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COMPARATIVE STUDY OF LEMON BALM (*MELISSA OFFICINALIS* L.) YIELD IN ORGANIC AND CONVENTIONAL AGROECOSYSTEMS

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Abstract

The study was conducted in the period 2023-2025 in the land of the village of Bogdanitsa, Sadovo Municipality, Bulgaria. The growth and yield of dry and fresh mass of lemon balm in production fields under organic and conventional farming conditions were studied. In both agrocenoses, the soil fertilizers triple superphosphate (30 kg/da) were applied in the conventional field and Lumbreco (200 ml/da) + Biohumus (40 kg/da) in the organic field. The samples were collected at the beginning of the flowering phenophase. Separation of the leaves was done manually, and the drying of the plant mass in the shade at room temperature. The indicators were recorded: fresh mass (l+s), fresh leaves, fresh stems, dry leaves (herba), dry stems. The values of the indicators (fresh mass and herb) of the organic lemon balm plantation did not fall behind those of the conventional one over the years. From 1 kg fresh mass of lemon balm from the organic plantation in 2024, higher values for herb (l+s) are obtained - 363.8 g, which is nearly 4% more than that of the conventional plantation - 329.67 g. A higher yield of fresh mass and fresh leaf mass of lemon balm by 12%, and of leaf herb by 3% was recorded in the organic plantation compared to the conventional one.
Keywords: herb, lemon balm, organic farming, yield

INTRODUCTION

Lemon balm (*Melissa officinalis* L.) belongs to the Lamiaceae family and is a popular herb whose qualities have been valued since ancient times, which is why it has been used in traditional medicine as a medicinal plant. The extract from the plant has antioxidant, anti-inflammatory, analgesic, and other valuable properties that improve cognitive disorders, anxiety, and insomnia in humans (Zarei et al. 2015). According to Oliveira et al. (2025), the positive effects on sleep quality are attributed to the presence of rosmarinic acid, which influences the activity of γ-aminobutyric acid transaminase. Regarding cognitive functions, it has been found

that the plant improves cognitive performance and mood in humans. This defines lemon balm as a suitable dietary supplement for improving sleep, reducing anxiety, and stress. Evidence suggests its potential to alleviate symptoms related to Alzheimer's disease, which is significant for older adults without dementia. Melissa officinalis L. is widely used both as an herb and in the cosmetic industry due to the composition of its essential oil. To improve the quality of the essential oil and lemon balm production, various agricultural practices with organic and mineral fertilization have been studied. In their study, Sodré et al. (2012) found that, under different doses and types of fertilization, the chemical components in the oil remain the same, but their ratios change depending on the fertilization technology. The main components are neral, geranial, and citronellal. Seidler-Łożykowska et al. (2015) emphasize the importance of the origin and quality of raw materials from medicinal plants. For their use in the herbal and cosmetic industries, the raw material must be of high quality in terms of active substances, free of residual pesticides and heavy metals, and ensure stable yields. This directs the attention of producers toward the organic cultivation of lemon balm for clean and high-quality production. A study on organically and conventionally grown lemon balm in Poland found that the yield is higher in the conventional agroecosystem, while the content of essential oil, its composition, and quality do not differ. A key difference was found in the quantitative content of two compounds in the essential oil: neral and geranial, which are present in higher concentrations in lemon balm from the conventional agroecosystem. This supports the research of Sodré et al. (2012), who mentioned changes in the content of the compounds neral, geranial, and citronellal. The use of different cultivation methods and technologies, such as planting density and harvesting techniques, along with environmental conditions, determine the yield and quality of the lemon balm raw material (Nurzynska-Wierdak et al., 2023). According to the authors, a lower planting density (40x40 cm) is a better option for achieving better results in yields of fresh biomass, dry plant material (herb), leaf herb, essential oil, tannins, and flavonoids compared to a density of 30x30 cm. Better yields are obtained when harvesting twice, in July and September, compared to a single harvest in September. Growing lemon balm in a temperate climate and combining suitable climatic factors is as effective as growing it in warmer regions. Similar studies on the impact of planting density on lemon balm yields and essential oil, as well as the use of mulching film, were conducted in Serbia across three regions. An economic evaluation was also made based on different cultivation variants (Gordanić et al., 2025). In a comparative study of organically grown and conventionally grown lemon balm, Kazimierczak et al. (2015) reported that organically grown plants contain more vitamin C, total flavonoids, and phenolic acids, while conventionally grown plants contain more carotenoids. The authors determined that the bioactive substances in medicinal plants grown through organic farming are a prerequisite for their widespread use in a healthy diet. Organically produced raw materials have pharmacological effects, and the flavonoid content depends on the year’s conditions and the type of medicinal plants. Their results are also supported by other studies on medicinal plants (Kazimierczak et al., 2010; Kazimierczak, Hallmann et al., 2010), which report a higher content of dry matter in the fresh biomass of organically grown

