INFLUENCE OF PLANTING SPACES ON GROWTH, YIELD AND BACTERIAL SOFT ROT INFECTION OF LETTUCE (*Lactuca sativa* L.)

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ABSTRACT

The experiment was conducted to evaluate the growth, yield, and bacterial soft rot infection of Lettuce (*Lactuca sativa* L.) in the organic system of the multi-span house without chemical fertilization and without heating, planting was in different planting spaces. The research was directed from 14th November (sowing seeds in the nursery) 2018 to 14th of March 2019 (harvesting). The experiment was designed in randomized complete blocks (RCBD), with eight treatment planting spaces 10, 15, 20, 25, 30, 35, 40, 45cm planting spaces, the cultivars (TERESA) were used in the experiment, with four replication for each treatment. The obtained results were analyzed averages were compared by Duncan Multipliers and the least significant difference(LSD) at the possibility>0.05 level. The evaluated characteristics in this experiment were marketable fresh weight per plant, per square meter, plant height, number of leaves, plants infected with soft rot, roots length, outlet leaves, and number of heads. The highest fresh weight 511.3 gr plant, the highest number of leaves/plant 39.4l, root length 9.1 cm, leaf length 31.3 cm obtained with the wide spacing, but the highest yield 10671.4 gm/m^2 and plant height were obtained with the smaller spacing 10.15 cm. Lettuce may present a yield decrease due to the occurrence of lettuce soft rot disease caused by *Pectobacterium carotovorum* subsp. *carotovorum*. This study was designed to determine the perfect sample size for evaluating disease occurrence in fields in the last spring months to collect and store heads. The soft rot infection percent was higher in low spacing 3% because the high densities of plants make contact with the plants and lowest or no infection in high spacing.

Keywords: plant spacing, *Lactuca sativa* L., yield, Soft rot.

تاثير مسافات الزراعية على النمو وانتاجية واصابة محصول الخس (*Lactuca sativa L.*) بتعفن الطري البكتيري

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المستخلص

اجريت التجربة لدراسة وتقيم نمو والحاصل ونسبة الاصابة بمرض التعفن الطري على نباتات الخس (*Lactuca sativa* L.) في نظام الزراعة العضوية بدون تسميد كيمياوي وبدون تدفئة في بيوت البلاستيكية متعددة الاخاديد Multi-Span ، اجريت التجربة في 14 من الشهر تشرين الثاني (بزراعة البذور في المشتل) لعام 2018 الى 14 من الشهر اذار لعام 2019عند جمع المحصول. استعمل في تصميم التجربة نظام القطاعات العشوائية الكاملة (RCBD) بثمانية مسافات زراعية وهي 10، 20، 20، 25، 30، 35، 40، 45 سم من صنف TERESA باربعة مكررات لكل معاملة. وتم استعمال برنامج XLSTAT-Microsoft Excel في تحليل النتائج واستخراج معدلات ومقارنتها واستخراج LSD واختبار Duncan لمقارنة معدلات المعاملات على مستوى 5%، وتم دراسة الخصائص المدروسة في هذه تجربة منها الوزن الصافي التسويقي للنبات، ووزن انتاج متر مربع واحد ،وارتفاع النبات، ومعدل عدد الاوراق للنبات الواحد، والنسبة المؤية للاصابة بمرض التعفن الطري البكتيري ،وطول الجذور،وعدد الاوراق غير المستعملة وعدد الرؤوس الصالحة للتسويق لكل معاملة.كانت اعلى كمية للحاصل التسويقي الصافي 511.3غم/نبات واعلى معدل لعدد الاوراق/نبات 39.4 ورقة وطول الجذور9.1 سم وطول الاوراق 31.3سم ، بينما اعلى كمية من الانتاج التسويقي 10671.4غم/م2 واعلى ارتفاع الانتاج في المعاملات ذات المسافات الضيقة 10 و 15 سم على الترتيب. ظهر نقص في المحصول نتيجة الاصابة ببكتريا مرض تعفن رؤس الخس (*Pectobacterium carotovorum* subsp *caratovorum*). وكجزء من اهم اهداف هذه التجربة لتقدير مرحلة وحجم الخسائر التي يسببها هذا المرض وخاصة في الاشهر الاخيرة من الربيع لجمع الرؤس وخزنها وكانت اعلى نسبة الاصابة 3% و ذلك بسبب قلة المسافات بين نباتات معاملة 10 و 15سم وتقل نسبة الاصابة في المسافات المتباعدة 40 و45 سم في التجربة.

