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Effect of Poultry Manure and Plant Density on The growth and Productivity of Lettuce Plant

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Abstract:
Two field experiments were conducted during the 2017/2018 winter seasons in the Qandula region in the Al-Jabel Al-Akhdar, south of the city of Al-Bayda - Libya. In order to study the effect of adding four levels of poultry manure fertilizer (0, 10, 20, 30 tons/ hectare), on the growth and productivity of the lettuce plant and cultivated with two cultivation distances (20×60 cm) and (40×60 cm) between the other plant along the line and the distance between the lines is 60 cm. The two experiments were designed on the basis of a split-plot system, using a complete randomized block design with three replications.
The results showed that the poultry manure and the planting distance had a significant effect on the vegetative and yield characteristics of the lettuce plant, as the gradual increase in the levels of poultry manure and the planting distance (40×60 cm) led to significant differences for all the studied characteristics, as the average was given the fertilizer 30 tons / ha and (40×60 cm) the highest significant values of vegetative and yield characteristics compared to control treatment. Nevertheless, the high plant density (20×60) had a significant superiority in crop characteristics such as total head yield, fresh total yield and dry total yield (ton / ha).
The results also showed that the increase in poultry manure levels led to an increase in the values of vegetative and yield characteristics of the lettuce plant with an increase in the number of plants per unit area. The results showed that the increase in poultry manure levels was accompanied by an increase in the fresh head weight of the lettuce plant with a global treatment of 30 tons of organic fertilizer + (40x60 cm). The results of the interaction effect on the characteristics of the total yield of heads, fresh total yield and dry total yield also showed that the increase in plant density under any level of poultry manure was accompanied by a significant increase.

Key words: *Lactuca sativa L., lettuce, plant density, poultry manure, organic fertilizer.*

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I. Introduction

Lettuce is one of the most important vegetable crops of the *Asteraceae* family and is scientifically known is *Lactuca sativa* L., and there is a wide range of morphological differences between the cultivated lettuce types. Lettuce is grown for its leaves, which are eaten fresh, and lettuce is one of the most important salad crops on the global level, in terms of the area cultivated from it. According to studies conducted by Steven (1974) in America, where lettuce ranked twenty- sixth in terms of nutritional value between vegetable and fruit crops. The cultivated area in 2019 of lettuce was about 1316028 hectares, with an average productivity per hectare of 21.138 tons, according to the estimates of the World Food and Agriculture Organization (FAO, 2021).

Given that the excessive use of mineral nitrogen fertilizers increases production costs, in addition to pollution of the agricultural environment (Fishar and Riehter, 1984), losing about 50% of the mineral nitrogen fertilizers added to the soil, and the plants do not benefit from them (Hassouna, *et al*., 1995). As a result, other fertilizer alternatives must be used that are safer and less expensive, and hence the need to use organic fertilizers as partial substitutes for mineral fertilizers, as organic fertilizers of all kinds and forms are an important source of organic matter in the soil, which is a direct or indirect source, For many of the nutrients needed by plants, in addition to improving the overall physical and chemical properties of the soil (El-Gala, 2002, and Audi, 2002). In order to maintain an adequate level of organic matter in the soil, various additions of plant and animal wastes or a mixture of these materials are required (Rivero, *et al*., 2004). The use of organic fertilizers serves as an additional stock of nitrogen, phosphorous, potassium, and trace elements. In addition to its role in improving the physical and chemical properties of the soil and its role in facilitating many nutrients in the soil for the plant (Ranijan, *et al*., 2007)), and the organic fertilizers used are poultry manure, which is characterized by its high

content of nutrients. (Hirzel, *et al*., 2007) indicated that poultry manure is the richest in its nitrogen content, compared to other organic fertilizers. This may be due to the fact that poultry feed contains a high percentage of nitrogen, and poultry manure is used for most agricultural crops, due to its high nitrogen content and some other nutrients.

