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EFFECT OF USING ORGANIC FERTILIZERS ON LETTUCE TYPE 'LOLLO ROSSO' UNDER OUTDOOR METEOROLOGICAL CONDITIONS

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Abstract

This paper presents the results of an experiment related to cultivation of red-leaf lettuce type 'Lollo rosso' variety 'Tuska' outdoors, in transition to organic production. The experiment has been conducted in field conditions on the premises of the Agricultural University in the region of Plovdiv. During the lettuce growth several variants were tested: 1. NPK (mineral fertilization); 2. Control (non-fertilization); 3. Italpollina; 4. Arkobaleno; 5. LC (Lumbricompost); and 6. Ekoprop NX. The effect of the different organic fertilizers has been studied through the main biometrical parameters. Statistically significant differences have been reported for the most important indicators - fresh mass weight g and number of leaves with highest values observed in variants 6. Ekoprop NX and 4. Arkobaleno. Organic fertilization successfully replaces the fertilization with a combined fertilizer (NPK) under the different hydrothermal conditions of the experimental period.

Key words*: Lettuce (Lactuca sativa), organic fertilization, climate change, hydrothermal coefficient, vegetative behaviour.*

INTRODUCTION

Organic farming helps to improve the health of the agro-ecosystem through its holistic approach, using agronomic, biological and mechanical methods on the farm and excluding all types of synthetic raw materials (Patle et al., 2020). It is defined as a unique production management system, which cares for the environment, including biodiversity, biological cycles and soil resources (Lester, 2006; Oberč et al., 2020; Duru et al., 2015; Dall'Asta et al., 2020). Its benefits for human health are undeniable (Shafi and Rennie, 2009) at a time when food is a major factor. In conditions of climate change and fluctuations, more and more often this direction in plant growing falls into the focus of modern scientific research with tendencies to increase the share of the fields for organic farming. The relationship between the environment and food production and the future development of agriculture is discussed (Margat and Vallée, 2000; Funk and Brown, 2009; Aggarwal, 2008) as well as its economic profitability over time. Serious attention is paid to the excessive use of chemical fertilizers, plant protection products and pesticides on the ecosystem (Sharma and Singhvi, 2017; Bourguet and Guillemaud, 2016; Lichtfouse, 2016). Emphasis is placed on the benefits of organically produced food over conventionally grown products (Forman et al., 2012; Tuomisto et al., 2012; Seufert et al., 2012; Meier et al., 2015). People nowadays are turning to sustainable farming methods with good yields and minimal impact on the environment (Horrigan et al., 2002; Jensen et al., 2020; Tuomisto et al., 2012). For products, intended only for fresh consumption and participating in many dietary programs, such as lettuce, purity of production and avoidance of fertilizers is of great importance. Lettuce is an economically important crop for small and medium-sized producers. When grown in adverse environmental conditions, lettuce is vulnerable to deterioration in yield and quality. Leaf salad variety Lollo Rosso is red in color, rich in carotene, with a slightly bitter taste and useful substances. Among the different varieties of lettuce, red coral lettuce shows the highest total antioxidants and antioxidant activity. It is most often used for decoration and

as an addition to other types of leaf salads, as well as in combination with local types of food, which determines its small and standard sizes compared to other types of cold-resistant leaf and head salads. In Bulgarian weather conditions it is grown mainly in pre-winter time in unheated facilities, and in the open air in early spring, when the temperatures are still lower and sunshine less (short days). In recent years, increase in the air temperature and changes in the course and distribution of the precipitation in different regions of Bulgaria have been registered by a number of authors (Georgieva et al., 2017; Marinova et al., 2017; Alexandrov and Shopova, 2020). The observed climatic fluctuations in the study area over the last three decades have affected the conditions of growth and development of spring plants, and of the leaf lettuce in the open air, in particular. This study analyzes the influence of different fertilization technologies on the development of the Lollo Rosso leaf lettuce, grown outdoors under the hydro-thermal conditions of the experimental period 2018-2020 through its basic biometric indicators.

