

## THE EFFECT OF ORGANIC FERTILIZATION ON PRODUCTIVITY AND BIOCHEMICAL COMPOSITION IN THREE CULTIVARS OF *Lavandula angustifolia* Mill. GROWN IN THE BUZĂU PLAIN

Traian Ciprian STROE<sup>1,2</sup>, Liliana MIRON<sup>2</sup>, Corina GAVĂȚ<sup>2</sup>, Dan Răzvan POPOVICIU<sup>2</sup>,  
Liliana PANAITESCU<sup>1,2</sup>

<sup>1</sup>University of Agronomic Sciences and Veterinary Medicine of Bucharest,  
59 Mărăști Blvd, District 1, Bucharest, Romania

<sup>2</sup>Ovidius University of Constanța, University Alley, Campus building B,  
900470, Constanța, Romania

Corresponding author email: str\_ciprian@yahoo.com

### Abstract

A multiannual study (2020-2024) was carried out in the Buzău Plain to assess the impact of organic fertilization on productivity and biochemical composition in three cultivars of *Lavandula angustifolia* Mill. ('Vera', 'Munstead', 'Codreanca'). The fertilization regime included organic nitrogen sources (blood meal, compost), phosphorus (natural phosphates), and potassium (mineral-origin potassium sulfate), with periodic supplementation of basalt rock meal. Growth and yield parameters (plant height, number of flowering stems, inflorescence mass, essential oil yield) were monitored alongside biochemical indicators (phenolic compounds, carotenoids, ascorbic acid). Significant cultivar-dependent differences were observed, with 'Vera' consistently showing superior performance in both productivity and secondary metabolite accumulation. Statistical analysis revealed strong correlations between the number of flowering stems and essential oil yield ( $r = 0.87$ ), as well as between fertilization intensity and phenolic compound content (~40% increase from minimum to maximum dose). The findings demonstrate that organic fertilization plays a crucial role not only in sustaining floral yield but also in enhancing biochemical quality. This study underlines the synergistic effect of genetic background and sustainable nutrient management, offering practical recommendations for expanding organic lavender cultivation and improving the economic and therapeutic value of its raw material.

**Key words:** Buzău Plain, carotenoids, essential oil, lavender, organic fertilization, phenolic compounds, productivity.

### INTRODUCTION

Lavender (*Lavandula angustifolia* Mill.) is one of the most valued aromatic and medicinal species worldwide, with its essential oil extensively used in perfumery, cosmetics, the food industry, and phytotherapy due to its aromatic profile and bioactive potential. Review literature attributes sedative, anxiolytic, and antimicrobial properties to the oil, while also emphasizing the variability of its composition depending on genetic origin and environment (Basch et al., 2004; Prusinowska & Smigielski, 2014).

Medicinal and aromatic plants represent an important resource for both agriculture and industry, due to their biochemical diversity and wide range of applications. Recent studies conducted in Romania emphasize the need to optimize cultivation practices and harvesting technologies for medicinal species grown on

small areas, in order to improve yield and quality parameters (Muscalu et al., 2022). Sustainable horticultural systems that integrate aromatic and medicinal plants in co-cultivation schemes have also demonstrated important agronomic and ecological benefits (Maknea et al., 2022), supporting the interest in developing environmentally friendly management strategies for high-value crops.

The composition of *Lavandula angustifolia* oil is dominated by oxygenated monoterpenes (e.g., linalool and linalyl acetate), whose proportions are linked to phenological stage, growth conditions, and cultivation technology. Studies on European and Romanian populations/cultivars have revealed marked differences in aromatic profiles and bioactivity, reflecting both genetic background and local pedoclimatic conditions (Jianu et al., 2013; Carrasco et al., 2016). Alongside volatile components, the polyphenolic fraction

(phenolic acids, flavonoids, tannins) and other non-volatile antioxidants contribute to the functional potential of the raw material. Analytical research on *Lavandula angustifolia* has identified both quantitative variation in phenolics and the occurrence of new compounds with potential impact on the antioxidant and antimicrobial properties of extracts (Rădulescu et al., 2017; Yadikar et al., 2018). Essential oil yield and quality are strongly influenced by environmental factors (temperature, light, humidity), flowering stage, and harvest/conditioning technology. The dynamics of oil production during flowering require the adaptation of agronomic practices to the optimal window for content and quality (Hassiotis et al., 2014; Erland & Mahmoud, 2016; Crișan et al., 2023). At the genetic and physiological levels, significant resources exist for regulating oil biosynthesis, and genomic tools provide pathways for understanding the metabolic control that determines yield and compositional profile (Lane et al., 2010). These advances support the selection/breeding of genotypes adapted to stress and targeted quality profiles, an increasingly relevant objective in the context of climate change (Balmus & Calalb, 2020).

Beyond genetic and climatic factors, nutritional management plays a central role. Although lavender is relatively modest in its requirements, the ratio and source of nutrients can modulate both vegetative/reproductive biomass and the yield and signature of the oil. Results obtained under Romanian pedoclimatic conditions suggest the existence of an optimal nitrogen level, while balanced fertilization remains critical to avoid dilution of volatile compounds or excessive stimulation of vegetative growth at the expense of inflorescences (Paraianu & Marinica, 1994; Hassiotis et al., 2014).

Interest in ecological fertilization and crop protection solutions has grown, both due to market demand (for “clean label” products) and environmental considerations. At the same time, discussions on the use of lavender oils as adjuvants/bioprotectants in the food chain highlight the importance of standardized-quality raw materials (Kumar et al., 2025).

In Romania, lowland areas with chernozem soils and moderate rainfall regimes offer

favorable conditions for lavender cultivation, and regional studies have documented differences in productivity and quality depending on ecotope and applied technology. Furthermore, the emergence of new cultivars in Eastern Europe confirms the species’ plasticity and adaptation potential to local conditions (Pokajewicz et al., 2021; Crișan et al., 2023).

