Academic Journal of Nawroz University (AJNU), Vol.13, No.1, 2024

https://doi.org/10.25007/ajnu.v13n1a1590

Effect of Foliar Application by Nano and Non-Nano NPK Fertilizers on Growth, Yield and Quality of Two Lettuce (*Lactuca sativa* L.) Cultivars Under Plastic House Conditions

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ABSTRACT: The experiment was conducted during the fall agricultural season 2021-2022 under a plastic house at the Department of Horticulture, College of Agriculture Engineering Science university of Duhok, Kurdistan region, Iraq. The experiment was carried out in a split-split plot system using a randomized complete block design (R.C.B.D), which included 54 treatments resulting from the combination of two cultivars of lettuce, three levels of non-nano NPK, namely (0 g, 2 g, 4 g) per liter of the recommended amount, and three levels of Nano-NPK (0 g, 2 g, 4 g) per liter of the recommended amount for three replicates, to study the effect of spraying with nano and non-nano-NPK on lettuce productivity, growth, and yield of two lettuce cultivar (Fajr and Rawaa). The results showed that the Fajr cultivar was superior to the Rawaa cultivar in (head weight, total yield, marketable yield, number of leaves per plant, chlorophyll content, nitrogen percentage, phosphor percentage, and potassium percentage), The spraying with non-nano-NPK did not show any significant difference in most of all parameters. The result appeared that a significant increase in most characteristics of vegetative growth, total yield, and yield component was with the foliar application of nano-NPK at level (4 g. l^{-1}).

Keywords: *lettuce, Nano fertilizers, NPK, cultivars, foliar application.*

1. Introduction

Lettuce (*Lactuca sativa* L.) is one of the plants of the compound family Asteraceae and one of the winter vegetables crops that is grown in Iraq, and it is of high nutritional value in addition to medicinal value. Lettuce is in sequence 26 in the list of nutritional value in vegetable and fruit crops, but its consumption is relatively large quantities reaching fourth place after tomato, oranges, and potatoes in terms of consumption in America (Hassan, 2003).

Lettuce contains many healthy components such as iron, zinc, calcium, phosphorous, magnesium, manganese, potassium, and health-promoting bioactive compounds (Kim *et al*., 2016).

Due to the presence of phenolic compounds, vitamins A, C, and carotenoids, it is one of the most significant members of the Compositae family that can prevent cancer. These substances have a role in nutrition and healthcare that may improve the human body's capability to fight cell damage and decrease cancer and inflammatory diseases (Lin *et al*., 2014; Pepe *et al*., 2015).

The lettuce plant has many varieties, and each variety has its characteristics in terms of production, quantity, and quality. The local varieties and majority of foreign varieties grown in Iraq belong to the elongated head lettuce group (Cos or Romaine), and this group is one of the groups rich in its nutritional value (Ryder, 1999).

Since the lettuce plant is one of the vegetables whose leaves are eaten, so it needs a lot of fertilization. (Akram & Muhammad, 2009) concluded that foliar application of mineral nutrients (N, P, K) declines the harmful effects of NaCl in numerous crops. Fertilizers are chemical compounds applied to promote plant and fruit growth (Behera & Panda, 2009). But 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 (Mahmoud *et al*., 2017). Optimal fertilization application and use of N, P, and K have important to increase the yield and quality of agriculture crops and decreased production costs (Zandvakili *et al*., 2019), and the use of chemical fertilizers leads to health problems for humans as well as pollution of the environment. Therefore, it is necessary to resort to the use of the organic farming system.

Nowadays nanotechnology is used in agriculture and related industries (Froggett, 2009), which includes all agricultural systems that lead to the production of plant foods by environmentally perfect means. In another hand, (Tarafdar *et al*., 2012) found a significant yield increase by to foliar application of nano fertilizers, and it is much easier and superior to the soil application of nano fertilizers.

Therefore, the study aimed to produce lettuce crops early under protected cultivation, and evaluation of the performance of two varieties of lettuce to choose the best one and find the best concentration of liquid organic fertilizer (Nano-NPK) in the growth and productivity of lettuce in the Duhok Governorate.