plants compared to those grown in a conventional. It has been reported that the use of mineral nitrogen fertilizers in conventional agroecosystems increases both the yield and the water content in the cells, which is accompanied by a lower dry matter content in conventionally grown plants (Brandt & Mølgaard, 2001). A study on the concentration of bioactive compounds in other herbs from organic and conventional farming (Hallmann & Sabata, 2020) confirmed that herbs grown under organic farming conditions contain significantly more total polyphenols, flavonoids, and phenolic acids compared to conventionally grown herbs, which are richer in chlorophylls and carotenoids. The age of the plants influences the concentration of components in the essential oil derived from dried lemon balm leaves (herb). Essential oil obtained from two-year-old plants has a richer chemical composition compared to that from one-year-old plants (Nurzyńska-Wierdak et al., 2014). A positive effect on the growth, development and yield of fresh and dry mass (herba) after the application of organic fertilizers was also found in another study with lemon balm grown in an organic agroecosystem. According to Zorovski et al., (2020) the application of various organic foliar fertilizers had a positive effect on the height, number of stems and weight of fresh mass (fertilization with Triven); the number of branches and leaves and weight of leaf mass (fertilization with Amalgerol); weight of dry mass of leaves (herba) after treatment with Amalgerl and Litovit. No changes in the occurrence of phenological phases in organically grown lemon balm were found as a result of the application of organic fertilizers. The different stages of harvesting lemon balm have an impact on some yield and quality characteristics. In their study, Avaci & Giachino (2016) harvested lemon balm in three growth periods: before flowering (in May), during flowering (in August) and after flowering (in November). The analyses show that plant height, fresh herb yield, dry herb yield (herba), dry stem yield and essential oil content are influenced by the stages of harvesting. The highest essential oil content was obtained in the flowering phase of the plant. Interest in lemon balm is growing due to its proven health benefits, especially in the psychological field. Pharmacological studies have shown that lemon balm and the substances it contains have calming and antidepressant properties and improve sleep quality (Mathews et al., 2024). Cultivation of essential oil and flavor plants is a serious economic alternative for owners of low-yielding semi-mountainous and mountainous lands. Additional research in this area will complement or confirm previous studies in this area. The aim of the present study is to compare the yields of lemon balm grown in organic and conventional agroecosystem conditions. This will present the importance of organic production, the stability of the organic agroecosystem and the opportunities for lemon balm producers.