The adoption of sustainable agricultural practices has become increasingly relevant, as farmers seek to improve soil fertility and reduce environmental impact. Surveys conducted in Romanian agricultural regions have shown a growing interest in carbon-friendly and sustainable farming activities (Oroian et al., 2024), which aligns with the principles of organic fertilization applied in the present study. Such approaches are essential for maintaining long-term productivity and supporting the resilience of agroecosystems.

In lavender crops, fertilization directly influences vegetative development and the quantity and quality of essential oil. Although the species is considered rustic and capable of valorizing soils with low fertility, its response to nutrition cannot be neglected. Research carried out in Romania has shown that rational nitrogen application positively influences biomass, but that there is an optimal threshold above which excessive nitrogen may reduce the concentration of key aromatic compounds (Paraianu & Marinica, 1994). These results highlight the need for balanced doses adapted to local pedoclimatic conditions. The current trend favors organic fertilization, using sources of nitrogen, phosphorus, and potassium that provide slow release and better synchronization with plant development. In addition, such technologies reduce environmental impact and generate a final product compatible with organic market standards. Recent studies have emphasized that not only nutrient input but also the timing and method of application influence both vegetation dynamics and the metabolic quality of flowers and extracted oil (Crișan et al., 2023; Hassiotis et al., 2014).

In the scientific literature, multiple studies have demonstrated the influence of fertilization on the development and yield of *Lavandula angustifolia*. For example, Manescu and Dudau (2024) showed that both organic and mineral fertilizers stimulate vegetative growth and

flowering in young lavender plants, with direct implications for the economic value of crops. Their results underscore the importance of balancing nutrient sources to avoid excesses that could affect the metabolic quality of inflorescences. Similarly, Mihalascu et al. (2020) reported that differentiated fertilization leads to significant variations in flower and essential oil yield across several lavender varieties grown in southeastern Romania. Panaitescu et al. (2018) also confirmed that lavender's productive potential is closely correlated with adaptability to local pedoclimatic conditions and with the application of appropriate nutritional technology. These findings contribute to the growing body of knowledge on the role of fertilization in optimizing both yield and biochemical quality in lavender.

Furthermore, recent investigations into the biochemical potential of essential oils extracted from various medicinal plants revealed significant antifungal and bioactive properties, highlighting the importance of understanding how cultivation practices influence phytochemical profiles (Stan et al., 2022). These findings reinforce the relevance of evaluating both productivity and biochemical attributes in *Lavandula angustifolia* under organic fertilization regimes.

The aim of the present study is to integrate, based on multiannual determinations in the Buzău Plain, the evaluation of crop productivity (morpho-productive indicators and oil yield from inflorescences) with the biochemical profile of raw material (phenolic compounds, carotenoids, ascorbic acid) under an organic fertilization regime. The approach seeks both to quantify five year averages and to discuss the relationships between nutritional management, agronomic performance, and oil quality, in order to formulate practical recommendations applicable to local pedoclimatic conditions.

## MATERIALS AND METHODS

The study was designed as a multiannual experiment, conducted over five years (2020-2024) in the Buzău Plain, an area characterized by a moderately continental climate and cambic chernozem soil, with neutral reaction and an

average humus content of approximately 2.8%, conditions considered favorable for aromatic species (Hassiotis et al., 2014). The choice of this location was based on lavender's adaptability to relatively restrictive pedoclimatic conditions, as well as the growing interest in aromatic plant cultivation in lowland areas.

The biological material included three cultivars of *Lavandula angustifolia* Mill., each with distinctive morphology and composition: 'Vera', of British origin, recognized for its fine aroma and high essential oil yield; 'Codreanca', bred in Romania, valued for its winter hardiness and specific carotenoid content; and 'Munstead', a traditional cultivar with consistent productivity and good oil quality. The crop was established in the spring of 2019 using rooted cuttings planted at 100 cm between rows and 80 cm between plants within the row, resulting in a density of approximately 12,500 plants/ha.

In each experimental year, an organic fertilization regime was applied, using products permitted in organic farming, with doses expressed in active substance. Organic nitrogen sources included blood meal and mature compost, equivalent to an annual rate of 60 kg N/ha. Phosphorus was supplied via soft natural phosphates (40 kg P<sub>2</sub>O<sub>5</sub>/ha), and potassium through mineral-origin potassium sulfate (50 kg K<sub>2</sub>O/ha), applied mainly in autumn to ensure availability at the onset of vegetation. Every two years, basalt rock meal was added (300 kg/ha) to supply microelements.

The organic fertilization scheme was conceived as a staged process to provide both basic nutrition and gradual replenishment of humus and mineral reserves in the soil. The scheme was repeated annually, with slight adjustments depending on weather conditions, but the basic principles remained constant. Thus, each autumn, after the last maintenance work and before dormancy, phosphorus and potassium were applied: soft natural phosphates (40 kg P<sub>2</sub>O<sub>5</sub>/ha) and natural potassium sulfate (50 kg K<sub>2</sub>O/ha), incorporated superficially into the arable layer by light discing. This aimed to stimulate the development of a healthy root system and ensure a good start for the following season.

In early spring (march), immediately after vegetation resumed, organic nitrogen sources were applied: blood meal and mature compost. The 60 kg N/ha dose was split into two fractions: half incorporated before vegetation onset, and half applied at the beginning of flower stem formation (april-may). This fractioning was intended to prevent leaching losses and synchronize nitrogen availability with the plant's peak demand. To maintain overall soil fertility, basalt rock meal (300 kg/ha) was applied every two years, providing microelements such as Mg, Fe, Mn, and Zn, essential for enzymatic activity and the synthesis of aromatic compounds. In addition, moderate doses of plant compost (5 t/ha) were applied annually to supply organic matter and improve soil structure. The entire fertilization scheme was designed in accordance with organic farming regulations, avoiding any synthetic chemical inputs. Doses were calibrated to support balanced growth: sufficient vegetative mass to sustain flower production, but without excessive stimulation of foliage at the expense of aromatic compound accumulation (Paraianu & Marinica, 1994).

The choice of fertilization scheme was informed by observations from similar studies conducted in Romania. Manescu and Dudau (2024) reported that combined application of organic and mineral fertilizers leads to harmonious vegetative development and enhanced flowering. Similarly, Mihalascu et al. (2020) demonstrated that fertilizer type and dose significantly influence not only flower yield but also essential oil yield, supporting the relevance of differentiated nutritional technologies.