2. Material and Methods

The experiment was conducted at the Horticulture Department, College of Agriculture Engineering Science University of Duhok, during the autumn season (2021). The experiment was laid out in a split-split plot design with the lettuce cultivars in the main plot and Non-nano-NPK fertilizer treatments in the subplots and Nano-NPK in the sub subplots.

They were arranged in a (2 * 3 * 3) factorial design (RCBD), which means the experiment consisted of three factors. Factor A- consisted of two cultivars of lettuce which are A_1= Fajr (romaine lettuce) (Germination = 96 %, purity = 99 %) and A_2= Rawaa (romaine lettuce) (Germination = 96%, purity = 99 %) B- Three levels of Non-Nano-NPK (20, 20, 20) viz. B_1= 0 g, B_2= 2 g, and B_3= 4 g per litter. C- Three levels of Nano-NPK fertilizer (20, 20, 20) viz. C_1= 0 g, C_2= 2 g, and C_3= 4 g per litter, with three replications equal (54 experimental units).

First, lettuce seeds were sown in plastic trays on 20th Sep. 2021, the planting medium was peat moss only, then after one month they moved to their permanent place (experimental site) in the plastic house on 20th Oct. 2021 with a spacing of 30 cm between them, and 60 cm between rows. Both fertilizers were applied three times as a foliar application by a backpack sprayer one month after planting the seedling in a plastic house, the second spray after one week, and the third spray a week after the second spray. Lettuce was irrigated with a drip irrigation system.

Lettuce was harvested 90 days after planting the seeds. Five lettuce plants were selected randomly from each experimental unit for recording data on the following parameters which have been taken in the physiology lab. The number of leaves plant $^{-1}$, head weight plant $^{-1}$, total yield t. ha^{-1}, marketable size t.ha^{-1}, number of leaves, Chlorophyll content, N, P, and K percentage.

The recorded data on various parameters were statistically analyzed by using SAS statistical analyses software (SAS, 2007), using a factorial analysis of variance (ANOVA, PROC MIXED), and the difference between treatment means were determined by Duncan`s Multiple Range Test (DMRT) at 5% level of probability.

3. Results

3.1 Number of leaves per plant (leaf. plant^{-1}).

Table (1) shows the effects of non-nano NPK, and nano NPK, and their interaction on the number of leaves from lettuce cultivars. Effect of the main factor which on cultivars showed that the Fajr cultivar had significant differences compared to the Rawaa cultivar. The highest mean number of leaves (65.70) Leaves per plant was observed in the Fajr cultivar while (60.85) leaves per plant is noticed in the Rawaa cultivar, whereas adding non-nano NPK had no significant effect on this parameter. The third level of nano (4 g.l^{-1}) had a significant influence on the number of leaves per plant, which gave the highest value (64.70) leaves per plant compared to the other treatment levels. In an interaction between cultivars and non-nano NPK found that the second level of non-nano (2 g.l^{-1}) was significantly affected in the Fajr cultivar, the maximum number of leaves was (66.20) leaves per plant compared to the lowest value, which was (60.60) leaves in Rawaa cultivar. Meanwhile, the third level of nano (4 g.l^{-1}) significantly affected the cultivars which gave (67.11) leaves in the interaction between cultivars and nano NPK treatments. And the third level of nano (4 g.l^{-1}) was superior in the number of leaves in a combination of nano and non-nano NPK with the second level of non-nano NPK fertilizer (2 g.l^{-1}). Finally, the table shows the interaction between all factors, the third level (4 g.l^{-1}) of nano NPK was superior for Fajer cultivar on all other levels.