MATERIALS AND METHODS

The experiment was conducted on the experimental field of the Agricultural University of Plovdiv in 2019-2020 on alluvial meadow soil (Mollic fluvisol, FAO 2006). The red lettuce plants (type 'Lollo rosso') were planted on 12th of April in 4 rows according to the scheme 70+30+30+30/30 cm with a profile of the soil surface a high level bed (100+60cm). The experiment was based on the block method with four repetitions, using 28 plants per repetition, and a plot size of 3.36 m2. Organic seeds were provided for seedling production using container technology with 150-hole Styrofoam boards in the following combination - organic seeds - 80.0 %, Perlite - 20.0 %, Lumbricompost for bioproduction of seedlings (Kostadinov and Filipov, 2013). Several variants were tested: 1. Control (non-fertilization); 2. NPK (mineral fertilization); 3. Italpollina; 4. Arkobaleno; 5. LC (Lumbricompost); and 6. Ekoprop NX. The granular fertilizers were introduced as basic fertilization, with soil pre-transplantation at the following norms: N-12.5kg/da, P2O5-1.25 kg/da, + K2O-4.75 kg/da, Italpollina-25 kg/da, Arkobaleno - 100 kg/da, and Lumbricompost - 400 l/da. The liquid bio fertilizer Ekoprop NX was applied by double treatment in a dose of 100 g/da, before planting - in the 5th leaf seedling phase, and 10 days later on, after the adaptation to the soil. The remaining bio fertilizers are granulated and introduced into the soil before the last tillage and before planting the seedlings. The biometric measurements were taken three times at one-week intervals in stage-typical leaf mass reached. Meteorological observations from Plovdiv AU (Agricultural University) station (42 ° 14′N, 24 ° 75′E and 162 m above sea level) were used for the outdoor temperature analysis. The data were collected according to the recommendations of the WMO (World Meteorological Organization) and are comparable with the climatic norm for the region. The daily air temperature was recorded by means of a weather station Meteobot® Pro (https://meteobot.com/). For analysis of the hydro-thermal conditions, the hydrothermal coefficient of Selyaninov (1928), was calculated according to the formula: HTC = ΣR /0.1*ΣT, where ΣR is the sum of the rainfall in mm, and ΣT is the sum of the temperature for the months (IV-VI) with an average temperature above 10°C and classification: <0.4-extremely dry; 0.41-0.7 very dry; 0.71-1-0 dry; 1.01-1.3 quite dry; 1.31-1.6 optimum; 1.6-2.01 quite wet; 2.01-2.5 wet; 2.51-3 very wet. A statistical analysis was conducted using analysis of variance for the main effects; the means of the values were compared with the least significant difference (p = 0.05).

RESULTS AND DISCUSSIONS

According to some Bulgarian and foreign authors (Kartalov et al., 2007; Lorenz and Maynrad, 1988), the optimal temperature for lattuce development is 16.0-18.0°C. Well-rooted plants in phenophase 7-9 leaves can withstand temperatures down to minus 6.0°C (Divina, 2016; Cholakov, 2009). The range of development of the species is between 5.0°C and 25.0°C and below 5.0°C, the growth slows down and stops (Cholakov, 2009). Other authors (Kristensen et al., 1987; Morgan, 1999) consider the temperature of 4.0°C to be

biological minimum. The degree to which lettuce can tolerate adverse temperatures varies considerably depending on the variety. Growing the lettuce outdoors during the three years of the experiment was carried out in different weather conditions. The moment of planting, according to the agro-technical terms, is in the middle of April and the plants adapt to the outdoor conditions for a week. In 2018, the planting and adaptation of the young plants was carried out in an extremely warm month, with an average temperature of 16.4°C and a positive deviation of 4.2°C (Table 1).

Table 1. Amount of precipitation, temperature and deviation compared to the period 1961-1990

Months/years	av. t°C	∂ t °C	max. t°C	date	min. t°C	date	Σmm.	Q/Qn	max.Σmm.	date
April 2018	16,4	4,2	30,5	24	0,4	3	25	59	15	7
May 2018	19,2	2,1	30,2	5	10	3	58	93	17	27
June 2018	22	1,1	33,2	22	11,4	1	119	220	37	29
April 2019	12,6	0,4	27	26	-1,2	3	61	145	21	9
May 2019	18,4	1,3	32	28	2	9	22	34	6	31
June 2019	23,4	2,5	34,2	8	10,6	4	197	364	79	3
April 2020	11,5	-0,7	27,8	18	-2,5	8	90	215	37	5
May 2020	17,6	0,5	32	8	5,4	8	71	108	13	1
June 2020	21,5	0,6	34,7	30	11,3	4	54	101	14	16

In the second year, this period occurred at an average temperature close to the norm (12.6°C) and a positive deviation of 0.4°C, and in 2020 it took place in a colder April (11.5°C) with a negative deviation of (-0.7°C). Lettuce is a cold-resistant crop and the extremely warm April in 2018 was an unfavorable factor for its adaptation and initial development.