Morpho-productive measurements included vegetative size (plant height, average diameter, effective density per hectare) and reproductive performance (number of flowering stems per plant, inflorescence length and mass, both fresh and dry). Essential oil production was quantified by classical hydrodistillation using Clevenger apparatus, expressed as milliliters of oil per 100 g of dried flowers and extrapolated to yield per hectare.

In addition to agronomic parameters, biochemical characteristics of inflorescences were analyzed. Dried and ground samples were subjected to determination of carotenoids (total

and fractions -  $\beta$ -carotene, lutein, lycopene) by UV-VIS spectrophotometry; phenolic compounds by the Folin-Ciocalteu method and spectrophotometric fractionation (phenolic acids, flavonoids, tannins, anthocyanins) (Yadikar et al., 2018); and ascorbic acid content by colorimetric reaction with ammonium molybdate. Determinations were performed in triplicate, and results expressed as multiannual means.

Statistical analysis included both one-way ANOVA tests to compare differences among cultivars and calculation of Pearson correlation coefficients to assess relationships between morpho-productive and biochemical parameters. In addition, simple linear regression models were fitted to test the prediction of essential oil production based on the number of flowering stems, as well as on phenolic compound and carotenoid content (Crişan et al., 2023). The significance threshold was set at  $p < 0.05$ .

## RESULTS AND DISCUSSIONS

The determinations carried out over the five years of study provided relevant data on the productive potential and biochemical quality of the tested *Lavandula angustifolia* cultivars. The values presented in table below (Table 1) reflect multiannual means and highlight consistent differences among genotypes. The cultivar 'Vera' stood out with the highest values for most morphological indicators: the average plant height was 59.5 cm, significantly exceeding both 'Codreanca' (55.2 cm) and 'Munstead' (57.5 cm). These differences were statistically confirmed by ANOVA testing ( $p < 0.05$ ).

Shrub diameter followed the same trend, with values of 105.2 cm for 'Vera', compared to 97.8 cm for 'Codreanca' and 101.2 cm for 'Munstead'. This dimensional superiority partly explains the higher floral production capacity observed in 'Vera'. The average number of flowering stems per plant was 228 in 'Vera', representing a clear advantage over 200 in 'Munstead' and 190 in 'Codreanca'. Similar productivity trends have been reported for other medicinal species cultivated under Romanian conditions, where optimized harvesting and cultivation practices significantly influenced

yield parameters (Muscalu et al., 2022). These findings underline the importance of adapted agronomic techniques in maximizing biomass accumulation, even in species traditionally considered resilient or low-input. This parameter is essential, as it directly determines the plant's reproductive potential and the volume of raw material available for essential oil extraction. Indeed, the literature indicates that oil yield is closely correlated with the number and length of flowering stems (Crişan et al., 2023), an observation confirmed by the present data.

Regarding inflorescence mass, differences among cultivars were also evident. The average fresh mass per inflorescence was 0.95 g in 'Vera', compared to 0.88 g in 'Munstead' and only 0.82 g in 'Codreanca'. After drying, masses decreased but relative differences were maintained: 0.45 g for 'Vera', 0.40 g for 'Munstead', and 0.39 g for 'Codreanca'. These

results confirm that both biomass and drying quality depend on genetic particularities, as well as their interaction with the applied cultivation technology (Hassiotis et al., 2014).

Analysis of the annual data series (not presented in detail in this article) showed that 'Vera' and 'Munstead' recorded smaller variations depending on climatic conditions, while 'Codreanca' displayed wider fluctuations, especially in drought years. This stability is essential for growers, as it ensures greater predictability of income, and for the processing industry it is important for maintaining consistent quality of the final product. Thus, the superior yield of 'Vera' is not only a punctual advantage but also a guarantee of long-term consistent performance, which recommends it as a reference cultivar for lowland areas under organic fertilization technology.

Table 1. Morphological, productive, and biochemical parameters of three *Lavandula angustifolia* Mill. cultivars (multiannual means, 2020-2024)

No.	Cultivar	Plant height, cm	Bush diameter, cm	No. Flower stems/bush	Fresh inflorescence mass, g	Dry inflorescence mass, g	Essential oil yield ml/100 g DW	Carotenoids, mg/kg	Total phenolics, mg/kg	Ascorbic acid, mg/kg
1.	Vera	59.5	105.2	228	0.95	0.45	1.35	26.4	35753	1278
2.	Codreanca	55.2	97.8	190	0.82	0.39	1.20	20.7	20313	189
3.	Munstead	57.5	101.2	200	0.88	0.40	1.30	22.1	28500	620

Essential oil yield followed the same pattern. As shown in (Figure 1), the 'Vera' cultivar recorded an average value of 1.35 ml oil/100 g dry weight, significantly higher than 'Codreanca' (1.20 ml/100 g). Although 'Munstead' approached the level of 'Vera' (1.30 ml/100 g), the difference remained statistically significant ( $p < 0.05$ ). Although 'Munstead' approached the level of 'Vera' (1.30 ml/100 g), the difference remained statistically significant ( $p < 0.05$ ). It is important to note that these values fall within the ranges previously reported for *Lavandula angustifolia* cultivated in Romania and other European countries (Jianu et al., 2013; Carrasco et al., 2016), attesting both the adaptability of the cultivars and the accuracy of the applied methodology.

These differences among cultivars can be explained by the genetic particularities of the biological material as well as by its interaction with the applied fertilization regime. The 'Vera' cultivar, with a more developed foliar system

and a higher number of flowering stems, made more efficient use of the available nutrients, which led to the accumulation of greater reproductive biomass and, implicitly, to superior oil yield. The results confirm previous observations that cultivars with vigorous vegetative growth have the capacity to transform nutrient resources not only into vegetative mass but also into valuable secondary metabolites (Erland & Mahmoud, 2016). At the same time, the lower values recorded for 'Codreanca' suggest a less efficient use of nutrient resources, a trait that may be explained by its stronger adaptation to restrictive pedoclimatic conditions rather than to maximizing yield. Another noteworthy aspect is that the differences among cultivars were not limited to the amount of oil but also extended to the stability of production across the five years of study.