Table 1: The effect of Cultivars by foliar application of non-Nano and Nano NPK, and their interactions on the number of leaves per plant of lettuce.

cultivar	Non-Nano NPK ($g.L^{-1}$)	Nano NPK ($g.L^{-1}$)			Cultivar* Non-Nano NPK	Mean effect of Cultivar
		0	2	4		
Fajr	0	64.20 cde	64.80 cd	66.40 abc	65.13 a	65.70 a
	2	65.27 bcd	66.07 abc	67.27 ab	66.20 a	
	4	64.47 cde	65.13 bcd	67.67 a	65.76 a	
Rawaa	0	59.33 h	60.80 fgh	62.27 efg	60.80 b	60.85 b
	2	60.53 gh	59.93 h	63.00 def	61.16 b	
	4	59.53 h	60.67 gh	61.60 fgh	60.60 b	
Mean effect of Nano NPK		62.22 b	62.90 b	64.70 a	Mean effect of Non-Nano NPK	
Cultivar* Nano NPK	Fajr	64.64 b	65.33 b	67.11 a		
	Rawaa	59.80 d	60.47 d	62.29 c		
Non-Nano* Nano	0	61.77 c	62.80 bc	64.33 ab	0	62.97 a
	2	62.90 bc	63.00 bc	65.13 a	2	63.68 a
	4	62.00 c	62.90 bc	64.63 a	4	63.18 a

*Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple range test at 5% level.

3.2 Chlorophyll content (SPAD):

Table (2) illustrates a superior Fajr cultivar to the Rawaa cultivar, but there were no significant differences in chlorophyll content in leaves in both cultivars. The plant treated with non-nano NPK fertilizer and nano NPK were similar. The highest chlorophyll content (42.35) was with spraying the lettuce with (2 $g.l^{-1}$) of non-nano NPK and (41.86) in treating the plant with (4 $g.l^{-1}$) of nano NPK fertilizer.

The interaction between cultivar and non-nano NPK had a significant effect on chlorophyll content, with the highest value (42.89) with the Fajr cultivar and (2 $g.l^{-1}$) of non-nano NPK, while the Rawaa cultivar got the lowest value (40.01) with (0 $g.l^{-1}$) of non-nano NPK fertilizer. The third level of nano NPK (4 $g.l^{-1}$) Fajr cultivar got (42.51) which is superior to other levels of all treatments, the lowest value obtained with Rawaa cultivar with control treatment [spraying with (0 $g.l^{-1}$) of nano (water)] in the interaction between cultivar and nano NPK. In combination with nano and non-nano NPK, (2 $g.l^{-1}$) got the highest value (44.06), and the lowest value was (40.41) with (0 $g.l^{-1}$) of non-nano and (2 $g.l^{-1}$) of nano NPK fertilizer.

The interaction among three experimental factors resulted that the second level of non-nano NPK and the second level of nano NPK significantly affected the chlorophyll content.

Table 2: The effect of Cultivars by foliar application of non-Nano and Nano NPK, and their interactions on chlorophyll content (SPAD) of lettuce.

cultivar	Non-Nano NPK ($g.L^{-1}$)	Nano NPK ($g.L^{-1}$)			Cultivar* Non-Nano NPK	Mean effect of Cultivar
		0	2	4		
Fajr	0	41.89 a-e	41.18 b-e	42.93 abc	42.00 ab	42.23 a
	2	42.53 a-d	43.62 ab	42.51 a-d	42.89 a	
	4	41.03 b-e	42.33 a-e	42.07 a-e	41.81 ab	
Rawaa	0	39.87 dce	39.63 de	40.51 b-e	40.01 b	40.73 a
	2	39.42 de	44.49 a	41.55 a-e	41.82 ab	
	4	40.35 dce	39.18 e	41.57 a-e	40.37 ab	
Mean effect of Nano NPK		40.85 a	41.74 a	41.86 a	Mean effect of Non-Nano NPK	
Cultivar* Nano NPK	Fajr	41.82 a	42.38 a	42.51 a		
	Rawaa	39.88 b	41.11 ab	41.21 ab		
Non-Nano* Nano	0	40.88 b	40.41 b	41.72 b	0	41.00 a
	2	40.97 b	44.06 a	42.03 b	2	42.35 a
	4	40.69 b	40.75 b	41.82 b	4	41.09 a

*Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple range test at 5% level.