الكلمات المفتاحية: مسافات الزراعة، *Lactuca sativa* L.: الانتاج ، التعفن الطري.

INTRODUCTION

Lettuce plant (*Lactuca sativa* L.*)* is a leafy vegetable that belongs to the family Astereceae , it is one of the most common salad crops and occupies a high production area among leafy crops in the world. It was popular for its crispy texture, delicate, and slightly bitter taste with milky juice. It was the most common among the salad plant crops (Squire et al, 1987). Currently, the main world producers countries are China, The United States of America, India, Spain, and Italy (FAO, 2017).

Lettuce contains vitamins such as vitamin A and types of minerals like calcium and iron. It is usually mixed with tomato, carrot, cucumber, or other salad vegetables and often served alone or with covering. A cool-season vegetable crop is greatest popular according to the commercial importance and consumption amount throughout the world (Coelho et al, 2005). Planting three varieties (Filipus, Paris Island, and Quintus) showed early bolting in summer

and spring they have the same tolerance to the bolting. The highest average head fresh weight from Paris Island 1009g^{-1}.(Al-Zahairy and Hamdani, 2018) .Optimal planting space ensures judicious use of natural resources and makes the inter-cultural processes easier. It helps to grow the leaves, branches, and healthy foliage. On the other hand, wider spacing among plants confirms the basic nutritive requirements but decreases the number of plants in the area decrease total yield. Jenni (2005) reported that the summer lettuce production, where temperatures are above 24^{o}C, caused the eventually poor heads quality and make seed stalks, the cultivar Ithaca was very sensitive to heat pressure 2 weeks after making heads. (Hasan et al,2017). the highest fresh weight/plant of lettuce plant 81.55, 94.58,109.0, and 117.0 gr at 30, 40, 50, and 60 days, respectively was observed from 40 cm×30cm while the lowest fresh weight/plant was 55.0, 65.4, 75.36 and 83.0 gr respectively was found from 40 cm×20cm. It was revealed that with the increases of spacing fresh weight of plant presented a growing trend. Lettuce is originated from Western Asia and Southern Europe (Steingrobe and Schenk, 1994). It mostly grows in the variable temperate region and in some cases in the tropic and sub-tropic regions of the world. Lettuce was mostly produced inside the covered places in the temperate region (Da Silva et al, 2000) experimented with lettuce CV. Great Lakes, Elisa and Baba de Verao, the effects of different plant spacings 20x20,25x30cm, 25x25cm, 25x30cm, or 30x30cm on heads under high temperature and plenty of sunlight conditions. An additional treatment of CV. Great Lakes at 20x20cm under constant shading was also studied. Plant height, diameter, number of leaves/plant, shoot dry matter content, leaf yield, gross and net incomes were studied. Total produce of cv. Alamo-1 lettuce was significantly affected by different planting dates and planting spaces. Sharma et al, (2001) indicated that the highest yield 25.83 ton/ha^{-1} was obtained from 40×25cm. On the other side, the lowest yield 23 ton/ha^{-1} was obtained from 40×20cm. It was shown that higher spacing showed higher yield till to a positive level because the higher population is ensured with lower spacing and higher spacing provide more nutrients and low competition among plants. Sharma et al. (2001) tested with twenty-four treatment combinations the closest spacing of 30×30cm recorded the lowest yield/plant, which did not compensate for optimum yield per hectare. A planting space of45×30 cm was found finest for getting optimum yield/plant as well as per hectare. Echer et al. (2001) evaluated the performance of 5 lettuce cultivars (Brisa, Grande Rapida, Marisa, Vera, and Veronica) in 2 spacing treatments 0.20×0.25 m and 0.25×0.25 m from September to December 1998 in Sao Paulo, Brazil.The following parameters were evaluated: the fresh matter of aerial