Carotenoids also showed considerable variability among cultivars. The values were

26.4 mg/kg in ‘Vera’, 22.1 mg/kg in ‘Munstead’, and 20.7 mg/kg in ‘Codreanca’. As shown in (Figure 2), the relationship between carotenoids and phenolics illustrates a positive correlation, suggesting that cultivars with an active secondary metabolism tend to accumulate higher levels of antioxidants from different classes simultaneously. Similar correlations were reported by Yadikar et al. (2018), who identified new phenolic compounds in *Lavandula angustifolia* and highlighted links between these and carotenoid pigments.

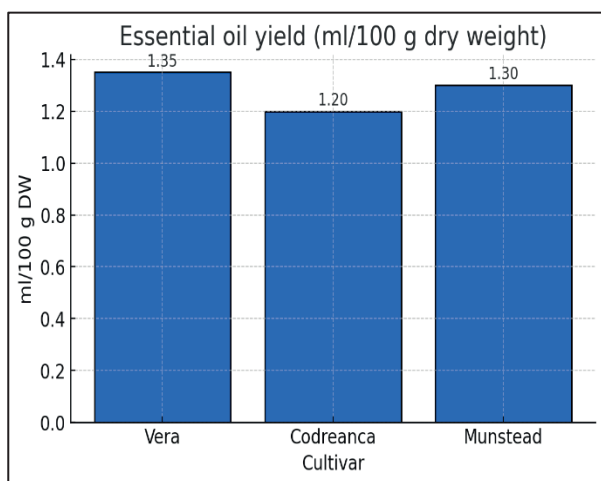


Figure 1. Multiannual average essential oil yield (ml/100 g dry weight) in three cultivars of *Lavandula angustifolia* Mill. under organic fertilization in the Buzău Plain

The observed correlation between phenolics and carotenoids has important practical significance, as it suggests that selection for one quality parameter (e.g., total phenolic content) may indirectly lead to increased levels of other antioxidant compounds. In this case, ‘Vera’, which stood out with high levels of phenolics, also recorded the highest carotenoid content. This association is relevant for the pharmaceutical and cosmetic industries, where both classes of compounds contribute to the biological activity of extracts. Recent analyses of essential oils from medicinal plants have also emphasized the strong bioactive potential of their phenolic components, supporting the importance of biochemical characterization in lavender (Stan et al., 2022). Phenolics are recognized for their antimicrobial and antioxidant roles, while carotenoids are valued for their photoprotective properties and ability to neutralize free radicals (Rădulescu et al., 2017).

Therefore, cultivars that combine these two characteristics can provide superior raw material quality for multiple uses. Moreover, the correlation analysis suggests that the organic fertilization applied in this study may have positively influenced both classes of metabolites. It is well known that a balanced supply of macro- and microelements stimulates the enzymes involved in the biosynthesis of both phenolic compounds and carotenoid pigments (Crișan et al., 2023). In this context, the results confirm not only the genetic differences among cultivars but also the role of cultivation technology in modulating secondary metabolism. This interaction between genetics and nutrition opens interesting perspectives for optimizing lavender quality in organic farming systems, where the emphasis is placed not only on yield but also on the biochemical profile of the final product.

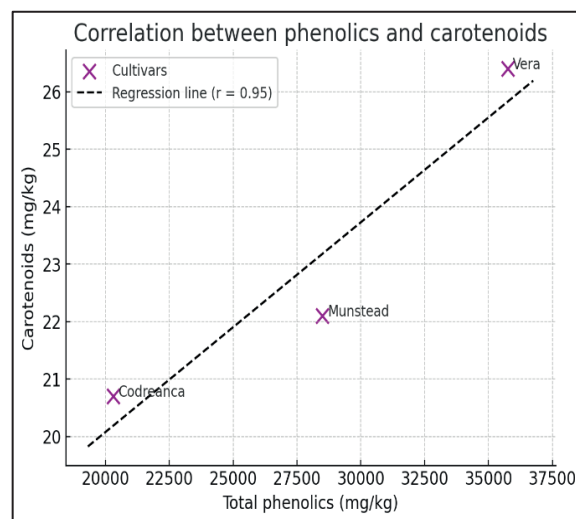


Figure 2. Correlation between total phenolics and carotenoids in three *Lavandula angustifolia* cultivars (‘Vera’, ‘Codreanca’, ‘Munstead’). Regression analysis indicates a strong positive correlation ( $r = 0.95$ )

A particularly interesting result concerns the variability of ascorbic acid. As shown in (Figure 3), ‘Vera’ reached a level of 1278 mg/kg, far above the values obtained for ‘Munstead’ (620 mg/kg) and ‘Codreanca’ (189 mg/kg). The nearly sevenfold difference between ‘Vera’ and ‘Codreanca’ underscores the genetic diversity in the synthesis of this compound, with direct implications for the antioxidant potential of the flowers. These results are consistent with the observations of Erland & Mahmoud (2016), who highlighted

the variability of secondary metabolite content in lavender depending on cultivar and agricultural technology.