MATERIALS AND METHODS

A study was conducted in the period 2023-2025 in two production plantations with lemon balm (*Melissa officinalis* L.) variety Melissa in the region of the village of Bogdanitsa, Bulgaria. The two plantations were created in different agroecosystems - conventional and organic (certified organic farming field) with spatial isolation and different technologies for growing the crop. Soil analyses were performed using testing methods (Validated Laboratory Methods): BDS ENISO 10390:2022; ISO/TS 14256-1:2003; BDS ISO 11263:2006; GOST 26209:1992 in

the Laboratory Testing Complex at the Agricultural University of Plovdiv. The plantations were fertilized with triple superphosphate (30 kg/da) in the conventional and Lumbreco (200 ml/da) + Biohumus (40 kg/da) in the organic plantation. The height of the plants at technical maturity x 10 units was measured in three replicates. The fresh plant mass from the lemon balm was harvested at the beginning of the phenological flowering phase /June - July/. The amount of the collected sample of fresh plant mass (leaves + stems) for analysis was 1000g in 3 replicates. The separation of the fresh leaves from the stems was done manually in laboratory conditions, and drying was done in the dark at room temperature. The following indicators were recorded: weight of fresh leaf mass, g; weight of dry leaf mass (herb), g; weight of fresh stems, g; weight of dry stems (herb), g; ratio of fresh to dry mass of lemon balm (%) under the conditions of two different agroecosystems (organic and conventional). Statistical processing of the experimental data was performed using SPSS V.13.0 for Microsoft Windows using Duncan's method, Anova (SAS Institute Inc. 1999).

RESULTS AND DISCUSSION

1. Agroclimatic characteristics.

Climatic conditions during the growing season are one of the main factors that have a strong influence on the growth, yield and quality of the crop production. The data on the monthly precipitation amounts and average monthly temperature values for the three-year study period 2023 - 2025 characterize the individual years as relatively warm, with temperature values above the norm for the long-term period and unevenly distributed precipitation by month (Table 1). The months from January to March have temperature values above the norm in all three years, which defines them as warm and the lemon balm vegetation starts at the end of February. These months are accompanied by a precipitation amount close to the norm with the exception of February, when it is scarce in all three years compared to that for the long-term period.

Table 1. Average monthly air temperatures and monthly amount of rainfall for the study period (2023-2025).

Months	I	II	III	IV	V	VI	VII
Years	Temperature (˚C)						
2023	5.9	6.5	8.9	12.3	16.3	22	27.2
2024	3.7	9.5	10.6	16.2	16.9	26.3	27.6
2025	3.3	1.7	10.3	12.5	17.5	24.8	27.5
Average monthly temperature - norm 1965 – 1995	-0.4	2,2	6	12,2	17.2	20.9	23.2
	Rainfall (mm/m^2)						
2023	33.1	3	31	58	65.1	79	25
2024	47	6	39	32	83	2	24
2025	26	20	49	78	64	28	11.4
Amount of rainfall - norm 1965 - 1995	40	48	44	39	32	36	42

From March to July, when the harvest is, the precipitation is unevenly distributed, as in the months of April and May they are even above the norm. This amount of precipitation, combined with temperature values close to normal, allows for plant growth and the formation of a large above-ground mass. The most abundant rainfall in April is 2025, and 2024 in May. June 2023 has the highest rainfall values compared to the other two years, and in 2024 they are even scarce (2 mm/m^2 at a rate of 36 mm/m^2). During this period, the plantations suffer from drought and reduce the yield of lemon balm leaves (Table 4), as they dry out and fall off before mowing.

The low amount of rainfall before mowing in July and the warm weather contribute to the accumulation of dry matter in the plants in different years. In general, the studied period 2023-2025 is characterized by warm weather and good, but unevenly distributed monthly amount of rainfall. These conditions, together with the specific cultivation technology: organic and conventional, reflect on the yield of fresh and dry mass of lemon balm in the two different agroecosystems.

2. Soil characteristics in organic and conventional lemon balm plantations.

The soil environment is the main factor for the growth and development of plants, providing them with a nutrient environment and conditions for yield and quality production. The soils in the studied agroecosystems in the region of the village of Bogdanitsa (Sadovo municipality) are closely located areas and are of the same soil type with a heavy mechanical composition.

During the study period, the soil in the conventional lemon balm plantation is characterized by an alkaline reaction - pH 8.14. It has an average phosphorus supply, a good potassium supply and a low nitrogen supply. It is characterized by a heavy mechanical composition, with a clay content of 43.36% (Table 2).