In general, during the three experimental years, extremely warm, close to the norm and cool conditions of development were observed. In April 2018, the amount of precipitation was 25 mm, less than usual, with the highest precipitation of 15 mm registered about 10 days before implantation - on 7.04. In the second year the amount was 61 mm, more than the norm, and there were conditions for appearance of an additional stress factor from over wetting. In April 2020 the rainfall was also extremely high - 90 mm, and a single amount of 37 mm fell down 5 days before planting the plants in the soil. During the months of active vegetation, of reaching economic maturity and harvesting in 2018, the temperature conditions were warmer than usual, May-19.2°C with a positive deviation of 2.1°C and June-22°C with a positive deviation of 1.1°C. In 2019, the development after adaptation in the soil and outdoor conditions took place at elevated temperatures with a deviation of 1.3°C for May and 2.5°C for April and May, insufficient rainfall in May and extremely wet June. During the last experimental year the vegetation took place at temperatures close to the norms: May - 17.6°C, June - 21.5°C; and excessive rainfall: May - 71 mm; June - 54 mm, which created conditions for deteriorating product quality, although to a lesser extent compared to 2019 (table 1). The lowest negative temperatures were registered on April 8, 2020 and April 3, 2019: -2.5°C and -1.2°C, respectively, before planting the seedlings. The maximum temperatures exceeded 33.0°C in 2018 and were slightly below 35.0°C in 2020.

The daily average air temperatures had the highest values in 2018 (Figures 1 and 2).

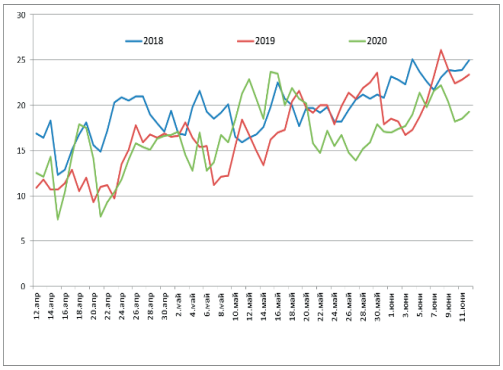

Figure 1. Daly air temperature (t°C), 2018-2020

Lettuce is a cold-resistant vegetable and the warmer weather conditions inhibit its development. The highest productivity and the best biometric indicators were observed for all variants in 2019 - the second year of the study.

During the vegetation until reaching economic maturity, the thermal conditions were closest to the requirements of the species and the warmest period was the one between the first and last harvest, which does not affect the growth of the lettuce, but can affect its taste and qualities. In the third year, the yield values were close, but slightly lower. High temperature amplitudes were observed during the period of planting and adaptation of the plants. In the period of growth and increase of the leaf mass the temperatures were the highest compared to the first and second year, being the lowest between the first and the last harvest.

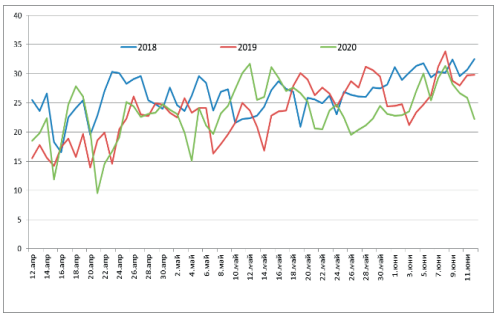

Figure 2. Daly max. temperature (t°C), 2018-2020

The Hydro-thermal Coefficient of Selyaninov, 1928 (HTC, Table 2) was calculated to characterize the humidification under natural conditions.

Table 2. Selyaninov's HTCoef., 2018-2020

Year	month	Selyaninov's HTCoef.	Classification
2018	April	0.51	very dry
2019	April	1.61	quite wet
2020	April	2.61	very wet
2018	May	0.97	Dry
2019	May	0.39	extremely dry
2020	May	1.30	optimum
2018	June	1.80	quite wet
2019	June	2.81	very wet
2020	June	0.84	dry

There were dry periods during adaptation and initial development in April 2018, during the period of accumulation of leaf formation in 2019 and when reaching economic maturity and harvest in 2020. Conditions for stress from overwetting were reported in April 2020, June 2019 and June 2020. In terms of climate, the area of the experiment has values <1.0, and during the experiment extreme manifestations of the weather with high frequency and intensity were observed, which is characteristic of the changes and fluctuations of the climate in the last decades.

Regarding the biometric measurements, the influence of both the combined synthetic fertilizer NPK and of the organic fertilizers on basic parameters such as the number of leaves, the weight of fresh mass g, the diameter of rosette cm, etc. was studied. Both statistically significant differences with respect to the control variants (Cheng-Wei Liu et al, 2014; Alisson Franco Torres da Silva et al, 2017) and higher but not significant ones (Reis et al., 2013; Reis et al., 2014) have been reported, according to the type and concentration of the used fertilizers.

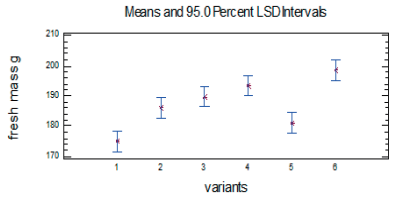

Figure 3. Statistical results - fresh mass weight (g) 29.05

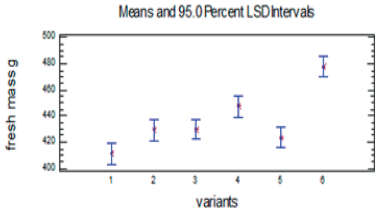

Figure 4. Statistical results - fresh mass weight (g) 12.06

In the recent years, research on the effect of fertilization has aimed at developing a strategy for production of healthy salads with low content of nitrates.

