Influence of Plant Density and Mulching on Growth and Yield of Lettuce (*Lactuca sativa* var. *romana* L.)

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***Abstract*—** *The aim of the paper was to present the influence of plant density and different types of organic mulch on growth and yield of Romain lettuce. The field experiment was carried out in 2014 in the experimental field of University of Forestry – Sofia, with Romaine lettuce cv. Yellow beauty. The seedlings were planted at a distance of 30 x 30 cm and two different schemes were tested: parallel planting to form a 4-row bed and a chess planting to form a 7-row bed. For the purpose of the study were used different organic mulches, which were waste products from organic agriculture: barley straw (BS), well-rotted horse manure (HM), walnut wood sawdust (WS) and grass windrow (GW) and non-mulched control plots (NMC). The mulching materials were spread manually in a 5-6 cm thick layer, after strengthen the seedlings of Romain lettuce. On the 60th day after planting was the beginning of harvesting. It was found out that the seven-row bed and mulching influenced growth and yield of Romain lettuce. Mulching with HM has a significant effect on growth and yield. In the cultivation of lettuce in combination with horse manure mulch and seven-row bed, the yield increased by 18% compared to the non-mulched control in the same planting scheme and was 2.3 times higher than the non-mulched control in a four-row bed. A significant effect on the mulched variants was established.*

***Keywords*— grass windrow mulch, horse manure mulch, lettuce, seven-row bed, yield.**

I. INTRODUCTION

Lettuce (Lactuca sativa L.) is an annual plant of the Asteraceae family. Due to its short vegetation period and its cold resistance it is one of the first fresh leafy vegetables in the spring. The density of growing plants is one of the factors which affect the yield and quality of produce. Optimum density of plants enabling them to grow uniformly, through effective use of moisture, nutrients, and light, and thus helps to obtain maximum yield. [6]. According to several authors, recommended plant spacing when growing lettuce, usually ranging from 20 to 50 cm between rows and 20 to 45 cm between plants. It has been found that by increasing the spacing of the growing plant height and diameter of the lettuce are greater, leading to an increase in the fresh weight of a plant. At the same time, the reduced number of plants leads to a decrease in the total yield. The significant increase in yield at a high density of plants can only be attributed to the larger number of plants per unit area. [7]. But smaller distances also lead to reduced yields due to competition between plants for light, water, food, etc. [2, 6, 9]

Mulching is an agrotechnical event, which is covering the soil surface with a layer of organic or inorganic materials, which aims to improve the conditions for plant growth. It helps to maintain a constant soil temperature, controls weeds, retain soil moisture and more [7, 11]. The advantage of organic mulch is that they keep a moderate temperature; omit water from precipitation and maintain better soil humidity, [4, 15, 16]; increase total yield; improving soil fertility, as after their plowing at the end of vegetation, they are a valuable source of organic matter [12, 13, 14].

Although the lettuce has a short growing season, mulching favorably affect growth and development. It has been shown that lettuce grown with mulching soil surface increase their height and diameter compared to non-mulching plants. The fresh and dry weight of the plants is increased. The positive effect is probably due to the reduction in the loss of nutrients from washing, improved temperature regime of the soil and maintain its humidity [3, 6, 7]. Mulching of the soil with chicken manure showed good results in soil temperature and humidity and farmers can use this organic fertilizer as mulch when there are no other organic materials [8]. At the same time, mulch can have both positive and negative effects on crops [4, 5].

The aim of this study is to determine the impact of plant densities and soil mulching with different organic materials, on growth and yield in the cultivation of early spring lettuce.

II. MATERIAL AND METHOD

The experiment was conducted in 2014, in the experimental field of the University of Forestry – Sofia (42°7′ N, 23°43′E and 552 m altitude). The soil is fluvisol, slightly stony, slightly acidic. This area came under a continental climatic sub region, in a mountain climatic region.

The average daily air temperature during this period indicates that the months are cool, as a daily average temperature of the third ten days of May are suboptimal for the growth and development of lettuce. During the experiment, the monthly rainfall is abundant but not evenly distributed. Summary for April rainfall was 150,5 l / m2, and in May was 148,2 l / m2 (Fig. 1)

