemical fertilizers of NPK were used as a control. Nitrogen sources were ammonium nitrate 33% (40 kg /fed), calcium nitrate 15.5% (50 kg /fed) and ammonium sulfate 20.5% (100 kg/fed). Phosphorus was acquired from calcium super phosphate 15% (250 kg/fed) was added at soil preparation. Potassium was resulted from potassium sulfate 48% (75 kg/ fed) was applied at three doses during growth seasons; it is equivalent to 41-39-36 units of nitrogen, phosphorous and potassium per feddan respectively. Moreover, agriculture sulfur was added during soil preparation at the rate of 200 kg/fed according to (Hassan, 2011). The nano of NPK was obtained from Nano FAB Technology Company, 4 Saraya Building, 6 October City, Cairo, Egypt. The treatment of Nano fertilizers NPK were applied to soil at the rats of 0, 12.5, 25, and 50 % of the recommended mineral fertilizer three times after the transplanting date every two weeks with irrigation water in comparison to the conventional NPK application. Chemical characteristics of nano N, P and K fertilizers are shown in Table (2).

The examined treatments:

Nano and conventional of NPK fertilizers treatments were shown in Table (3).

Data of experimental measurements:

Physical characteristics:

Five Plants per each experimental plot were chosen randomized from three replicates (from the inner rows) to determine the following characters: 1) Plant weight (g), 2) Head fresh weight (g), 3) Size (cm^3), 4) Diameter (cm) 5) Head firmness (g/cm^3) was determined according to (Opena and Lo, 1980).

Chemical characteristics:

Chemical characteristics were determined in the lettuce head such as: 1) Ascorbic acid (mg/100 g F.W)2) Total soluble solids (%) which determined according to (A.O.A.C., 2000), 3) Dry matter percentage was determined in mixed small pieces of 100 g after drying at 70°C until constant weight was attained. The dry matter was calculated according to following formula: Dry matter (%) =Dry weight / Fresh weight × 100, 4) Total sugar (g/100 mg DW) (Smith et al., 1956), 5) Nitrate in heads (mg/ kg D.W) calorimetrically according to (Cataldo et al., 1975), 6) Total phosphorus of leaves (mg/100 mg D.W) was determined as reported by (Troug and Meyer 1939), 7) Total potassium in the leaves (mg/ 100 mg D.W) was determined according to (Cottenie *et al.,* 1982).

Yield characteristics:

Total yield (ton/fed) was determined by a digital balance and marketable yield (ton/fed) after removing the outer leaves of plants in by a digital balance also.

Statistical analysis

The obtained data of plant and head characteristics were subjected to the analysis of variance and L.S.D. tests at 0.05 confidence level according to (Snedecor and Cochran, 1980). according to one way anova complete randomized design.

RESULTS

The obtained results of soil application with nano NPK on the plant and head characteristics of lettuce are summarized in the following items:

Physical characteristics:

The effect of soil application of nano NPK fertilizers on physical characteristics in the two seasons 2017 and 2018 are tabulated in Tables (4 - 5) showing that plant fresh weight, leaf area, head fresh weight and head size significantly increased by the application of nano N, P and K fertilizers. Moreover, the highest obtained values were recorded with nano nitrogen at the rate of 50 % compared to other nano treatments and NPK conventional fertilizers (control). The head diameter and firmness significantly increased in the two seasons of study by soil addition with nano NPK fertilizers. However the rate of 50% nano nitrogen produced the highest significant increase in these characteristics.

Chemical characteristics:

The effect of soil application of nano NPK fertilizers during the two seasons on chemical parameters such as dry matter, head ascorbic acid, total soluble solids, total sugars, nitrate, phosphorus, and potassium content are showed in Tables (5 - 6) reveal that the highest significant increase in dry matter content was obtained with nano nitrogen treatment at 50% in both seasons compared to other treatment and control. Meanwhile, the highest significant values of head ascorbic acid were produced from soil application of 50% nano potassium fertilizer compared to other nano treatments and control. Total soluble solids significantly increased with 25 and 50% nano phosphorus and nano potassium respectively.