Plant density is also considered one of the most important factors affecting the economics of both agricultural soil use and production, especially in countries that suffer from a shortage of arable soil, as agriculture with the optimum plant density and achieving the highest productivity increases the efficiency of agricultural soil use. Reirers and Riggs (1997) also mentioned that increasing the number of plants per unit area with keen interest in feeding with nitrogen and choosing the appropriate variety are factors that increase the yield resulting from the unit area in agricultural lands, which in turn leads to the economy of land, workers, fertilizers and agricultural machinery costs As confirmed by many researchers, on the effect of the agricultural density of lettuce on both the vegetative and chemical characteristics of the lettuce plant (Abu-Rayyan, *etal* ., 2004).

This research aims to determine the optimum rate of poultry manure that achieves the highest yield of lettuce. And determining the plant density used under the conditions of Al Jabal Al Akhdar region in Libya that achieve the highest productivity of the lettuce plant and increase the efficiency of using available agricultural lands by increasing the production per unit area and the effect of the interaction between them on the lettuce crop.

II. Material And Methods

Before starting the field experiments, several representative soil samples were taken from the experiment site with a depth of (20 cm) to identify the natural and chemical characteristics of the soil at the site of the experiment, according to the method explained by (Black, 1965) and some natural characteristics, as shown in Table No. (1).

Table (1): The chemical and physical analyzes of the experimental site of study

Measurements		**Planting site in the first season**	**Planting site in the second season**
Particle Size distribution	**Sand (%)**	15.25	14.25
	Silt (%)	53.60	51.15
	Clay (%)	31.15	34.60
Organic Matter (%)		2.45	2.30
E.C Mmhos/ cm		1.30	1.36
Total Nitrogen (%)		0.23	0.21
Soil pH		7.96	7.87
CO_3^{--}%		1.26	1.35
P ppm		118	115

The effect of four levels of poultry manure as a source of organic matter was studied, in addition of the treatment control (0, 10, 20, 30 tons/ ha). These quantities were added, according to the calculated rates per hectare, in trenches with a depth of (15-20 cm) before planting, the quantities of organic fertilizer before planting according to each level of study for organic fertilizer. Random samples of poultry manure were taken during the two seasons of the study, and some physical and chemical analyzes were performed on them, as shown in Table (2).

Table (2): Analysis of poultry manure (based on dry weight) used in the two seasons of the study.

The contents of poultry manure	The first season	The second season
pH	7.15	7.30
Electrical conduction (EC) dS / m-1	4.2	4.3
Organic matter	68%	70%

Total nitrogen	3.65%	3.745%
Total phosphorous	1.55%	1.32%
Total potassium	1.09%	71.0%

The experiment was carried out using the tested levels of poultry manure (0, 10, 20, 30 tons/ ha), and the seedlings of lettuce were planted with maintaining distance row to row 60 cm and plant to plant 20 cm and 40 cm.

This study was designed using the split-plot system with complete randomized block design (CRBD) with three replicates.

In addition, all the agricultural operations recommended and followed in the agricultural production of lettuce plants were carried out. All experimental units were fertilized with mono calcium superphosphate (15.5% P_2O_5) and potassium sulfate (48% K_2O) at a rate of 400 and 250 kg per hectare, respectively, and mono superphosphate fertilizer was added A week before planting during soil preparation, potassium sulfate was added in two equal batches, the first with superphosphate fertilizer before planting, while the second batch was 10 days after planting. The drip irrigation system was followed in this study. Also, a program of prevention of insect and disease pests was implemented according to the recommendations in the commercial production of lettuce crop.

Data collection:
Three plants were selected randomly from each of the unit plot for the collection of the following parameters

A. Vegetative measurements:
1- Number of unwrapped leaves (leaf/ plant): The average number of unwrapped leaves was calculated in the three plants.
2- Plant height (cm / plant): The height of plant was recorded by a ruler in centimeter, the height was measured from the attachment of the ground level up to the tip of the growing point.
3- Plant fresh and dry weights (g / plant) : The average fresh weight of the leaves and the head was calculated in a sample of the plants, and then the samples were taken for drying in order to calculate the dry weight for each of them.
4- Fresh weight of unwrapped leaves (g): The average weight of unwrapped leaves for a whole plant were calculated.