Table 2. Data from a study of soil samples from a conventional and organic lemon balm plantation, village of Bogdanitsa.

Variant	pH	Mobile total nitrogen, mg/1000g	Mobile phosphoru, P_2O_5	Mobile potassiu, K_2O	Sand	Dust	Clay
			mg/100g	mg/100g	%	%	%
Conventional agroecosystem	8.14	16.39	31.50	44.86	18.08	48.28	43.36
Organic agroecosystem	8.19	10.27	36.71	51.37	15.16	45.57	34.70

In the biological agrocenosis with lemon balm, the soil is of the same soil type with an alkaline reaction - pH 8.19, low nitrogen content (10.27 mg/1000g), average phosphorus (36.71mg/100g) and very good potassium (51.37 mg/100g). The soil has a heavy mechanical composition, and the clay content is 34.7%. The soil conditions in both agroecosystems are similar and provide the same soil environment for plants. The soil fertilizers used in both agroecosystems during the lemon balm vegetation period have an impact on plant nutrition, yield and quality of the resulting production.

3. Biometric indicators of lemon balm in organic and conventional agroecosystems.

3.1. Plant height at technological maturity.

Plant height is an indicator that is influenced by the cultivation method and environmental conditions. From the data in Table 3, it can be seen that in 2023 and 2025, the plants in both agroecosystems reached relatively the same height, and although statistically unproven, higher values of the indicator were obtained in the conventional agroecosystem. In it, the plants were taller than those in the organic one by 11 cm in 2023 and by 5.7 cm in 2025. These differences can be due to both the composition of the fertilizers used and the rate of absorption by the lemon balm grown using both technologies - conventional and organic.

Table 3. Height of lemon balm plants in conventional and organic agroecosystems during the study period, cm.

Variant / Year	Height			Average for the period
	2023	2024	2025	
Conventional agroecosystem	59.6[b]	90.13[a]	56.07[b]	68.6
Organic agroecosystem	48.6[b]	90.37[a]	50.33[b]	63.1

*Means followed by the same letter are not statistically different (P<0.05) by Duncan's multiple range test

The highest height was recorded in 2024. which is explained by the combination of heavy rainfall in May significantly above normal, high temperatures (Table 1.) and delayed mowing. Statistical differences in plant height between the two agroecosystems within individual years are not proven. On average for the study period, plants from the conventional agroecosystem are taller – 68.6 cm compared to those in the biological – 63.1 cm.

4. Yield of fresh and dry plant matter from lemon balm in a conventional and organic agroecosystem.

The data show that the distribution of individual elements of lemon balm yield between the different years of study varies within narrow limits within the variant. The largest share of fresh mass of leaves and stems was recorded in 2023 in both growing technologies - conventional and organic. A greater amount of fresh leaf mass was recorded in lemon balm grown in organic farming conditions compared to that in the conventional agroecosystem (Table 4). In 2025 in organically grown lemon balm the largest amount of fresh leaf mass was recorded - 614g/1000g fresh mass (l+s) at 334.49g/1000g for the conventional. In contrast, the amount of fresh stems is highest in the conventional agroecosystem compared to the organic one. The distribution of herbage yield is higher in all three years in the organic lemon balm, and herba stems in the conventional one. The total amount of herba (l+s) is highest in the lemon balm grown under organic farming conditions.Тенденцията в показателите от отделните години се запазва и в средните им стойности за тригодишния период на проучване. The proven highest value of fresh stem mass – 637.79g/1000g fresh mass (l+s) (63.8%) was recorded in the conventional agroecosystem, and the smallest share was for herba leaves – 12.3%. In the organic agroecosystem, the proven highest amount was for