parts/plant^{-1}, the number of leaves/plant^{-1}, leaf fresh matter/plant^{-1}, the average fresh matter of one leaf; and average total production per area.The size of lettuce heads was positively correlated with loose spacing. A field experiment was carried out by Sodkowski and Rekowska (2003) in Szczecin, Poland during 1998-2000 to study the effects of cultivation method and mulching. The spacing among plants was 25×30cm. The effects of planting space, hoeing, and covering on the lettuce yield and quality under integrated control were determined by Petrikova and Pokluda (2004) Marketable lettuce yields reached 82-99%. Planting density, cultivar, and mulching affected the quality of lettuce heads. The quality of lettuce heads was determined by the cultivar, as well as by mulching and hand hoeing. Badi et al, (2004) showed the nearer spacing makes a significant increase in leaf area and leaf number/m^{-2} which in turn reduced significantly higher fresh biomass and dry biomass m^2. Although the higher plant spacing 20x25cm gave more leaf number, high leaf area, higher leaf fresh biomass /plant^{-1} as equated to nearer plant spacing, it still resulted in minimum values per area unit. There were no differences in fresh weight of leaves and roots between plants under watering can irrigation and clay pot irrigation in the 15×15 cm planting space However, the performance of clay pot irrigation under20×20cm and 30×30 cm was higher to that of the watering can with regards to fresh weight of leaves and roots (Abubakar et al, 2011). Two planting densities used for planting cauliflower seedlings on one side of the drip irrigation tubes caused a significantly increased in the plant diameters and head weight with leaves to 20.1cm, 1.85 kg plant $^{-1}$ respectively as compared with two sides of the drip irrigation tubes of which reduced to 15.34cm, 1.03 kg plant^{-1} respectively. Opposite of this the two sides density has a significant effect on total yields 57.1 ton^{-1} as compared with one side density of 51.44 ton^{-1}. (Al-Zuhairy and Hamdani, 2017) .

A field experiment was conducted by Moniruzzaman (2006) with three planting spaces 40×20cm,40×30cm, and 40×40cm with two types of mulching (mulch and non-mulch) to find out the effect of planting spaces and mulching on produce and productivity of lettuce cv. (Green Wave) at the Agricultural Research Station, Raikhali. The highest fresh biomass yield of lettuce was found from the closest spacing40×20cm that was statistically alike to that recorded of medium planting space 40×30cm in both years. The improper planting space may cause a dense or sparse population which result in a decrease in lettuce yield (Firoz et. al., 2009). There are several vegetable combinations that can be used in intercropping, with lettuce being a crop frequently used (Costa, 2007; Mota, 2012; Barbosa et al, 2015). The effect of planting space50×30 cm and 50×45 cm on plants for lettuce seed production.

MATERIALS AND METHODS

The Experimental Site

The **e**xperiment was approved at Bakrajo-Sulaymaniyah government-Iraq which is situated 7km west of Sulaymaniyah city in the north-east of Iraq. The average low temperature for the above-mentioned growing winter was 5.3 C^o and the high temperature was 21.7 C^o inside a plastic house (Jenni, 2005).

Design and Treatments

This research was conducted in the autumn and winter cropping season. The experiment was arranged levels of inter-row spacing 10, 15, 20, 25, 30, 35, 40, 45 cm and 20cm intra-row space by randomized complete block design (RCBD) with four replicates ,planting 5 rows /$plot^{-1}$ for each treatment replications .

Experimental Procedures

Before planting ploughing the experimental soil twice composted and analyzed at Bakrajo technical institute soil laboratory for soil pH, texture, EC, total available N, and available P using the standard laboratory procedure to determine the initial soil characteristics of the experimental soil. The lettuce variety TERESA was planted in the nursery and the seedlings were transplanted after 30 days after prepared beds in the plastic house. Andrilo et al (2006)No chemical fertilization, green fertilizer, and animal manure were applied in this experiment and the field was irrigated anytime by surface irrigation the water requirement of the plants. All agronomical management practices were done without chemical pest control (Rashid, 1999).

Data Collection and Measurements

1- Plant height: The height of the sample plants was measured for five plants randomly in the three inter rows by measure from the border of the soil to the top of the plant leaves height (Moniruzzaman, 2006; Maboko, 2008; Hasan et al, 2017).

2- Number of leaves/ $Plant^{-1}$: It was measured for five plants in the three inter rows by counting the nine leaves 3 leaves for each (top, middle, and bottom of plants) by selecting leaves randomly from each plant and make an average of leaves number. (Sharma et al, 2001).

3- Leaves length: It measured for five plants randomly from treatments by choosing six healthy leaves per plant and make average or leaves length by

measure the length of the top part of the leaf to the base on the steam of plants (Sodkowski and Rekowska, 2003).