B. Total yield and crop components in lettuce measurements:
1 - Head weight (g/ plant): The average head weight was calculated after excluding leaves that were unwrapped.
2 – Total fresh yield (ton/ hectare): The total yield was calculated on the basis of the total fresh weight of the plants that were harvested from each experimental unit from the three replicates, and mathematically converted into (tons/ hectare).
3 - Total dry yield (ton/ hectare): the fresh total plant yield were placed in oven and dried at $70C^o$ until the weight was stable, and given the dry weight of the sample were calculated mathematically and converted into (tones/ ha).
Statistical analysis:
Statistical analysis Statistical analysis of each characteristic under study was performed in the two seasons of cultivation, as described by Snedecor and Cochran (1980). The averages were separated using the lowest significant difference LSD under the 5% level of significance.

III. Result and Discussion

Characteristics of vegetative growth:
The effect of poultry manure:

The results obtained during the two years of the study and shown in Tables (3) that there is a significant response to all measurements of the vegetative characteristics recorded in this study, as the study showed that a gradual increase in the added rates of organic fertilizer from 0 tons/ ha to 30 tons/ h of poultry manure was met by a significant increase in both the fresh and dry weight of the plant, as well as the dry weight of the unwrapped leaves and the plant height of lettuce plants during the two seasons of the study, where the highest values obtained from the studied traits were when fertilizing plants at a rate of 30 tons / ha compared to the rest of the treatments under studying. These positive effects of poultry manure may be attributed to the effective role of organic fertilizer in activating the vegetative growth of the plant, as the organic fertilizer improves the natural

and chemical properties of the soil, which creates suitable conditions for the growth and spread of the root system, which in turn increases its absorption efficiency of the nutrients from the soil, which is positively reflected in the increase vegetative growth and thus increase the efficiency of photosynthesis (Choe et al., 1989: Nazaryuk 1991: Ahmed 1993). The results of the present study agree with what was found by (Mohamed 2010) in his study on the lettuce plant and the results of this study also, agree with the results of (Brito, 2001). Similarly, Haan (1977) obtained an increase in the vegetative characteristics of the growth of lettuce plants fertilized with organic sources.

Table (3): The main effects of poultry manure on the vegetative growth characteristics of lettuce plants.

Poultry manure treatment (ton/h)	Fresh plant weight (g)	Fresh weight of unwrapped leaves (g)	Plant height (cm)	Number of unwrapped leaves / plant	Dry weight (g)
The first season					
0	595.5D*	119.667 B	14.80 D	13.22 D	12.97D
10	630.46	120.125 B	15.36 C	13.85 C	1.37C
20	672.38B	146.708 A	15.95 B	14.37 B	23.66B
30	712.21	151.958 A	16.44 A	14.85 A	35.46A
The second season					
0	548.29C	153.116D	15.45D	14.05D	14.36D
10	553.75C	159.66C	16.258C	14.45C	16.55C
20	569.12B	165.04 B	16.8 B	14.975 B	23.96B
30	580.70 A	171.91 A	17.3 A	15.6 A	30.89A

* The values followed by the same alphabetical letter (or letters), within each group are averages for each attribute, not significantly different between them according to the test of the lowest mean difference of the rate at the level of significance 0.05.

The effect of plant density:

The averages that reflect the main effects of the tested plant density on the vegetative characteristics of the lettuce plant in the two years of the study are recorded in Table (4). The results indicated that the increase in the planting distance between the plants was matched by a significant and gradual increase in all the vegetative characteristics under study represented in the fresh and dry weight of the plant. And the fresh weight of the unwrapped leaves, the number and the height of the plant, and that the highest values of the mentioned vegetative growth characteristics were obtained from plants grown with less plant density (40 x 60 cm). These values exceeded those obtained from plants grown with more plant density (40 x 60 cm). cm). These positive effects of plant density on the tested vegetative growth characteristics were attributed to the increase in the available area of soil for plant growth by reducing the density of plants per unit area (40x60 cm), as it led to a reduction in competition between plants for the available resources of nutrients, Light and water, and other factors affecting growth, which in turn positively affect vegetative growth in general. Also, the plants grown at a lower plant density, their roots spread in a larger area of the soil, and consequently their leaves are more exposed to light, which increases their representative efficiency and thus increases their production of dry matter. The results of the present study agree with what was found by (Abu-Rayyan, *et al*. 2004: Tahsin, 2010) that low plant density has a positive effect on the vegetative characteristics and the vegetative growth characteristics of lettuce plants.