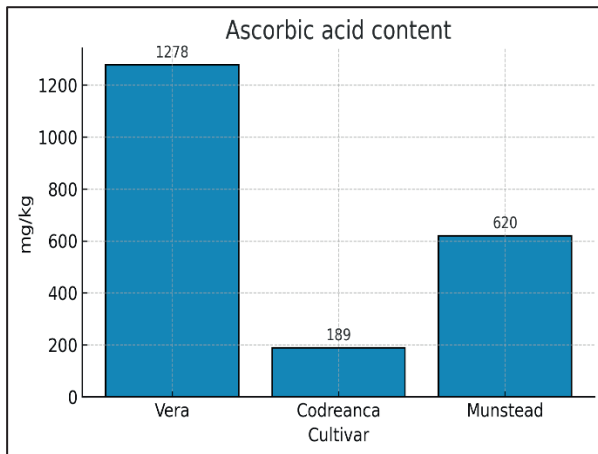


Figure 3. Ascorbic acid content (mg/kg) in three *Lavandula angustifolia* cultivars ('Vera', 'Codreanca', 'Munstead') grown under organic fertilization (multiannual means, 2020-2024)

The findings suggest that ascorbic acid content is not only a consequence of genetic characteristics but also of technological conditions, especially the nutritional regime. It is well known that the availability of essential macro- and microelements such as nitrogen, phosphorus, and potassium directly influences the enzymatic reactions involved in ascorbic acid biosynthesis, particularly those related to the redox cycle and glucose metabolism (Paraianu & Marinica, 1994). In this case, the applied organic fertilization provided sufficient resources to stimulate these processes, which may explain the high levels observed in 'Vera'. By contrast, 'Codreanca', although cultivated under the same technological conditions, showed low values, indicating a reduced metabolic capacity to convert nutrients into antioxidant secondary metabolites.

Another important aspect is the potential correlation between ascorbic acid and the other antioxidants studied (phenolics and carotenoids). Balanced fertilization not only stimulates floral biomass production but can also have a synergistic effect on the biosynthesis of different classes of compounds. Recent studies show that in aromatic plants there is an interdependence between nutrient supply and the ability to simultaneously accumulate multiple secondary metabolites (Crişan et al., 2023). From this perspective, the

high levels of ascorbic acid observed in 'Vera' should not be interpreted in isolation but as part of a complex metabolic profile, favored by both genetics and the applied organic fertilization. This interaction confirms the importance of a well-balanced cultivation technology for maximizing the quality of the floral phytochemical complex in lavender.

The relationship between plant architecture and essential oil yield was analyzed using simple linear regression. According to (Figure 4), there is a clear positive relationship between the number of flowering stems per plant and oil yield, with a high correlation coefficient ( $r = 0.90$ ). The regression slope indicates that each increase of 10 stems corresponds, on average, to a 0.02 ml increase in oil per 100 g dry weight. This relationship confirms the hypothesis that morphological parameters are predictors of technological yield and can be used as selection criteria in lavender breeding.

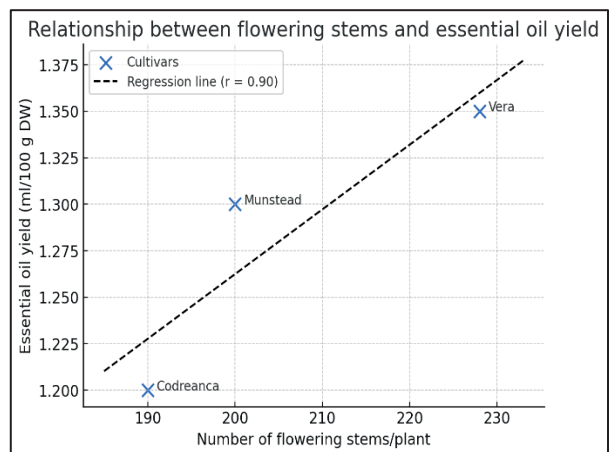


Figure 4. Relationship between the number of flowering stems per plant and essential oil yield in three *Lavandula angustifolia* cultivars ('Vera', 'Codreanca', 'Munstead')

This statistical relationship highlights that essential oil yield does not depend exclusively on genetic factors but also on the way the plant develops its architecture in interaction with cultivation technology. The applied organic fertilization contributed to stimulating branching and the formation of a higher number of flowering stems, which amplified flower production and consequently the amount of extracted oil. Under deficient nutrition conditions, a reduction in the number of fertile branches is usually observed, which significantly limits productive potential (Paraianu & Marinica, 1994; Panaitescu et al., 2018).

Our data suggest that a balanced nutrient supply is essential for maintaining the positive relationship between plant morphology and essential oil accumulation. The importance of integrating sustainable practices in the cultivation of aromatic and medicinal species has also been emphasized in recent research on co-cultivation systems, which enhance both ecological performance and plant productivity (Maknea et al., 2022). Moreover, the regression indicates that oil yield can be predicted reliably based on vegetative characteristics. From a practical perspective, this means that farmers can quickly evaluate the production potential of a crop through simple morphological measurements, such as the number of flowering stems per plant, without the need for complex and costly analyses. Furthermore, correlating these data with fertilization level suggests that through appropriate nutrient management, growth can be directed towards maximizing reproductive organs, which is a major advantage in organic farming systems. This perspective confirms the idea that well-adapted agricultural technology can enhance the genetic characteristics of cultivars, leading to greater efficiency in essential oil production.

The analysis of biochemical composition provides additional insights into the quality of raw materials. A clear difference among cultivars is evident in (Figure 5), where ‘Vera’ accumulated the highest amount of phenolic compounds (35,753 mg/kg), compared to 28,500 mg/kg in ‘Munstead’ and only 20,313 mg/kg in ‘Codreanca’. These differences are significant and confirm the observations of Rădulescu et al. (2017), who reported that phenolic content varies considerably depending on genotype and environmental conditions. Significant differences between cultivars were confirmed by ANOVA ( $p < 0.05$ ).

The importance of phenolics lies in their antioxidant role and their contribution to the stability of cosmetic and food products derived from lavender. The obtained results indicate that phenolics are not only a biochemical marker of lavender flower quality but also a parameter sensitive to cultivation technology. The applied organic fertilization, through its balanced supply of macro- and microelements, created optimal conditions for the activation of enzymes involved in phenolic biosynthesis.