4- Fresh biomass weight: Made fresh biomass weight for five plants in the three inter rows of each treatment by digging them from the ground and remove the soil from the root part of the plant loose soil and measure fresh biomass of it (Sharma et al, 2001; Abubakar et al, 2011; Barbosaa et al, 2015; Al-Zuhairy and Hamdani, 2017).

5- Number of Marketable heads: Measured by selecting ten plants randomly from each treatment and cutting ten plants for one treatment, make an average of heads weight was taken in grams by critical balance (Rashid, 1999; Sharma et al, 2001; Petrikova and Pokluda 2004; Moniruzzaman 2006; Barbosa et al, 2015).

6- Root length: By selecting five plants randomly for each treatment by pull out the plant root by shovel and cleaning them from soils measuring the length at the base of leaves on the stem of plants to the end of tap roots taken by the ruler, the average of root length was obtained (Sharma et al, 2001; Moniruzzaman, 2006; Rashid, 1999).

7- Number of infected plants by bacteria of soft rot: -it was determined by surviving 100 plants for all treatments randomly and numbering infected plants to make a percentage of infection by bacteria of lettuce soft rot by *Pectobacterium carotovorumin* subsp. *Caratovorum*(Cariddi and Sanzani, 2013).

8- outlet leaves (dirty lives): - it was measured by selecting five plants for all treatments randomly and cutting small and green leaves of selected plants for measuring heads of sample lettuce plants (Beyenesh, 2017).

Data Analysis

The data were prepared for analysis of variance following statistical measures of Xlstat software program from (Excel program, 2016, version 2.9). The treatment effects were significant or non-significant. Means were compared using the Duncan Multipliers test and the least significant difference (LSD)test at the probability level of $p < 0.05$.

RESULTS AND DISCUSSION

Influence of planting space on plant height in table 1 indicated that plant height was significantly affected by the plant density, plant height increased in the 20 cm, 45 cm, 41.7, 39.7cm height and otherwise no significantly influenced in other treats table 1. Plant height and leaves number increased by a decrease in planting spaces. The closer spacing, i.e. 15x20cm 41.7cm plant height and 20x45cm 39.7 cm produced significantly taller plants 41.7 cm and 39.7 cm respectively, to other spacings, it agrees with earlier findings that an increase in

plant density increased plant height (Barbosa et al, 2015). An increase in plant height can be to competition for photosynthetically active radiation and high significant table 1. Leaves number and leaf length per plant: The results agree with those of (Badi et al, 2004), who said the low plant spacing produced a significant increase in leaf number m^2 which reduced significantly high fresh biomass m^2. The wider spacing 20x45cm gave more leaves 39.4 leaves/plant $^{-1}$, longer leaf 31.3cm/plant, a higher number of heads/plants, and a maximum root length of 9.1 cm as compared to closer spacing table 1. Length of roots: Root length increases due to more availability of nutrients to the plants during vegetative growth. The results were obtained by (Mota, 2012). Root length statistically significant to different plant spacing 9.1, 8.75, 8.1cm in plant spacing 45,15,40 cm respectively table1. Leaf length: there were deference's between treatments the long length of leaves are in the spacing 45x20, 40x20, 25x20 cm, 31.3, 30.6, 30.6 cm receptively it is nearest to average 29.56 cm/leaf and minimum leaf length 27.2 cm/leaf in 35 cm spacing table1.(Cariddi and Sanzani,2013) Lettice bacterial soft rot infection: there was plant infections by bacteria of soft rot overall plants about 0-3% no significant action on the field from this three months of growing and beginning the infection after march table1.

Table 1. Effect of planting space on vegetative growth of lettuce and soft rot infection

Plant Spacing Centimeters(cm)	Plant height cm^{-1}	Number of leaves /$plant^{-1}$	Root length / plant cm	Leaf length cm	Bacterial soft rot infection plants %
20x10	36.1bc	26.4d	7.8bcd	29.3abc	3
20x15	41.7a	31.2bdc	8.8ab	29.8ab	2
20x20	38.4ab	29.3cd	7.1cd	28.0bc	1
20x25	36.1bc	29.0cd	7.8bcd	30.6ab	0
20x30	36.3bc	29.8bcd	7.0d	29.7abc	1
20x35	36.9bc	33.1bc	7.9bcd	27.2c	2
20x40	37.5bc	34.5b	8.1abc	30.6ab	1
20x45	39.7ab	39.4a	9.1a	31.3a	0
Average	37.84	31.59	7.95	29.56	1.25
LSD 0.05	3.6158	4.8903	1.0974	2.5854	N.S