Table (4): Main effects of plant density on the vegetative characteristics of plant lettuce

Plant density treatments (cm)	Fresh plant weight (g)	Fresh weight of unwrapped leaves (g)	Plant height (cm)	Number of unwrapped leaves / plant	Dry weight (g)
The first season					
20×60	634.58B*	131.188B	15.51B	14.94B	21.04B
40×60	669A	138.041A	15.77A	14.21A	22.19A
The second season					
20×60	560.81 B	160.75 B	16.320 B	14.620 B	21.35B
40×60	565.12 A	164.14 A	16.583 A	14.917 A	21.53A

* The values followed by the same alphabetical letter (or letters), within each group are averages for each attribute, not significantly different between them according to the test of the lowest mean difference of the rate at the level of significance 0.05.

The effect of the interaction between poultry manure and planting distances on the vegetative growth characteristics of lettuce plants.

The results in Table (5) show the effect of the interaction between poultry manure and plant density on the vegetative characteristics of lettuce plants, which showed that there are significant effects of the interaction between levels of poultry manure and plant density on most vegetative characteristics of lettuce plants during

the two seasons of cultivation. Where the results showed that the gradual increase in the levels of poultry manure residues (0, 10, 20 and 30 tons / ha) was accompanied by an increase in the values of the vegetative characteristics of the lettuce plant during the two seasons of cultivation with the increase in the number of plants per unit area and the reduction of plant density (reducing the planting distance from 40x60 cm to 20 x 60 cm) where the highest significant values were recorded in the two seasons of cultivation for the vegetative characteristics, fresh and dry weight of the plant, weight of unwrapped leaves, number and plant height were recorded with the level of poultry manure 30 tons/ ha and the reduction of plant density per unit area with a treatment (40x 60 cm), compared to the rest of the tested treatments.

The results of the current study, and in this aspect related to the effect of the interaction between poultry manure and plant density, agree with many studies, which confirmed that increasing organic fertilizer and reducing plant density led to a significant increase in the overall vegetative characteristics of lettuce plants. AL-Bayati, *et al.,* (2019) obtained similar results to the results of this study on lettuce plants, where it was found that the interaction between organic fertilizer and planting distances was very significant on all vegetative characteristics of lettuce plants. It also agrees with the results also with what they found by Islam, *et al.,* (2016) on cabbage plants, obtained the highest values of vegetative characteristics represented in the number of roots, plant height, thickness and head diameter when reducing the plant density per unit area overlapping with a specific system of organic and mineral fertilizers (2/3 organic fertilizer +1/3 mineral fertilizer), as it significantly outperformed the rest of the treatments.

Table (5): The effect of the interaction between poultry manure and plant density on vegetative growth characteristics:

Treatments		Fresh plant weight (g)	Fresh weight of unwrapped leaves (g)	Plant height (cm)	Number of unwrapped leaves / plant	Dry weight (g)
Poultry manure (ton/ha)	Plant density (cm)					
The first season						
0	20×60	567.25e*	114.25c	14.58 e	13.09h	12.42g
	40×60	617.75d	125.08c	15.03d	13.34g	13.52f
10	20×60	624.91d	122.83e	15.16d	13.73f	14.24e
	40×60	636cd	117.41c	15.55c	13.97e	14.50e
20	20×60	655.25c	148.66 b	15.94b	14.2d	23.06d
	40×60	689.5b	144.75b	15.95b	14.53c	24.27c
30	20×60	691.66 b	139b	16.35a	14.72b	34.44b
	40×60	732.75a	164.91a	16.53a	14.97a	36.49a
The second season						
0	20×60	548.41 e	152.08h	15.36 g	13.88 h	14.36e
	40×60	548.41e	154.25g	15.53 g	14.21 g	14.36e
10	20×60	552.08 de	157.75f	16.06f	14.35f	16.50d
	40×60	555.41d	161.58e	16.45e	14.55e	16.60d
20	20×60	563.75c	163.33d	16.66d	14.8d	23.73c
	40×60	574.5b	166.75c	16.93c	15.15c	24.18d
30	20×60	579ab	169.83b	17.18b	15.45b	30.80a
	40×60	582a	174a	17.41a	15.75a	30.98a

* The values followed by the same alphabetical letter (or letters), within each group are averages for each attribute, not significantly different between them according to the test of the lowest mean difference of the rate at the level of significance 0.05.