3.3 Nitrogen percentage (%)

The data presented in the Table (3) revealed that the two cultivars had no significant effect on nitrogen percentage in the plant, but the Fajr cultivar was overcome at a rate of (1.776) % compared to the Rawaa cultivar which obtained (1.727) %. The binary interaction between cultivars and non-nano NPK showed increasing in nitrogen percentage in lettuce where the highest value was recorded in the Fajr cultivar and the third level of non-nano NPK which obtained (1.896) % compared to the other treatments. Also, the interaction between cultivar and nano NPK fertilizer showed no significant effect. The interaction between non-nano NPK and nano NPK showed that the superior of third level (4 $g.l^{-1}$) of non-nano and nano NPK which gave (1.913) % compared to other treatments, whereas the triple interaction significantly increased the nitrogen percentage in the Fajr cultivar at the level of (4 $g.l^{-1}$) of non-nano NPK on all other treatment, the highest value was recorded in Fajr cultivar 2.165% at level (4 $g.l^{-1}$) of non-nano and nano NPK

fertilizers.

Table 3: The effect of Cultivars by foliar application of non-Nano and Nano NPK, and their interactions on nitrogen percentage of lettuce.

Cultivar	Non-Nano NPK ($g.L^{-1}$)	Nano NPK ($g.L^{-1}$)			Cultivar* Non-Nano NPK	Mean effect of Cultivar
		0	2	4		
Fajr	0	1.784 ab	1.910 ab	1.710 ab	1.801 a	1.776 a
	2	1.848 ab	1.605 ab	1.443 b	1.632 a	
	4	1.721 ab	1.802 ab	2.165 a	1.896 a	
Rawaa	0	1.904 ab	1.587 ab	1.587 ab	1.693 a	1.727 a
	2	1.923 ab	1.729 ab	1.667 ab	1.773 a	
	4	1.582 ab	1.904 ab	1.661 ab	1.716 a	
Mean effect of Nano NPK		1.794 a	1.756 a	1.705 a	Mean effect of Non-Nano NPK	
Cultivar* Nano NPK	Fajr	1.784 a	1.773 a	1.773 a		
	Rawaa	1.803 a	1.740 a	1.638 a		
Non-Nano* Nano	0	1.844 a	1.748 a	1.648 a	0	1.747 a
	2	1.885 a	1.667 a	1.555 a	2	1.702 a
	4	1.651 a	1.853 a	1.913 a	4	1.806 a

*Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple range test at 5% level.

3.4 Phosphorous percentage (%)

The data presented in Table 4 revealed that the two cultivars had no significant effect on Phosphorous percentage in the plant, but the Fajr cv. was overcome at a rate of (0.316) % compared to the Rawaa cv. which obtained (0.305) %. Also, non-nano NPK and nano NPK factors resulted in no significant differences in this parameter, where the maximum value was got at the level (4 $g.l^{-1}$) of non-nano which achieved (0.327) % compared to the minimum value of (0.299) % in (2 $g.l^{-1}$) of non-nano NPK. But the second level of nano NPK got the higher percentage at (0.319) %. The binary interaction between cultivars and non-nano NPK showed increasing in phosphorous percentage in lettuce where the highest value was recorded in the Fajr cv. and the third level of non-nano NPK which obtained

(0.331) % compared to the other treatments. Also, the interaction between cultivar and nano NPK fertilizer led to a positive increase in phosphorous percentage in the Fajr cv. at the third level of (0.358) % of nano NPK. The interaction between non-nano NPK and nano NPK showed that the superior third level (4 $g.l^{-1}$) of non-nano and nano NPK which gave (0.362) % compared to other treatments, whereas the triple interaction showed overcoming the level of (4 $g.l^{-1}$) of non-nano NPK and nano NPK in the Fajr cv. at on all other treatment, the highest value was recorded in Fajr cv. (0.373)% at level (4 $g.l^{-1}$) of non-nano and nano NPK fertilizers.