The highest significant values of total sugars were recorded with the treatment of nano potassium fertilizer at the rate of 50% in both seasons. Head phosphorus and potassium content resulted from 50% of nano phosphorus and nano potassium in both seasons respectively. On the other hand the highest significant values of head nitrate content were registered from the control NPK conventional fertilizers over other nano treatments in both seasons.

Total and marketable yield:

The influence of soil application with nano NPK fertilizers in the two seasons on yield and marketable yield of lettuce were shown in Table (8) displayed that the yield and marketable yield were significantly increased gradually with the increase in nano N – P – and K rates. Moreover the highest significant increase in total and marketable yield was produced from nano nitrogen application at the rate of 50% compared to other nano treatments and control.

DISCUSSION

Soil application of nano NPK fertilizers on lettuce plants produced significant increases in plant fresh weight, leaf area head fresh weight, head size, diameter, firmness, total and marketable yield besides head ascorbic acid, T.S.S, dry matter, total sugars, phosphorus and head potassium content . The enhancement effect of nano fertilizers on these studied characteristics may be attributed to the fact that it has a dimension ranging from 30 to 40 nm which is able to hold numerous ions because of their high surface area and slowly release them in a timely manner to cope with crop demand. Moreover, their slow release and super sorbent phosphatic and nitrogenous fertilizers (Lal, 2008). The increment in the previous plant vegetative growth parameters may be due to higher availability of nitrogen element at lower doses compared with the conventional nitrogen sources, nitrogen insufficient amount may limit plant growth. A similar linear increase in plant fresh weight was recorded on Swiss chard by (Echer et al., 2012). This increment may be due to high essentiality of N as a component of amino acids, proteins, nucleic acids, pigments and many enzymes (Marschner, 1995). So, nitrogen is critical for growth and development of plants, especially during cell division and cell enlargement phase of growth. This trend was in agreement with (Haque and Jakhro 1996) who reported that nitrogen promotes vegetative growth and its deficiency leads to stunted growth and low production. This positive effect of nano fertilizers may also due to increasing the photosynthetic rates and the assimilation rates, which is leading to increase the most vegetative parameters and increased the heads yield of lettuce (Saleh et al., 2010). Phosphorus is considered as an important macronutrient plant, making up about 0.2 % of a plant's dry weight. It is one component of key molecules such as nucleic acids, phospholipids and ATPs. It is involved in several plant functions, including controlling enzyme reactions, regulation of metabolic pathways, energy transfer, photosynthesis and transformation of carbohydrates as well as formation of protein leading to increases in vegetative growth parameters (Marschner, 1995). Potassium is directly involved in enzyme activation, maintenance of water