The effect of poultry manure on the yield and yield characteristics of lettuce

The results during the two years of the study and recorded in table (6) showed the effect of the main factor (poultry manure), with its graded levels, on the yield characteristics of the lettuce plant. The increase in the levels of poultry manure from 0 to 30 tons/ ha resulted in a gradual increase in its effect on the yield characteristics of the lettuce plant, with clear significant differences for each of the studied traits as a positive response to increasing the levels of poultry manure during the two years of the study, even if there was a variation in the values. The average of 30 tons/ ha fertilizer was given the highest and best significant values of poultry manure compared to the control treatment that was not fertilized for all crop characteristics, as the increase in these crop characteristics was 11.75%, 12.02%, 13.%, 144%, respectively, for each fresh weight. Head (g), total yield of heads (tons / ha), fresh total yield (tons / ha), dry total yield (tons / ha), as an average for the two years of the study. The increases in the tested yield characteristics as a result of adding poultry manure can be attributed to its active and vital role in its positive effect of the tested vegetative growth characteristics (Table 3), which is due to the role of organic fertilizer in improving the natural, chemical and biological characteristics of the soil, which is reflected positively on the vegetative growth characteristics and thus leads to

Increase the overall yield and yield of heads. The results of the total yield and the yield of heads in this study were in agreement with the results of both on the lettuce plant, as they unanimously agreed that the increase in the added rates of organic fertilizer resulted in an increase in the yield characteristics and yield of heads of lettuce plants (Rubeiz *et al.*, 1992: Hosseny & Ahmed, 2009: Mohamed, 2010: Hossain. & Ryu. 2017).

Table (6): Main effect of poultry manure on the yield and yield characteristics of lettuce.

Poultry manure transactions (ton/h)	Fresh total yield (tons / ha)	Dry total yield (tons / ha)	Total head yield (ton / ha)	Head Fresh Weight (g)
The first season				
0	**36.475D***	**0.798D**	**28.943C**	**470.58C**
10	**39.256C**	**0.895C**	**31.921B**	**515.70B**
20	**41.632B**	**1.465B**	**32.256B**	**521.5B**
30	**44.049A**	**2.193A**	**34.829A**	**560.25A**
The second season				
0	**34.243C**	**0.897D**	**24.615C**	**395.12B**
10	**34.547C**	**1.033C**	**24.700BC**	**394.33B**
20	**35.429B**	**1.245B**	**25.168AB**	**404.33A**
30	**36.229A**	**1.927A**	**25.536A**	**408.791A**

* The values followed by the same alphabetical letter (or letters), within each group are averages for each attribute, not significantly different between them according to the test of the lowest mean difference of the rate at the level of significance 0.05

The effect of plant density on yield and yield traits of lettuce.

Comparisons reflecting the main effects of the tested plant density on the yield and yield characteristics of lettuce in the two years of the study are recorded in table (7). The results showed, in general, that the increase in planting distance between plants from (20×60 cm) to (40×60 cm) was met by a significant response in the characteristic of fresh weight of the head, while the low plant density (20×60 cm) was significantly higher. In the characteristics of the total yield of heads, fresh total yield and dry total yield (tons / ha), where the average increase for the two years of the study for the previous traits was respectively (94.57%, 94.35% and 87.42%). Over a wide distance leads to less competition between plants for food sources and other environmental factors, which encourages plants to grow better. As for the increase in the characteristics of the total yield of heads, fresh total yield and dry total yield (tons/ h), this can be explained by the increase in the number of plants in Unit area. The results of the present study agree with what Abu-Rayyan, *et al*., (2004: Mohamed, 2010) found on (Tahsin, 2010: Tahsin & Islam, 2017) on lettuce and Fatma (2007) found on Cauliflower.

Table (7): Main effect of plant density on the yield and productivity characteristics of lettuce.

plant density transactions (cm)	Fresh total yield (tons/ ha)	Dry total yield (tons/ ha)	Total head yield (ton / ha)	Head Fresh Weight (g)
The first season				
60X20	**52.876A***	**1.753A**	**41.870A**	**502.64B**
60X40	**27.830B**	**0.923B**	**22.105B**	**531.37A**
The second season				
60X20	**46.715A**	**1.655A**	**33.325A**	**400.06A**
60X40	**23.509B**	**0.895B**	**16.685B**	**401.10A**

* The values followed by the same alphabetical letter (or letters), within each group are averages for each attribute, not significantly different between them according to the test of the lowest mean difference of the rate at the level of significance 0.05.