Table 4: The effect of Cultivars by foliar application of non-Nano and Nano NPK, and their interactions on the phosphorus percentage of lettuce.

cultivar	Non-Nano NPK ($g.L^{-1}$)	Nano NPK ($g.L^{-1}$)			Cultivar* Non-Nano NPK	Mean effect of Cultivar
		0	2	4		
Fajr	0	0.231 a	0.363 a	0.386 a	0.327 a	0.316 a
	2	0.301 a	0.256 a	0.315 a	0.291 a	
	4	0.292 a	0.330 a	0.373 a	0.331 a	
Rawaa	0	0.346 a	0.303 a	0.200 a	0.283 a	0.305 a
	2	0.356 a	0.316 a	0.253 a	0.308 a	
	4	0.273 a	0.345 a	0.351 a	0.323 a	
Mean effect of Nano NPK		0.300 a	0.319 a	0.313 a	Mean effect of Non-Nano NPK	
Cultivar* Nano NPK	Fajr	0.275 a	0.316 a	0.358 a		
	Rawaa	0.325 a	0.321 a	0.268 a		
Non-Nano* Nano	0	0.289 a	0.333 a	0.293 a	0	0.305 a
	2	0.329 a	0.286 a	0.284 a	2	0.299 a
	4	0.283 a	0.337 a	0.362 a	4	0.327 a

*Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple range test at 5% level.

3.5 Potassium percentage (%)

As shown in Table (5) , the Percentage of potassium in Fajr cultivar was higher than Rawaa cultivar was without any significant difference in potassium percentage. Also for spraying with non-nano NPK and nano NPK there were

no differences in potassium percentage in leaves. The interaction between cultivar and non-nano NPK showed no significant effect on potassium. About the binary interaction of (cultivar and nano NPK, non-nano and nano NPK) it was clear that no significant difference among them, noticing the superior third level (4 g.l^{-1}) of nano NPK.

Triple interaction among the three factors resulted in overcoming Fajr cv. with spraying nano and non-nano NPK at level (4 g.l^{-1}) of both fertilizers which recorded (5.181) %.

Table 5: The effect of Cultivars by foliar application of non-Nano and Nano NPK, and their interactions on potassium percentage of lettuce.

cultivar	Non-Nano NPK (g.L^{-1})	Nano NPK (g.L^{-1})			Cultivar* Non-Nano NPK	Mean effect of Cultivar
		0	2	4		
Fajr	0	4.674 a	4.307 a	4.789 a	4.590 a	4.774 a
	2	4.733 a	4.640 a	5.067 a	4.813 a	
	4	4.702 a	4.876 a	5.181 a	4.920 a	
Rawaa	0	4.918 a	4.957 a	4.916 a	4.930 a	4.710 a
	2	4.872 a	4.855 a	4.705 a	4.811 a	
	4	4.687 a	3.885 a	4.594 a	4.389 a	
Mean effect of Nano NPK		4.764 a	4.587 a	4.875 a	Mean effect of Non-Nano NPK	
Cultivar* Nano NPK	Fajr	4.703 a	4.608 a	5.012 a		
	Rawaa	4.826 a	4.566 a	4.739 a		
Non-Nano* Nano	0	4.796 a	4.632 a	4.853 a	0	4.760 a
	2	4.803 a	4.748 a	4.886 a	2	4.812 a
	4	4.694 a	4.381 a	4.887 a	4	4.654 a

*Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple range test at 5% level.

3.6 Head fresh weight (kg. plant^{-1}):

Results in table (6) indicate the effect of cultivars, non-nano NPK, and nano-NPK on head weight, a significant variance was observed between cultivars, Fajr provided (1.060) kg compared with Rawaa (0.988) kg. Regarding the influence of non-nano NPK, no significant differences among all foliar doses used in the study was observed. About the impact of nano NPK on a head weight, there was a significant change in head weight, in the level of (4 g.l^{-1}) provided (1.047) kg compared with zero rates of nano-NPK (1.010) kg. The collaboration between cultivar and non-

nano-NPK had significant differences, with the highest value recorded at (1.066 kg, 1.059 kg, and 1.054 kg) by the Fajr cv. at levels (4 $g.l^{-1}$, 2 $g.l^{-1}$, 0 $g.l^{-1}$) respectively, while the lowest value of head weight was noted with Rawaa cv. (0.991 kg). Concerning the interaction between cultivar and nano-NPK, the highest value (1.078) at level (4 $g.l^{-1}$).