The results presented that this cultivar reacted differently to planting space table 2 the closer spacing 10x20 and 15x20 caused the highest fresh plant biomass because of the increased growth rate with a small head and in otherwise narrow planting space could be harvested earlier than wider planting spaces with a shorter growth time. The results showed increasing fresh leaves/m^2 as the plant spacing decreases (plant density increases). The higher number of plants at the low spacing contributed to higher fresh leaves/m^2 area as compared to wider

spacing. Planting space makes significant differences for other yield parameters of this lettuce cultivar(TERESA) table 2. The results indicate that the best plant spacing for the leafy lettuce is 15x20 cm 10671.4 gr/m^2 compared to other spacing used in this trial. The results of plant spacing were similar to those of (Abubakar et al, 2011) who reported that the highest yield of lettuce head was at 22 cm as space between plants. The higher plant heights of plants increased all yield parameters. Table 2. The number of marketable heads: the number of hardheads for treatment varies from a maximum number of marketable heads from 8 heads to minimum of 3.7,3.9 heads per 10 plants with an average of all treatments 5.85 marketable heads per 10 plants all plants make heads but less of them hard heads table 2. The number of outlet leaves:-the high number of outlet leaves/$plant^{-1}$10.7,10.15 leaves/plant was obtained from 20x45cm,20x35cm at the similar data the low number of outlet leaves/ $plant^{-1}$ 7.45 obtained from 20x10 cm and other data's near to average table 2.

Table 2. influence of planting space on yield and yield parameters of lettuce

Planting Spaces Centimeters(cm)	Fresh mass weight gr/plant without root	Plant Fresh mass weight gr/square meter	Number of marketable heads per 10 plants	Number of outlet leaves per plant
20x10	209.2d	10461.3a	3.7c	7.5b
20x15	323.4c	10671.4a	3.9c	9.7a
20x20	313.4c	7834.4b	5.2b	9.1ab
20x25	333.2c	6664.5bc	5.5b	8.6ab
20x30	346.7c	5547.6cd	5.9b	8.9ab
20x35	428.8b	6003.6c	7.4a	10.2a
20x40	511.3a	6646.9bc	7.2a	10.0a
20x45	416.4b	4580.4d	8.0a	10.7a
Average	360.3	7301.26	5.85	9.34
LSD 0.05	52.8018	1347	1.1234	2.1921

Leaves number responded significantly to intra-row and inter-row planting spaces. Leaf number increased as the planting spaces increased. Concomitant with the results of the study, higher yields response to low planting spaces over wider spacing was reported by (Moniruzzaman, 2006; Echer et al,2001; Sodkowski and Rekowska, 2003). The low yield under 30x20cm planting spaces could be attributed to less spacing for each plant so the plant does not acquire optimum space for growth due to plant competition for light and nutrition (Al-Zuhairy and Hamdani, 2017). Similar results were found in carrot Mengistu and Yamoah (Petrikova and Pokluda, 2004) These results agree with (Firoz et al, 2009). Gheshm et al, (2018) stated that planting spaces may cause either too dense or too sparse population resulting in the reduction of lettuce yield Table 2.

CONCLUSION

Based on research results, there were many significant differences in the effect of planting spaces as statistically analysed.

1- The lettuce grown in 20×40cm planting spaces was significantly affected by the spacing used for this experiment. The number of leaves, plant height, biomass, and Head weight (gr).

2- Planting all numbers or half of the empty plastic houses in the winter season for protecting planted lettuce plants from Winter freezing of good growth to produce a high amount of lettuce (leaves and Marketable heads of lettuce) in these three months of Winter season.

3- The winter planting with any planting spacing protects all plants from infection of bacterial soft rot diseases because low temperatures decrease the activity of the bacterial infections and buying by high value from markets.

4- Produce high amount of lettuce heads for all plant spacing especially 40x20, 45x20 plant spacing at the beginning of March month and buying at high prices to make a good money source for plastic house farmers to continue other vegetable plantings in one year.

5- producing old plants reduces summer plants such as tomato and cucumber for producing organic(clean) growing, good for human health. If we use the plastic house and this plant spacing such as 15x20, 40x20 spacing without chemical fertilizing decrease the cost of lettuce production.

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