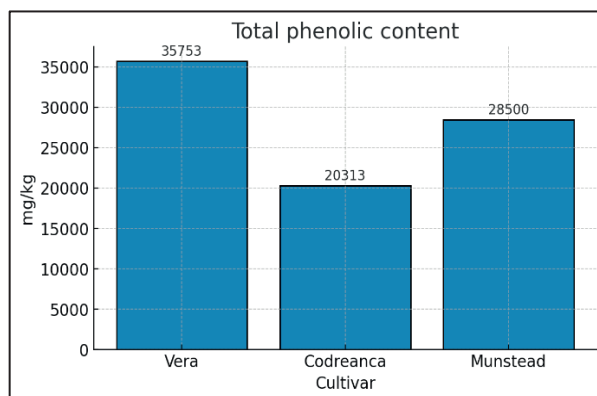


Figure 5. Total phenolic content (mg/kg) in three *Lavandula angustifolia* cultivars (‘Vera’, ‘Codreanca’, ‘Munstead’) grown under organic fertilization (multiannual means, 2020-2024)

It is well documented that the presence of potassium and phosphorus influences phenylpropanoid metabolism, a major biosynthetic pathway for phenolics (Crișan et al., 2023). Thus, the high values observed in ‘Vera’ may be attributed not only to genetic particularities but also to a more efficient use of nutrients, which favored the accumulation of these secondary compounds.

Another noteworthy aspect is the practical importance of varietal differences. The higher phenolic content in ‘Vera’ and ‘Munstead’ suggests greater added value for industries that use lavender not only as a source of oil but also for antioxidant extracts intended for cosmetic, food, or pharmaceutical products. In contrast, the lower level in ‘Codreanca’ indicates a more suitable orientation toward dried flower production or raw material for ornamental purposes, where the emphasis lies on agronomic resilience rather than biochemical concentration. From this perspective, correlating the phenolic profile with the type of valorization represents an essential criterion in cultivar choice and fertilization strategy.

Moreover, recent studies emphasize that phenolic-rich medicinal plants exhibit enhanced bioactive potential, reinforcing the relevance of selecting cultivars with superior biochemical profiles for high-value applications (Stan et al., 2022). Overall, these results underscore the close link between genetic background, nutrient management, and the functional value of lavender raw materials. Organic fertilization proved to be a decisive factor for both productivity and biochemical

quality. A linear increase in the number of inflorescences is evident in (Figure 6), where the total fertilization dose rising from 100 to 200 kg a.i./ha resulted in an increase from 170 to 225 inflorescences. These results confirm the conclusions of Paraianu & Marinica (1994), who reported a positive response of lavender to balanced fertilization, as well as recent observations emphasizing the importance of organic inputs in stimulating productivity (Crişan et al., 2023).

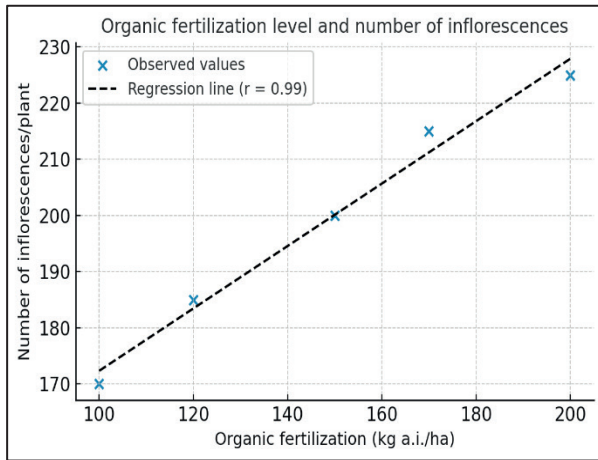


Figure 6. Relationship between organic fertilization level and number of inflorescences per plant in *Lavandula angustifolia*

The results suggest that organic fertilization acts not only as a source of nutrients but also as a factor of physiological balance for plants. The steady increase in the number of inflorescences with fertilization dose reflects a more efficient use of resources by the plants, which are able to sustain a greater number of flowering stems without compromising their viability. This observation is important, as it shows that up to the level of 200 kg a.i./ha there are no signs of saturation or negative effects, confirming the potential of organic systems to support high productivity.

By contrast, in the case of excessive conventional fertilization, the literature often reports a decrease in essential oil quality due to excessive nitrogen accumulation (Hassiotis et al., 2014), which was not observed here. Another noteworthy aspect is that the variability among cultivars decreased with increasing fertilization, suggesting that nutrient inputs can partially compensate for genetic differences. For example, at lower doses, 'Vera' clearly outperformed the other two cultivars in

terms of inflorescence number, but as the fertilization level increased, both 'Munstead' and 'Codreanca' showed relatively greater growth, narrowing the gap. Increasing the fertilization dose from 100 to 200 kg a.i./ha resulted in a linear increase in inflorescence number ( $r = 0.99$ ,  $p < 0.05$ ), confirming the positive effect of balanced organic inputs on floral productivity.

This trend is valuable for practitioners, as it indicates that balanced organic fertilization can enhance the performance even of cultivars with more modest genetic potential, making them more attractive for commercial cultivation. In addition, the impact of fertilization on biochemical quality becomes evident in (Figure 7). Phenolic content increased steadily with the intensification of fertilization, from 24,000 mg/kg to 33,000 mg/kg, suggesting that nutrient supply stimulates not only growth but also secondary metabolism. It is important to note that this relationship was linear, with no signs of plateau within the applied dosage range, indicating that there is still potential for quality improvement through technological adjustments. These results are consistent with literature reporting that organic fertilization influences the composition of essential oils and phenolic metabolites in aromatic plants (Basch et al., 2004; Hassiotis et al., 2014).

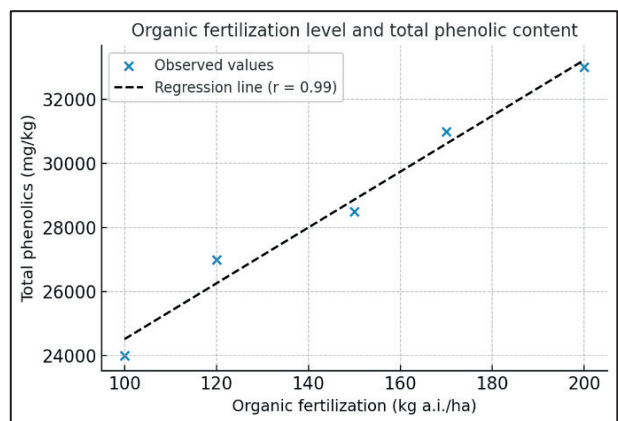


Figure 7. Relationship between organic fertilization level and total phenolic content in *Lavandula angustifolia*.