The interaction between non-nano-NPK and nano-NPK showed (1.057 kg) at (4 $g.l^{-1}$) of nano fertilizer and (2 $g.l^{-1}$) of non-nano NPK as a higher value and the lowest value was (1.001 kg) at (0 $g.1^{-1}$). Regarding the effect of the triple interaction among three factors, the Fajr cv. and level (4 $g.l^{-1}$) of non-nano and nano NPK got the highest head weight (1.081 kg) as compared with the lowest head weight (0.956 kg) which was recorded from Rawaa cultivar at level (0 $g.l^{-1}$) of nano and (2 $g.l^{-1}$) of non-nano NPK.

Table 6: The effect of Cultivars by foliar application of non-Nano and Nano NPK, and their interactions on head weight (Kg) of lettuce.

cultivar	Non-Nano NPK ($g.L^{-1}$)	Nano NPK ($g.L^{-1}$)			Cultivar* Non-Nano NPK	Mean effect of Cultivar
		0	2	4		
Fajr	0	1.041 abc	1.042 abc	1.080 a	1.054 a	1.060 a
	2	1.046 abc	1.058 ab	1.074 a	1.059 a	
	4	1.056 ab	1.063 ab	1.081 a	1.066 a	
Rawaa	0	0.991 cde	0.990 cde	0.992 cde	0.991 b	0.988 b
	2	0.956 e	0.959 de	1.040 abc	0.985 b	
	4	0.970 de	0.973 de	1.016 bcd	0.986 b	
Mean effect of Nano NPK		1.010 b	1.014 b	1.047 a	Mean effect of Non-Nano NPK	
Cultivar* Nano NPK	Fajr	1.047 bc	1.054 ab	1.078 a		
	Rawaa	0.972 d	0.974 d	1.016 c		
Non-Nano* Nano	0	1.016 bc	1.016 bc	1.036 abc	0	1.023 a
	2	1.001 c	1.008 bc	1.057 a	2	1.022 a
	4	1.013 bc	1.018 bc	1.048 ab	4	1.026 a

*Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple range test at 5% level.

3.7 Marketable yield (ton. ha^{-1})

Results presented in Table (7) reported that marketable yield was significantly influenced by cultivar. Fajr cv. gave higher results (3.583) $t.ha^{-1}$ in comparison to the Rawaa cv. (3.518) $t.ha^{-1}$. Non-nano NPK had no significant effect on the marketable yield of two lettuce, while spraying of nano NPK positively influenced and increased the marketable yield to a high value (3.505) $t.ha^{-1}$ at level (4 $g.l^{-1}$) of nano NPK. The interaction between cultivar and non-nano NPK significantly improved marketable yield and the best value was recorded from the Fajr cv. and (2 $g.l^{-1}$) of non-nano NPK which was (3.636) $t.ha^{-1}$. The interaction between cultivar and nano NPK was superior in the Fajr cultivar and (4 $g.l^{-1}$) of nano at (3.657) $t.ha^{-1}$. Also, the interaction between non-nano and nano NPK positively

increased marketable yield, and the highest value was from (4 g.l^{-1}) of non-nano and third level (4 g.l^{-1}) of nano NPK which resulted in (3.547) t.ha^{-1}.

Regarding the triple interaction among the factors, there were a significant increase among them and the highest results were obtained from the Fajr cv. plus (4 g.l^{-1}) of non-nano plus (4 g.l^{-1}) of nano NPK which got (3.683) t.ha^{-1} as compared to other treatments.