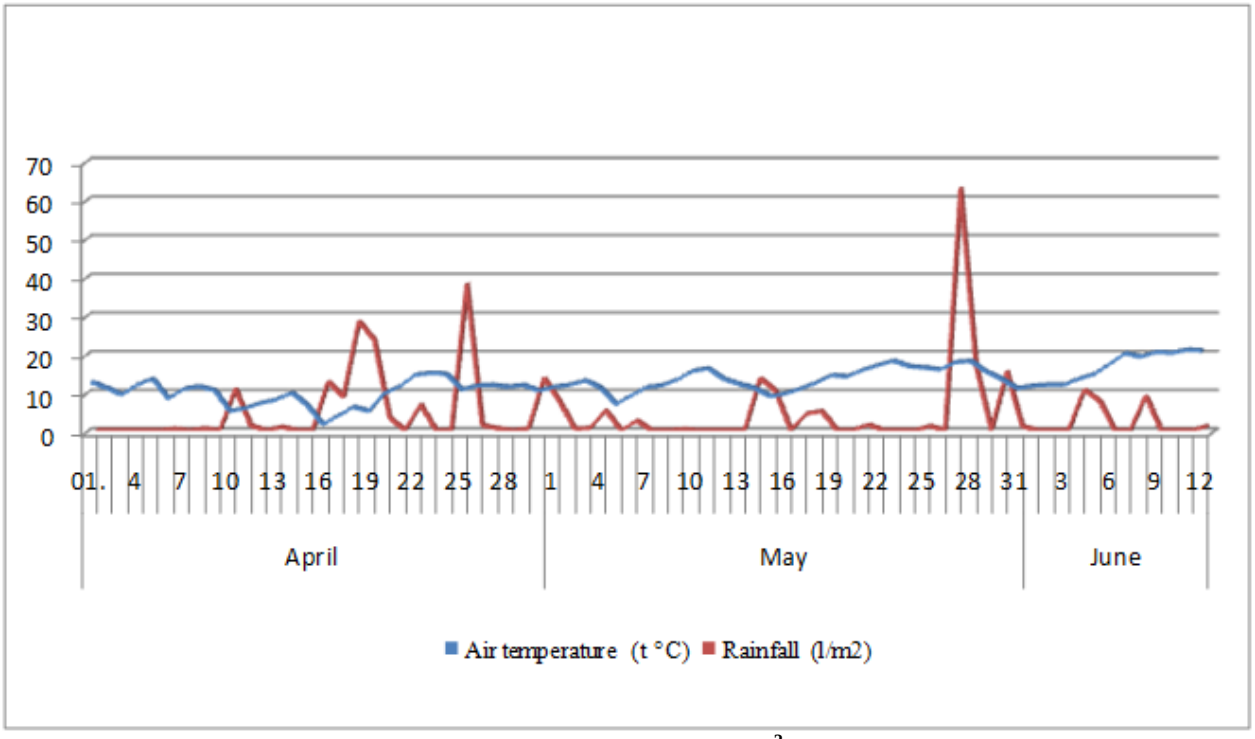

FIG. 1. AVERAGE AIR TEMPERATURE (t °C) AND RAINFALL (l/m^2) DURING THE EXPERIMENTAL PERIOD.

The study was performed with Romain lettuce (*Lactuca sativa* var. *romana*), cv. Yellow beauty, with growing period lasted 60-65 days, with pre-produced seedlings. Planting in the open field was carried out on 31th of March. All elements of agrotechnical activities (basic and pre-sowing cultivation, irrigation, etc.) were the same for all treatments. The plants were irrigated by drip irrigation system.

The experiment was designed with two different factors: A – plant density and B – soil mulcing. For Factor A the seedlings were planted at a distance of 30 x 30 cm and were tested two different schemes (Fig. 2): parallel planting to form a 4-row bed (R4) and a chess planting to form a 7-row bed (R7).

FIG. 2. TWO DIFFERENT SCHEMES OF CULTIVATION: PARALLEL PLANTING TO FORM A 4-ROW BED (R_4) AND A CHESS PLANTING TO FORM A 7-ROW BED (R_7)

For factor B were tested five treatments: bare soil with non-mulched and non-hoeing (weeded) control plot (NMC); mulch from barley straw (BSM); mulch from well-rotten horse manure (HMM); mulch from walnut wood sawdust (WSM); mulch from grass windrow (GWM).

The experiment was carried out by randomized complete block design with four replications and protection zones. The mulches were applied to the soil surface by hands at a thickness of 5-6 cm, after the seedlings of lettuce were strengthened. On the 60th day after planting was the beginning of harvesting. It was investigated plant height; plant diameter and plant weight. Data were obtained from 10 marked plants for each replication during harvesting period. The total yield is established in tones per hectar^{-1} (t/ha^{-1}) in replications and variants. Data were subjected to statistical analysis where was used an alpha level of .05. Test error rates were submitted to a two-way ANOVA. Differences between treatment means were compared with Fisher's Least Significant Differences (LSD).

III. RESULTS AND DISCUSSIONS

3.1 Main effect of plant density and mulching

Plant growth density has a significant impact on the biometric parameters and yields. In the seven-row bed (R_7), the plants have a bigger average height (24.65 cm) and a bigger average weight per plant (245 g), compared to the four-row bed (22.44 cm and 225 g). In contrast, the average plant diameter at the greater plant density is smaller (29.27 cm), compared to the average diameter (30.4 cm) of the four-row bed plants (Table 1). The total yield (3.572 t / ha^{-1}) at R7 compared to the total yield (1.872 t / ha^{-1}) is significantly higher (F (1.8) = 81.69, MSE = 0.088 p=.00002).

Soil mulching, as a single factor, also influences plant development and yield, and the impact is different depending on the type of used mulch. With the highest height (25.04 cm), a diameter (31.06 cm) and a weight per plant (273 g) are lettuces mulched with well-rotted horse manure. With the smallest diameter (28.95 cm) and the weight of one plant (211 g) are lettuces mulched with straw. At the smallest height (22.67 cm) are the lettuces mulched with weed sawdust, but in the comparison of the mean values by LSD test, there was no difference between them (Table 1). Of mulching variants, the total yield is highest (3,145 t / ha^{-1}) in the mulched plots with horse manure, and the lowest (2,421 t/ha^{-1}) in the straw mulch plots.