fresh leaf mass – 476.18g/1000g fresh mass (l+s) at 362.21g/1000g for the conventional, which is 47.6% to 36.2%, and fresh stem mass – 523.82g/1000g fresh mass. The ratio of fresh stem mass is 63.8% for the conventional at 52.4% for the organic agroecosystem. The yield of lemon balm herb leaves in conventional technology is 12.3% (122.84g/1000g), and in organic technology it is higher - 16.1% (161.04g/1000g fresh mass). In the yield of herb stems, the trend is the opposite. Higher values of the indicator were obtained from lemon balm grown in the conventional agroecosystem – 214.04g/1000g fresh mass, which is 21.4% compared to 17.7% for the organic one. On average for the study period 2023-2025 the yield of herb (l+s) from lemon balm is approximately the same in both growing technologies – conventional and organic.

Table 4. Distribution of structural elements of the yield of fresh and dry plant mass (herba) of lemon balm by variants during the study period, referred to 1000g fresh mass (leaves + stems).

Variant	Conventional agroecosystem (C)					Organic agroecosystem (O)					% compared to (C) Average for the period
Year Indicators	2023	2024	2025	Average	%	2023	2024	2025	Average	%	
Dry mass (Herba) (l+s), g	311.20	329.67	369.75	336.8^{b}	33.7	312.32	363.83	337.83	337.9^{b}	33.8	+0.33
Fresh leaves mass, g	529.50	222.63	334.49	362.2^{b}	36.2	565.1	249.43	614	476.2^{a}	47.6	+31.5
Dry leaves mass (Herba), g	169.53	77.19	121.79	122.8^{c}	12.3	181.31	93.52	208.28	161.0^{b}	16.1	+31.1
Fresh mass of stems, g	470.50	777.37	665.51	637.7^{a}	63.8	434.90	750.57	386	523.8^{a}	52.4	-18
Dry mass (Herba)stems,g	141.67	252.48	247.96	214.0^{bc}	21.4	131.01	270.31	129.55	176.9^{b}	17.7	-17

*Means followed by the same letter are not statistically different (P<0.05) by Duncan's multiple range test; "+", "-" – the percentage of the indicator in the biological agroecosystem compared to the same in the conventional one.

The percentage distribution of the structural elements of the yield of fresh plant mass shows that in the yield of lemon balm from the organic production option, the fresh mass of leaves is 31.5% higher, herb leaves by 31.1%, and the indicators of fresh mass and herb stems are lower compared to the conventional production option. The trends observed in the indicators over the years within the variant and the differences between the variants on average for the study period are due to both the influence of meteorological conditions and a number of other factors in the agroecosystem - soil type, composition of fertilizers used in the two agroecosystems, etc. From 1kg of fresh mass of the organic plantation, 476.18g of fresh leaves are obtained; fresh stems – 523.82g, herb leaves - 161.04g, herb

stems 176.96g and 337.9g herb (l+s). The data in Table 4 shows that the lemon balm in the organic agroecosystem has higher values of the indicators of fresh and dry leaves compared to that in the conventional one. These results confirm some results of other authors, according to which, depending on the types of fertilizers used in the two agroecosystems (organic and conventional), higher values for dry matter, herb and fresh mass are obtained in the organic one (Zorovski et al., 2020; Kazimierczak et al., 2010; Kazimierczak, Hallmann et al., 2010; Brandt & Mølgaard, 2001).

CONCLUSIONS

Meteorological conditions have a great influence on the yield and quality of the obtained fresh plant mass of lemon balm. Plants from both agroecosystems reach relatively equal height in technological maturity (phase beginning of flowering), and although statistically unproven higher values for plant height were obtained in the conventional agroecosystem. For the period of the study, plants from the conventional agroecosystem were 68.6cm tall compared to those in the organic one – 63.1cm. The yield of herb (l+s) from lemon balm is approximately the same in both agroecosystems – conventional and organic. The percentage distribution of the structural elements of fresh plant mass yield shows that in the organic production variant, the fresh mass of leaves is 31.5% higher, herb of leaves is 31.1% higher, and the indicators of fresh mass and herb of stems are higher in the conventional production variant.

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