Table 7: The effect of Cultivars by foliar application of non-Nano and Nano NPK, and their interactions on marketable yield (t. ha^{-1}) of lettuce.

cultivar	Non-Nano NPK (g.L^{-1})	Nano NPK (g.L^{-1})			Cultivar* Non-Nano NPK	Mean effect of Cultivar
		0	2	4		
Fajr	0	3.503 b-e	3.574 abc	3.618 ab	3.565 a	3.583 a
	2	3.608 ab	3.631 ab	3.669 ab	3.636 a	
	4	3.428 cde	3.527 a-d	3.683 a	3.546 a	
Rawaa	0	3.352 def	3.382 def	3.400 c-f	3.378 b	3.318 b
	2	3.394 ef	3.083 g	3.248 c-f	3.242 c	
	4	3.240 fg	3.352 def	3.411 c-f	3.334 bc	
Mean effect of Nano NPK		3.421 b	3.425 b	3.505 a	Mean effect of Non-Nano NPK	
Cultivar* Nano NPK	Fajr	3.513 b	3.578 ab	3.657 a		
	Rawaa	3.329 d	3.272 d	3.357 c		
Non-Nano* Nano	0	3.428 abc	3.478 ab	3.509 a	0	3.472 a
	2	3.501 ab	3.357 bc	3.459 a	2	3.439 a
	4	3.334 c	3.440 abc	3.547 a	4	3.440 a

*Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple range test at 5% level.

3.8 Plant total yield (t.ha^{-1})

Data presented in table (8) indicated that there were significant differences between the two cultivars on total yield (t.ha^{-1}) when the best mean value was got in the Fajr cv. (51.82) t.ha^{-1} compared to the Rawaa cultivar (48.28) t.ha^{-1}, but non-nano NPK showed no significant effect on total yield while spraying with nano NPK significantly influenced on plant total yield, the third level (4 g.l^{-1}) gave the highest result (51.20) t.ha^{-1}, when comparing to other treatments. Interaction between cultivar and non-nano NPK showed a difference among them, where the superior

interaction was recorded in Fajr cv. and at level (4,2,0) $g.l^{-1}$ of non-nano NPK which were (52.14, 51.78, 51.54) $t.ha^{-1}$ respectively. Also, the interaction between cultivar and nano NPK recorded significant influences on plant yield. The amount (4 $g.l^{-1}$) of Nano NPK in the Fajr cv. had the highest value (52.71) t. ha^{-1}, followed by (2 $g.l^{-1}$, and 0 $g.l^{-1}$), which were (51.55, 51.21) $t.ha^{-1}$, respectively compared to Rawaa cv. On the other hand, the interaction between non-nano and nano NPK resulted in a significant effect between them, where the maximum value was measured in the interaction between (2 $g.l^{-1}$) of non-nano plus (4 $g.l^{-1}$) of nano NPK which gave (51.69) $t.ha^{-1}$. The triple interaction, results revealed that there were significant differences among all factors in plant yield. Indicating that the Fajr cv. treated with (4 $g.l^{-1}$) of nano NPK and (4 $g.l^{-1}$) of non-nano NPK improved total yield to the highest value of (52.87) $t.ha^{-1}$, followed by (4 $g.l^{-1}$) of nano NPK and (0 $g.l^{-1}$) of nano NPK which was (52.78) $t.ha^{-1}$ as compared to other interaction.

Table 8: The effect of Cultivars by foliar application of non-Nano and Nano NPK, and their interactions on total yield **(**t. ha^{-1}**)** of lettuce.

cultivar	**Non-Nano NPK ($g.L^{-1}$)**	**Nano NPK ($g.L^{-1}$)**			**Cultivar* Non-Nano NPK**	**Mean effect of Cultivar**
		0	**2**	**4**		
Fajr	0	50.90 abc	50.95 abc	52.78 ab	51.54 a	51.82 a
	2	51.12 abc	51.70 ab	52.52 ab	51.78 a	
	4	51.61 ab	51.98 ab	52.87 a	52.14 a	
Rawaa	0	48.46 cde	48.42 cde	48.50 cde	48.46 b	48.28 b
	2	46.75 c	46.89 de	50.87 abc	48.17 b	
	4	47.41 de	47.56 de	49.69 bcd	48.22 b	
Mean effect of Nano NPK		49.37 b	49.59 b	51.20 a	Mean effect of Non-Nano NPK	
Cultivar* Nano NPK	Fajr	51.21 a	51.55 a	52.71 a		
	Rawaa	47.54 c	47.63 c	49.68 b		
Non-Nano* Nano	0	49.68 bc	49.69 bc	50.64 abc	0	50.00 a
	2	48.94 c	49.30 bc	51.69 a	2	49.98 a
	4	49.51 bc	49.77 abc	51.26 ab	4	50.18 a