The findings suggest that organic fertilization acts not only as a nutrient source but also as a stimulant of secondary metabolic pathways responsible for the biosynthesis of phenylpropanoids and other phenolic derivatives. The progressive increase in concentrations, from 24,000 mg/kg at the

minimum dose to over 33,000 mg/kg at the maximum dose, represents an almost 40% increase, confirming the capacity of organic inputs to enhance the biochemical value of raw material. From the perspective of organic agriculture, this result is essential, as it demonstrates that technology not only maintains but actually enhances the quality of the final product.

Furthermore, the correlation between fertilization level and phenolic content confirms the observations of other authors, who have shown that organic inputs improve the plant's redox status and stimulate enzymatic activity involved in the synthesis of secondary compounds (Rădulescu et al., 2017; Crișan et al., 2023). Increasing the fertilization dose from 100 to 200 kg a.i./ha resulted in a linear rise in phenolic concentration, from 24,000 to over 33,000 mg/kg ( $r = 0.99$ ,  $p < 0.05$ ), confirming the stimulatory role of organic inputs on secondary metabolism. This connection has important practical implications: by carefully adjusting organic fertilization doses, growers can direct the crop not only towards high yields but also towards obtaining a superior antioxidant profile, thereby increasing market value and expanding the uses of lavender, from cosmetics to pharmaceuticals and food.

The integration of all these data shows that the cultivar 'Vera' combines productivity parameters with biochemical quality most effectively, making it the most suitable option for commercial cultivation under the conditions of the Buzău Plain. 'Munstead' proved to be a stable cultivar with intermediate results, while 'Codreanca', although more modest in terms of biochemical content, may be valued for its agronomic resilience and adaptability. Overall, the results support the idea that organic fertilization, when applied in a balanced and consistent manner, not only increases flower and oil yield but also enhances the functional profile of the product, a particularly important aspect for a market oriented toward quality and sustainability.

The production and quality values obtained in this study fall within the internationally reported ranges for *Lavandula angustifolia*, but also show particularities determined by local conditions and applied technology. For example, the oil yields of 'Vera' are

comparable to those obtained in southern Spain (Carrasco et al., 2016), but higher than those reported in western Romania (Jianu et al., 2013), confirming the superior adaptability of this cultivar in areas with chernozem soils and a moderate continental climate. These regional differences emphasize the importance of conducting multiannual comparative studies to correctly adapt technologies to local specificity. From the perspective of organic agriculture, the results are particularly relevant. These findings are consistent with the increasing adoption of environmentally responsible agricultural practices among Romanian farmers, who show a growing interest in sustainable nutrient management (Oroian et al., 2024). The data show that organic fertilization, based on blood meal, mature compost, natural phosphates, and mineral-origin potassium sulfate, can ensure competitive production levels and even superior biochemical values compared to those reported in conventional systems. This finding contradicts the perception that organic systems sacrifice productivity in favor of quality. On the contrary, in the case of lavender, balanced organic fertilization simultaneously stimulates vegetative growth and the synthesis of secondary compounds, strengthening the position of this species as a model of sustainable cultivation.

Looking ahead, future research should focus not only on the overall quantification of oil and secondary metabolites but also on the detailed analysis of essential oil composition (proportions of linalool, linalyl acetate, minor terpenes, etc.) to establish how organic fertilization influences aromatic quality. Additionally, correlating fertilization doses with physiological plant parameters (photosynthesis, redox status, enzymatic activity) could provide mechanistic explanations for the observed variability. The integration of modern approaches such as metabolomics or high-resolution chromatography would allow for a more comprehensive understanding of how genetics and technology interact in determining lavender quality.

The results obtained in the present study are also supported by recent literature. For example, Manescu and Dudau (2024) reported that organic fertilizers contribute to yield increases comparable to mineral fertilizers,

while offering the advantage of better sustainability. Similarly, Mihalascu et al. (2020) highlighted that fertilization adapted to local ecological conditions leads to significant differences in productivity, confirming the importance of balanced doses and appropriate technology. These findings are consistent with the results obtained under the conditions of the Buzău Plain.

## CONCLUSIONS

Overall, the results of this multiannual study underline the fact that genetic diversity within *Lavandula angustifolia* cultivars strongly determines both productivity and biochemical quality. Among the tested genotypes, ‘Vera’ stood out by consistently combining vigorous vegetative growth, the highest number of flowering stems, superior inflorescence mass, and the maximum essential oil yield. Moreover, its biochemical profile, characterized by elevated levels of phenolics, carotenoids, and ascorbic acid, highlights its suitability for high-value uses in the pharmaceutical, cosmetic, and food industries, where both oil quality and antioxidant potential are key criteria. By contrast, ‘Munstead’ expressed an intermediate but very stable performance, with balanced yield and composition across years, proving reliable for farmers seeking predictability and uniformity in production. Its consistency, even under variable climatic conditions, makes it attractive for medium-scale cultivation where market stability is prioritized. ‘Codreanca’, while displaying lower biochemical content and reduced essential oil yield, confirmed its importance as a resilient cultivar, particularly valuable for harsher pedoclimatic areas in Romania due to its adaptability and winter hardiness. In practice, this cultivar can serve as a strategic option for extending lavender cultivation into more restrictive ecotopes where other genotypes may fail.

From a technological perspective, the results confirm that organic fertilization not only sustains competitive yields but also enhances the functional profile of lavender flowers by stimulating secondary metabolism. This dual benefit: productivity combined with improved quality, contradicts the widespread perception that organic systems must compromise yield.

Instead, the integration of balanced organic fertilization regimes with cultivar-specific traits provides an effective and sustainable production strategy.

Practically, these findings support the expansion of lavender cultivation in the Buzău Plain and similar pedoclimatic zones, offering farmers concrete guidelines for cultivar selection and nutrient management. By adopting ‘Vera’ for high-value production, ‘Munstead’ for stable medium performance, and ‘Codreanca’ for resilience under stress conditions, growers can tailor their crops to both ecological constraints and market demands. This cultivar-specific approach ensures not only ecological sustainability but also economic competitiveness, strengthening lavender’s role as a model crop for organic agriculture in Romania and beyond. Overall, the integration of genotype-specific performance with organic fertilization practices demonstrates that sustainable management can simultaneously enhance yield stability and biochemical quality. These results reinforce the value of tailoring cultivation strategies to local pedoclimatic conditions to optimize both productivity and functional attributes.