The effect of interaction between poultry manure levels and plant density on yield and yield characteristics of lettuce:

Data showing the effect of the interaction between levels of poultry manure and plant density on the yield and productivity characteristics of lettuce plants in the two seasons of cultivation are recorded in Table (8), where the results indicated that the gradual increase in levels of poultry manure from (0, 10, 20 and 30 tons/ h) was accompanied by an increase, The value of fresh head weight for lettuce plants during the first agricultural season was an average of 567.8 grams with a working treatment of 30 tons of organic fertilizer + (40x60 cm) planting distance, although it had not reached the moral limit. The matter in the second season was very similar and there were no significant differences, as well as the values were very close and for the same previous harmonic treatment (30 tons organic fertilizer + (20 x 60 cm) and (40 x 60 cm)), and for the fresh weight of the head, as shown the results of the reaction on the characteristics of the total yield of heads, fresh total yield and dry total yield, that the increase in the number of plants per unit area under any level of poultry manure fertilizer was accompanied by a clear significant increase during the two growing seasons with the average fertilizer (30 tons/ ha), and the average ratio was The percentage increase during the two seasons of cultivation is 116.47%, 117.58% and 370.04% for the characteristics of total head yield, fresh total yield and dry total yield, during the two seasons.

The results of the current study, and in this aspect related to the effect of the interaction between organic fertilizer and plant density, agree with many studies, which confirmed that increasing organic fertilizer and reducing plant density led to a significant increase in the overall vegetative and yield characteristics of lettuce plants. AL-Bayati, *et al.*, (2019) obtained similar results to the results of this study on lettuce plants, where it was found that the interaction between organic fertilizer and planting distances was very significant for all the overall vegetative and yield characteristics of lettuce plants. It also agrees with the results also with what Islam, et al., (2016) found on cabbage plants, you obtain the highest values of vegetative and productive characteristics when reducing the plant density per unit area overlapping with a specific system of organic and mineral fertilizers (2/3 organic fertilizer + 1 / Mineral fertilizer 3), which significantly outperformed all the tested treatments in their study.

Table (8): The effect of interaction between organic manure and planting distances on lettuce yield and its components:

Transactions		Fresh total yield (ton/ ha)	Dry total yield (ton/ ha)	Total head yield (ton / ha)	Head Fresh Weight (g)
Poultry manure (ton/h)	Plant density (cm)				
The first season					
0	20×60	47.252d*	1.034e	37.422c	449.2d
	40×60	25.698g	0.562f	20.463f	491.9c
10	20×60	52.05c	1.186d	41.823b	502.1c
	40×60	26.457g	0.603f	22.020e	529.3c
20	20×60	54.582b	1.921b	42.198b	506.5b
	40×60	28.683f	1.009e	22.315e	536.4b
30	20×60	57.615a	2.869a	46.037a	552.6a
	40×60	30.482e	1.518c	23.621d	567.8a
The second season					
0	20×60	47.252d	1.034e	37.422 **c**	449.2 d
	40×60	25.698g	0.562f	20.463f	491.9c
10	20×60	52.05c	1.186d	41.823b	502.1c
	40×60	26.457g	0.603f	22.020e	529.3c
20	20×60	54.582b	1.921b	42.198b	506.5b
	40×60	28.683f	1.009e	22.315e	536.4b
30	20×60	57.615a	2.869a	46.037a	552.6a
	40×60	30.482e	1.518c	23.621d	567.8a

* The values followed by the same alphabetical letter (or letters), within each group are averages for each attribute, not significantly different between them according to the test of the lowest mean difference of the rate at the level of significance 0.05.

IV. Conclusion

The poultry manure and the planting distance had a significant effect on the vegetative and yield characteristics of the lettuce plant, where as the gradual increase in the levels of poultry manure and the planting distance resulted in a dramatically improvement in all growth parameters and yield of lettuce plants.

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