TABLE 1
MAIN EFFECT OF PLANT DENSITY AND MULCHING ON BIOMETRIC DATA AND PLANT YIELDS.

Factors	Height (cm)	Diameter (cm)	Weight per plant (g)	Total yield (t/ha^{-1})
A – No of rows per bed				
R4	22,44 b	30,40 a	225 b	1,872 b
R7	24,65 a	29,27 b	245 a	3,572 a
LSD	0,831	0,499	13,365	0,953
Significance level	0.001	0.001	0.01	0.001
B - mulches				
NMC	23,09 b	29,64 bc	224 bc	2,595 b
BSM	22,85 b	28,95 c	211 c	2,421 b
HMM	25,04 a	31,06 a	273 a	3,145 a
WSM	22,67 b	29,43 bc	236 b	2,784 ab
GWM	24,06 a	30,10 b	229 bc	2,665 ab
LSD	0,736	0,789	21,132	0,486
Significance level	0.05	0.05	0.05	0.05

values followed by different letters within the same column are significant different.

Greater plant density leads to an increase in their height, and this could be due to competition between plants, which confirms the results obtained by Alahi et al. (2014) and contrary to the data obtained from Moniruzzaman (2006). The greater average weight per plant is obtained at a higher plant density. Similar results are also obtained from Khazaei1 et al. (2013), but are contrary with the one obtained by Moniruzzaman (2006).

The lower plant density in the four-row bed leads to a larger plant diameter as it provides better space for their development, the significant increase in total yields in the seven-line bed is mainly due to the increased number of plants per unit area in chess planting. These data are in agreement with data obtained from Moniruzzaman (2006).

Horse manure is dark in color and improves soil temperature, especially in cool spring. It helps maintain a consistent soil moisture and is rich in nutrients. This leads to an increase in yields, similar to those obtained from Moreira et al. (2014) using poultry manure.

As mulching material the grass windrow covers well the soil, retains moisture, and while the lower layer decays it leads to the warming of the soil [16]. Sinkevičienė et al. (2009) found that mulching with grass windrow significantly increased the yield of onions, beetroot, cabbage and potatoes. A similar effect is caused by mulch of grass windrow on the growth of lettuce, especially in cooler spring.

Whereas straw is poor in nutrients, bright in color, reflects the sun's rays and does not help warming the soil. In a cooler spring, as it is in the experiment year, the straw maintains lower soil temperatures, which results to slow growth. Plants mulched with straw have a smaller height and diameter as well as with a lower weight than the plants of the other mulched variants and non-milled control. The mulching material of weed sawdust did not have a unique effect on the growth and development of the plants.

In general, mulching has had a positive effect on lettuce growth and on total yields, compared with non-mulching plots, except the straw mulch.

3.2 Combined effect of plant density and mulching

Fischer's test for the smallest difference between the mean values of the indicators revealed significant differences between the different combinations of the two factors. The use of horse manure as a mulching material, combined with plant density, has a significant effect on the growth of lettuce. In the variant with a combination of the mulch of horse manure and seven-row bed lettuces had the highest height and weight per plant. It is followed by the variant of the mulch from grass windrow in the same growing scheme. When combining these two mulching materials with a four-row bed, the plants had the largest diameter. The highest total yield of lettuce was obtained by combining horse manure mulch and seven-row bed (Table 2).

TABLE 2
COMBINED EFFECT OF PLANT DENSITY AND MULCHING ON BIOMETRIC DATA AND PLANT YIELDS.

Variants	Height (cm)	Diameter (cm)	Weight per plant (g)	Total yield (t/ha^{-1})
R_4NMC	21,79 f	30,53 bc	210 de	1,746 e
R_4BSM	22,22 ef	29,59 cd	207 e	1,725 e
R_4HMM	23,68 cd	31,66 a	269 a	2,240 d
R_4WSM	21,56 f	29,24 de	212 de	1,762 e
R_4GWM	22,94 de	30,99 ab	226 bcd	1,886 de
R_7NMC	24,39 bc	28,74 de	239 b	3,445 bc
R_7BSM	23,49 cd	28,31 e	215 cde	3,117 c
R_7HMM	26,40 a	30,46 bc	278 a	4,050 a
R_7WSM	23,78 cd	29,63 cd	261 a	3,805 ab
R_7GWM	25,18 b	29,21 de	232 bc	3,444 bc
$LSD_{0.05}$	1,041	1,116	16,677	0,434
CV%	6,45	3,52	11,06	34.49

values followed by different letters within the same column are significant different.

IV. CONCLUSION

From the results obtained in the experiment, it can be summarized that the use of horse manure and grass windrow, as a mulching material in cool spring, has a positive effect on lettuce development and in combination with a bigger plant density (seven-row bed) a higher yield is also obtained. In a cooler spring, the straw mulch leads to slow growth of the lettuce and low yield.

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