status, energy relations, and translocation of assimilates. It has an important role in protein synthesis. It has also a main role in regulating cellular turgid pressure to avoid wilting, which in turn controls the stomata opening and hence greatly enhances drought tolerance (McCarty, 2005). The enzyme responsible for synthesis of starch (starch synthetase) is activated by potassium element. Thus, with inadequate K, the level of starch declines while soluble carbohydrates and N compounds accumulate (Patil, 2011). All of these vital roles of potassium may have a good simulative reaction on lettuce vegetative growth. The increase in ascorbic acid TSS and head sugar content may be attributed to The role of potassium in photosynthesis is very important due to the activation of enzymes by K and its involvement in adenosine triphosphate (ATP) production is probably more important in regulating the rate of photosynthesis. As it is known that, ascorbic acid synthesized from sugars supplied through photosynthesis in plants (Lee and Kader 2000). Based on some reports, reduced levels of vitamin C in juices of oranges, lemons, grapefruits, and mandarins resulted from the application of high levels of nitrogen fertilizer to those crops, while increased potassium fertilization markedly increased ascorbic acid content (Nagy, 1980). Potassium is directly involved in enzyme activation and photosynthetic process which affects the rate of sugar formation for ultimate starch production. So under high K levels, starch is efficiently moved from sites of production to storage organs at the form of sugar (Patil, 2011). The positive effect of nano fertilizers NPK on chemical composition of lettuce plants such as ascorbic acid, total soluble solids (T.S.S), dry matter, sugars, phosphorus and potassium content may be attributed to the presence of macro nutrients suggesting that nano-engineered N, P, K fertilizers appeared to enhance the uptake and use efficiency of nutrients by plants(Abdel-Aziz et al., 2016)**.**The highest nitrate concentration was recorded at the control conventional NPK treatment compared to other nano fertilizer treatments. This result was in agreement with (Corre, 1979; Maynard 1976 and Sorensen 1994) who reported that excessive use of nitrogen fertilizers markedly enhanced the vegetative growth of plants that is often accompanied by accumulation of NO_3 in the plant tissues. Meanwhile there was a slid increase in head nitrate content with increasing nano nitrogen concentrations. The same was reported on lettuce plants which is supplied with the full nitrogen dose in solution. It gave the highest leaf nitrate content and that was much lower in plants treated with under taken together supplementary higher lighting and withholding half nitrogen supply of nutrient solution (Khan et al., 2018). Our results were in agreement also with (Byrne et al., 2001) who found that increasing the rates of N in soils caused an increase in nitrate accumulation in lettuce, particularly in outer leaves.

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Table 1. Physical and chemical analyses of the field experimental soil during 2012/2013 and 2013/ 2014 seasons.

	Physical properties					Chemical properties											
											Cations mq/L				Anions mq/L		
Soil constituents	Sand %	Silt %	Clay %	Organic matter %	Texture class	EC (ds /m)	Ph	Total N mg/kg	Total P mg/kg	CaCo3 %	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3	Cl^{-}	$SO4^{=}$
Season 2017	78.1	13.2	8.7	0.57	Sandy loam	2.76	8.25	69.5	7.7	28.35	11	4	11.2	0.95	1.3	22	3.9
Season 2018	77.2	13.6	9.2	0.55	Sandy loam	2.55	8.15	63.6	7.5	30. 19	11.3	4.2	10.8	0.91	1.23	22.2	3.7

Table 2. Chemical composition of nano N, P and K fertilizers according to Nano FAB Technology Company.

Element	N	P	K
Source of element	Urea	Phosphoric acid	Potassium sulfate
Chemical formula	CH_4N_2O	H_3PO_4	$C_6H_5O_7K_3$
Appearance	White solid	White solid or colorless, viscous liquid(> 42 g. ml^{-1}) deliquescent	Colorless
Molar mass	60.60 g. ml^{-1}	97.99 g. ml^{-1}	306 g/ mol
Element ratio	20 %	20 %	20 %
Inert ingredient	80%	80%	80%

Table 3. Fertilization units of nano and conventional NPK fertilizers.

	Nano N. P. K		Conventional N. P. K once		
Elements	Nano %	Nano Unit	N Unit	P Unit	K Unit
Control	Zero	Zero	41	39	36
Nitrogen	Zero	Zero	Zero	39	36
	12.5%	5.125	zero	39	36
	25%	10.250	zero	39	36
	50%	20.500	Zero	39	36
Phosphorus	Zero	Zero	41	zero	36
	12.5%	4.875	41	zero	36
	25%	9.75	41	zero	36
	50%	19.5	41	zero	36
Potassium	Zero	Zero	41	39	zero
	12.5%	4.5	41	39	zero
	25%	9.0	41	39	zero
	50%	18	41	39	zero

Table 4. Effect of soil application of nano fertilizer on plant weight, plant height, leaf weight of lettuce plants in 2017 and 2018 seasons.