3. Discussion

Lettuce has many cultivars around the world, in this experiment Fajr cultivar was superior to the Rawaa cultivar significantly in most all studied parameters. This trend agreed with (Al-Obydy, 2014), who stated that the

superior Fajr cultivar significantly compared to the local cultivar and Marul cultivar in most studied characters. This could be due to that the cultivars have different potential for growth and productivity and the sensitivity of genes, morphological properties, and physiological factors during the crop's growth phase are responsible for this diversification, which primarily depends on physiological processes regulated by the interaction of genetic and environmental variance (Olaniyi *et al*., 2010).

Foliar applications of 4 $g.l^{-1}$ nano NPK gave a high value compared to other treatment levels and a significant increase in the number of leaves per plant (table 1), head weight (table 6), and marketable yields (table 7) total yield (table 8). The enhancement influence of nano-fertilizers on these studied parameters could be referred to as the fact that it has a surface dimension ranging from 30 to 40 nm, slowly release them at the best time to deal with crop demand. Also, could be because of their minute size, the nanoparticles can easily penetrate the stomata as mentioned in (Eichert *et al*., 2008; Pérez-de-Luque, 2017). The result of this research is similar to outcomes of (Merghany *et al*., 2019) who studied the effect of nano-fertilizer on cucumber, demonstrated that, in comparison to the control treatment, the cucumbers' growth and yield were greatly improved by the nano fertilizer treatments. All nano fertilizer treatments increased plant height, number of leaves per plant, yield, and NPK% in leaves. It also agreed with (Shang *et al*., 2019) that nano fertilizer improves crop growth, productivity, and yield. This encouragement effect of nano fertilizer could also be due to increasing the absorption rates and the photosynthetic rates, which lead to an increase in the most vegetative parameters and increased the yield of lettuce (Saleh *et al*., 2010). Also (Hosseny & Ahmed, 2009) resulted that head weight and yield of lettuce depend on the amount of nitrogen available for the crop. Phosphorus is regarded as an important macronutrient plant involved in several plant functions, including controlling enzyme reactions, energy transfer, regulation of metabolic pathways, Photosynthesis, and transformation of carbohydrates as well as the synthesis of protein leading to increases in vegetative growth parameters (Marschner, 1995). Potassium has an important role in protein formation. It has also a main role in regulating cellular turgid pressure to avoid wilting, which in turn controls the stomata opening and hence greatly enhanced drought tolerance (Murphy *et al*., 2005), which increased these three minerals in the case of nano NPK treatment. The presence of nano-NPK, fertilizers appeared to encourage the uptake and use efficiency of nutrients by the plant (Abdel-Aziz *et al*., 2016), that's why caused to increase in the yield.

4. Conclusion and Recommendation

The Nano technique in a foliar spray of NPK proved extremely efficient in increasing the growth parameter of lettuce. A foliar spray using nano-NPK fertilizer proved more effective than a foliar spray with ordinary NPK fertilizer. The current study's findings showed that the vegetative growth, chemical composition, and yield components of lettuce plants responded better to foliar applications of (4 $g.l^{-1}$) nano NPK with the Fajr cultivar.

According to the previous conclusions, planting the Fajr cultivar recommend which is the best choice for increasing lettuce under the plastic house, also practicing another level of NPK concentration as a foliar application to improve the yield, as well as using nano NPK instead of traditional NPK. Conducting more research about the effect of other cultivars to improve the vegetative growth and yield of lettuce under Kurdistan region conditions.

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