The results of previous studies show that providing lettuce with a combination of organic fertilizers and liquid fertilizers is superior in terms of soil quality, appearance, and the accumulation of nitrate (Cheng-Wei Liu et al., 2014).

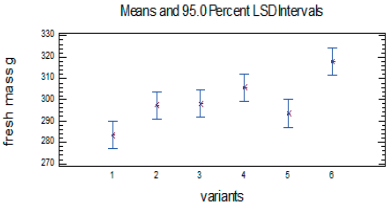

Figure 5. Statistical results at average values of the fresh mass weight

There are many varieties of lettuce in a huge range of colors, leaf shapes and sizes for almost any look. There are also burgundy or red leaved types like, and numerous types mottled or variegated in shades of green and red. Leaf shape varies with choices of smooth edged or

deeply indented, such as oak leaf types, and flat or frilly. 'Lollo Rosso' type plants are characterized by a moderate growth rate and development and form a smaller vegetative mass, which can also be seen from the measurements of the 'Tuska' variety. In this three-year experiment, the influence of different fertilization technologies was verified by means of the basic biometric data on key indicators such as fresh mass weight and number of leaves formed outdoors in different weather conditions. The results show that the plants have an average weight of 299.43 g, varying from 171.16 g. at the first measurement up to 487.05 g. at the third. The data show the highest values for variant 6 Ekoprop NX, followed by variants 4 and 2. All organically fertilized variants are superior over the non-fertilized ones, with the exception of variant 5 and also variant 2 NPK. The reported differences are statistically significant for the first and third measurements, as well as for the average value of the fresh mass weight (Figures 3, 4 and 5).

Similar results were found regarding the influence of fertilization on the number of formed leaves. It varied from 22 at the first measurement to 38, and on average the plants had 29 leaves. The smallest number of leaves had the unfertilized variant - 28.51, and the others – as it follows: 2- 29.45 3-29.39; 4-29.67; 5-29.20756; 6- 30.35.

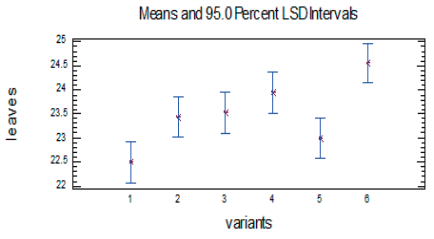

Figure 6. Statistical results - number of leaves 29.05

Variant 6 was with the largest number of leaves (with two more leaves), and all organic fertilization variants are superior both to the control one and to the synthetic fertilizer variant 2. The analysis shows statistically significant differences in this indicator as well (Figure 6). During the three years, the analysis of the biometric data showed a stable superiority of the biofertilized variants over the non-fertilized ones, variants 4 and 6 being superior over the NPK-fed variant as well.

CONCLUSIONS

Basic meteorological parameters such as air temperature and precipitation for the period 2018-2020 in the region of Plovdiv were measured and analyzed. The development of the plants in the considered variants took place in an extremely warm, a close to the norm and a slightly cooler spring. The hydrothermal conditions varied in a wide range, with HTC between extremely dry (0.34) and very wet (2.81) and there were prerequisites for deterioration due to over wetting. The three years of the experiment were characterized by the following values: HTC 2018 quite dry 1.05; 2019 wet 2.37; 2020 optimum 1.31. During the period extreme manifestations of the weather, characteristic of the climate changes in the last decades, were registered. This was also one of the reasons for studying outdoor organically grown lettuce as a method of adapting crop production to the current conditions. The biometric data on its fresh mass weight, rosette diameter and number of leaves were similar and stable over the three years of the experiment. Statistically significant differences in the weight of the fresh mass g and the number of leaves were reported, compared both to the control and to the NPK mineral fertilization variant, with the best indicators being with the variants fertilized with Arkobaleno and Ekoprop NX. The yields were highest in the second year, when the temperature conditions were closest to the norms, and lowest in the last experimental year. The organically grown plants consistently outperformed both the unfertilized plants and the synthetically fertilized variant, with the exception of the variant number 5 LC. The results show that widespread use of organic production of 'Lollo Rosso' lettuce in spring outdoor planting can be recommended, having in mind that the best indicators are reported for variants 4 and 6 - Arkobaleno and Ekoprop NX. It is possible to comment on the continuation of the research with higher concentrations of organic fertilizers, needless to say with consideration of nitrate content

accumulation in the leaves of the 'Lollo Rosso' salad.

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