Treatments	Plant weight (g)		Leaf area (cm^2)		Head fresh weight (g)		Head size (cm^3)	
	Season 2017	Season 2018	Season 2017	Season 2018	Season 2017	Season 2018	Season 2017	Season 2018
NPK (Control)	788.3 f	790.0 f	396.7 abc	381.33 def	749.7 cd	671.7 d	698.3 d	628.3 ef
0 nano N	400.0 j	418.3 i	270.4 ef	336.0 g	346.0 g	340.0 g	303.0 h	285.0 i
12.5% nano N	745.5 h	745.5 g	313. 8 cdef	358.0 fg	650.0 e	663.3 de	593.3 e	615.0 f
25% nano N	917.5 c	917.5 c	322. 3 cdef	428.5 dc	766.7 cd	849.7 b	615.0 e	805.0 b
50% nano N	1017.5 a	1017.5 a	455.5 a	502.8 a	933.3 a	920.0 a	862.7 a	870.0 a
0 nano P	730.0 i	430.0 i	267.5 f	375.5 ef	625.7 e	526.7 f	548.0 f	490.0 h
12.5% nano P	985.0 b	825.0 e	372.7 bc	433.3 b	782.8 c	756.7 c	676.7 d	670.0 d
25% nano P	825.0 e	924.0 c	293.9 ef	471.0 a	730.0 d	811.7 b	674.0 d	785.0 b
50% nano P	924.0 c	985.0 b	334.1 cde	487.2 a	866.8 b	843.3 b	805.0 b	805.0 b
0 nano K	765.0 g	740.0 g	255.3 f	364.0 fg	643.3 e	623.3 e	563.3 f	580.0 g
12.5% nano K	730.0 i	805.0 ef	297.1 def	378.3 ef	562.8 f	736.7 c	504.3 g	633.3 ef
25% nano K	835.0 e	735.0 g	406.0 ab	397.43 cde	744.7 cd	673.3 d	695.0 d	650.0 de
50% nano K	885.0 d	850.0 d	360.4 bcd	413.3 bcd	774.2 cd	763.3 c	725.0 c	730.0 c
LSD at 5%	12. 70	20.52	69.30	32.70	45.06	42.47	24.50	29.04

Table 5. Effect of soil application of nano fertilizers on head diameter and head firmness of lettuce plants during 2017 and 2018 seasons.

Treatments	Head diameter (cm)		Head firmness(g /cm^3)	
	Season 2017	Season 2018	Season 2017	Season 2018
NPK (Control)	12.0 abc	11.7 ab	3.07 b	2.56 de
0 nano N	10.2 ef	10.0 c	1.73 f	1.70 f
12.5% nano N	11.2 cd	10.5 c	2.32 de	2.62 de
25% nano N	11.5 bcd	11.7 b	3.01 b	2.99 bc
50% nano N	12.5 a	13.2 a	3.61 a	3.92 a
0 nano P	9.7 f	10.0 c	1.65 f	2.71 cde
12.5% nano P	11.5 bcd	10.4 b	3.01 b	2.66 cde
25% nano P	12.0 abc	12.0 b	3.15 b	2.90 bcd
50% nano P	12.2 ab	12.5 ab	2.92 bc	3.00 bc
0 nano K	9.7 f	10.0 c	1.75 f	2.46 e
12.5% nano K	10.7 de	11.7 b	2.14 e	2.58 de
25% nano K	11.7 abc	12.5 ab	2.20 e	2.73 cde
50% nano K	12.25 ab	12.7 ab	2.62 cd	3.20 b
LSD at 5%	0.871	1.188	0.369	1.697

Table 6. Effect of soil application of nano fertilizers on head ascorbic acid, and head TSS and dry matter of lettuce plants during 2017 and 2018 seasons.

	Ascorbic acid mg/100g FW		TSS %		Dry matter %	
Treatments	Season 2017	Season 2018	Season 2017	Season 2018	Season 2017	Season 2018
NPK (Control)	6.06 b	5.80 cd	4.1 f	4.2 cd	3.98 def	4.49 bc
0 nano N	3.48 e	3.40 h	3.3 h	2.4 f	2.53 h	2.67 f
12.5% nano N	6.29 b	6.23 bc	4.9 d	3.9 de	3.80 f	3.50 e
25% nano N	4.19d	4.54 g	5.3 c	4.5 bc	4.17 cde	4.03 d
50% nano N	4.67 c	5.12 ef	5.2 c	4. 2]cd	5.03 a	5.10 a
0 nano P	3.36 e	2.91 h	3.7 g	3.5 e	3.17 g	4.55 bc
12.5% nano P	4.40 cd	4.73 fg	4.6 e	4.7 ab	4.27 cde	4.67 b
25% nano P	6.28 b	5.37 de	5.7 a	4.8 ab	4.80 ab	4.48 bc
50% nano P	5.96 b	6.13 c	5.6 ab	4.8 ab	4.50 bc	4.50 bc
0 nano K	3.48 e	4.28 g	3.7 g	3.7 e	3.27 g	4.54 bc
12.5% nano K	6.00 b	6.25 abc	4.7 de	4.4 bc	3.93 ef	4.23 cd
25% nano K	6.27 b	6.68 abc	5.3 c	4.4 bc	4.23 cde	4.47 bc
50% nano K	7.06 a	6.77 a	5.4 bc	5.1 a	4.30 cd	4.53 bc
LSD at 5%	0.355	0.536	0.301	0.44098	0.3598	0.40602

Table 7. Effect of soil application of nano fertilizers on total sugar and nitrate content of lettuce plants during 2017 and 2018 seasons.

Treatments	Total sugar g /100 g. d.w		Total nitrate mg/ kg d.w	
	Season 2017	Season 2018	Season 2017	Season 2018
NPK (Control)	3.1 c	3.2 cd	202. 7 a	216.3 a
0 nano N	2.1 e	2.1 e	103.7 h	91.0 j
12.5% nano N	2.6 d	3.9 a	165.9 c	136.0 de
25% nano N	3.5 b	3.1 cd	171.3 c	149.3 c
50% nano N	2.9 cd	2.6 e	181.0 b	172.7 b
0 nano P	2.2 e	2.2 f	140.3 d	115.0 h
12.5% nano P	3.4 b	3.4 bc	122.9 f	130.7 ef
25% nano P	3. 6 ab	3.4 bc	118. 7 fg	117.7 gh
50% nano P	2.7 d	3.5 b	113.3 g	125.0 fg
0 nano K	2.0 e	2.4 ef	133.3 de	100.0 i
12.5% nano K	2.7 d	3.0 cd	132. 7 e	134.7 e
25% nano K	3.6 ab	3.4 bc	135.0 de	144.3 cd
50% nano K	3.8 a	4.0 a	132. 7 e	165.0 b
LSD at 5%	0.285	0.329	8.337	8.306

Table 8. Effect of soil application of nano fertilizers on phosphorus and potassium content of lettuce plants during 2017 and 2018 seasons.

Treatments	Phosphorus mg /100 g. d.w		Potassium mg /100 g. d.w	
	Season 2017	Season 2018	Season 2017	Season 2018
NPK (Control)	0.374 d	0.395 c	3.47	2.80 cd
0 nano N	0.289 e	0.245 i	1.70 g	1.64 f
12.5% nano N	0.391 d	0.404 c	2.05 f	2.87 cd
25% nano N	0.360 d	0.332 f	1.99 f	2.48 e
50% nano N	0.318 e	0.352 e	1.89 fg	2.44 e
0 nano P	0.289 e	0.268 h	1.74 g	1.65 f
12.5% nano P	0.446 b	0.394 c	2.86 e	2.72 d
25% nano P	0.486 b	0.444 b	3.27 cd	2.94 cd
50% nano P	0.527 a	0.490 a	3.36 cd	3.20 b
0 nano K	0.283 e	0.290 g	1.77 g	1.74 f
12.5% nano K	0.385 d	0.386 cd	3.25 d	2.74 cd
25% nano K	0.379 d	0.373 d	3.67 b	2.90 cd
50% nano K	0.372 d	0.343 ef	4.13 bc	3.62 a
LSD at 5%	0.0359	0.01930	0.20082	0.22181

Table 9. Effect of soil application of nano fertilizers on total yield and total marketable yield of lettuce plants during 2017 and 2018 seasons.

Treatments	Total yield Ton/fed		Total marketable yield Ton/fed	
	Season 2017	Season 2018	Season 2017	Season 2018
NPK (Control)	14.4 e	14.9 de	11.4 e	9.9 e
0 nano N	8.4 j	7.5 h	6.9	7.2 f
12.5% nano N	13.7 f	14.5 e	11.8	10.5 e
25% nano N	15.6 d	15.8 c	13.1	11.8 d
50% nano N	20.7 a	19.0 a	18.4	16.5 a
0 nano P	9.0 i	8.6 g	7.1	6.5 f
12.5% nano P	18.9 b	18.6 a	16.8	14.6 b
25% nano P	17.7 c	17.5 b	14.5	12.4 cd
50% nano P	15.5 d	15.6 cd	14. 8	12.8 c
0 nano K	11.4 h	13.3 f	11. 6 e	10.1 e
12.5% nano K	12.3 g	15. 6 cd	14. 8 c	13.3 c
25% nano K	12.4 g	15.6 cd	14.1 c	12.8 c
50% nano K	12.4 g	15.6 c	14.9 c	12.9 c
LSD at 5%	0.570	0.770	0.997	0.943

تأثير الإضافة الأرضية لأسمدة النانوNPK على نمو وإنتاجية وجودة الخس

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الملخص العربي

أجريت هذه الدراسة خلال العروة الشتوية لموسمي 2017 و2018 لدراسة تأثير إضافة أسمدة النانو NPKإلى التربة بمعدلات (0 ,12.5 ,25 ,50 %) من التسميد التقليدي الموصى من وحدات النيتروجين والفوسفور والبوتاسيوم على النمو والمحصول وجودة الخس. أظهرت النتائج أن التسميد بالنانو نيتروجين بالمعدل 50% أدى الى زيادة معنوية في النمو الخضري مثل وزن النبات ووزن الرأس وحجم الرأس وصلابة الرأس والمحصول الكلى والمحصول القابل للتسويق. بينما أدت المعاملة بالنانو بوتاسيوم بمعدل 50% إلى الحصول على أعلى زيادة معنوية في محتوى الرؤوس من حمض الأسكوربيك والمواد الصلبة الذائبة الكلية والسكريات الكلية بينما تم تسجيل أعلى قيمة معنوية لمحتوى الأوراق من الكلوروفيل والكاروتين والمادة الجافة مع المعاملة بالنانو نيتروجين 50% أيضا، في حين سجلت أعلى قيمة معنوية لكل من محتوى الرأس من الفسفور والبوتاسيوم من المعاملة بالنانو فوسفور والنانو بوتاسيوم بتركيز 50% على التوالي. وتم تسجيل أعلى القيم لمحتوى الرؤوس من النترات مع معاملة الكنترول (السماد الكيماوى التقليدى) مقارنة بمعاملات النانو الأخرى ويمكن استنتاج أن صفات النمو الخضري جميعها زادت مع المعاملة 50% نانو نيتروجين بينما زادت صفات الجودة في الرؤوس من خلال التسميد بالنانو بوتاسيوم بمعدل 50%.

الكلمات الاسترشادية: الأسمدة النانو- نيتروجين وفسفوروبوتاسيوم – الخس – المحصول- حمض الاسكوربيك - نترات