## REFERENCES

- Balmus, Z., & Calalb, T. (2020). Mitigating the consequences of climate change through the creation and implementation of high-yielding, drought- and frost-resistant, disease-tolerant medicinal and aromatic plant cultivars that ensure sustainable agricultural development and guarantee high-quality products for the perfumery, cosmetic, pharmaceutical, and food industries. 20.80009.5107.07.
- Basch, E., Foppa, I., Liebowitz, R., Nelson, J., Smith, M., Sollars, D., & Ulbricht, C. (2004). Lavender (*Lavandula angustifolia* Miller). *Journal of Herbal Pharmacotherapy*, 4(2), 63–78.
- Carrasco, A., Martinez-Gutierrez, R., Tomas, V., & Tudela, J. (2016). *Lavandula angustifolia* and *Lavandula latifolia* essential oils from Spain: aromatic profile and bioactivities. *Planta Medica*, 82(01/02), 163–170.
- Crișan, I., Ona, A., Vârban, D., Muntean, L., Vârban, R., Stoie, A., & Morea, A. (2023). Current trends for lavender (*Lavandula angustifolia* Mill.) crops and products with emphasis on essential oil quality. *Plants*, 12(2), 357.
- Denner, S. S. (2009). *Lavandula angustifolia* Miller: english lavender. *Holistic Nursing Practice*, 23(1), 57–64.

- Erland, L. A., & Mahmoud, S. S. (2016). Lavender (*Lavandula angustifolia*) oils. In *Essential oils in food preservation, flavor and safety*, 501–508.
- Hassiotis, C. N., Ntana, F., Lazari, D. M., Poullos, S., & Vlachonasios, K. E. (2014). Environmental and developmental factors affect essential oil production and quality of *Lavandula angustifolia* during the flowering period. *Industrial Crops and Products*, *62*, 359–366.
- Jianu, C., Pop, G., Gruia, A. T., & Horhat, F. G. (2013). Chemical composition and antimicrobial activity of essential oils of lavender (*Lavandula angustifolia*) and lavandin (*Lavandula x intermedia*) grown in Western Romania. *International Journal of Agriculture and Biology*, *15*(4), 772–776.
- Kumar, D., Samota, M. K., Roy, S., Silva, A. S., & Pandey, A. K. (2025). Lavender essential oils as natural food protectants: Myth or a viable substitute? *Sustainable Food Technology*, *3*(2), 354–374.
- Lane, A., Boeckleemann, A., Woronuk, G. N., Sarker, L., & Mahmoud, S. S. (2010). A genomics resource for investigating regulation of essential oil production in *Lavandula angustifolia*. *Planta*, *231*(4), 835–845.
- Maknea, K. I., Asănică, A., Fabian, C., Peticilă, A., Tzortzi, J. N., & Popescu, D. (2022). The use of co-cultivation of aromatic, medicinal plants and vegetables in sustainable urban horticulture. *AgroLife Scientific Journal*, *11*(1). <https://doi.org/10.17930/AGL2022113>
- Manescu, C., & Dudau, A. E. (2024). Effects of organic and mineral fertilizers on growth and flowering of young lavender (*Lavandula angustifolia* Mill.) plants. *Scientific Papers. Series B, Horticulture*, *68*(1), 645–650.
- Mihalascu, C., Tudor, V., Bolohan, C., Mihalache, M., & Teodorescu, R. I. (2020). The effect of different fertilization upon the growth and yield of some *Lavandula angustifolia* (Mill.) varieties grown in southeast Romania. *Scientific Papers. Series B, Horticulture*, *64*(1), 685–692.
- Muscalu, A., Tudora, C., Sorică, C., Vlăduț, N.-V., Mîrzan, O., & Naie, M. (2022). Experimental research on harvesting species of medicinal plants grown on small areas. *AgroLife Scientific Journal*, *11*(2). <https://doi.org/10.17930/AGL202214>
- Oroian, C., Odagiu, A., & Vizitiu, O. (2024). What carbon storage farming activities adopted by farmers? A survey from the North-Western region of Romania. *AgroLife Scientific Journal*, *13*(2), 192–199. <https://doi.org/10.17930/AGL2024217>
- Panaiteescu, L., Pricop, S. M., Stroe, T. C., & Niță, S. (2018). Studies regarding the manifestation of the productive potential in lavender culture (*Lavandula angustifolia* Mill.) in Buzău Plain. In *Proceedings of the International Conference on Life Sciences*, Filodiritto Editore, ISBN 978-88-85813-24-3, 800–807.
- Paraianu, M., & Marinica, A. (1994). Optimum nitrogen fertilization of lavender. *Lucrări Științifice. Stațiunea Centrală de Cercetări pentru Cultura Plantelor pe Nisipuri Dăbuleni (Romania)*, *8*.
- Pokajewicz, K., Białoń, M., Svydenko, L., Fedin, R., & Hudz, N. (2021). Chemical composition of the essential oil of the new cultivars of *Lavandula angustifolia* Mill. bred in Ukraine. *Molecules*, *26*(18), 5681.
- Prusinowska, R., & Smigielski, K. B. (2014). Composition, biological properties, and therapeutic effects of lavender (*Lavandula angustifolia* L.): A review. *Herba Polonica*, *60*(2).
- Rădulescu, C., Stihî, C., Ilie, M., Lazurcă, D., Gruia, R., Olaru, O. T., ... & Florescu, M. (2017). Characterization of phenolics in *Lavandula angustifolia*. *Analytical Letters*, *50*(17), 2839–2850.
- Stan (Tudora), C., Cardei, P., Muscalu, A., Boiu-Sicuia, O.-A., Vlăduț, N.-V., & Israel-Roming, F. (2022). Statistical analysis on the potential antifungal activity of some essential oils obtained from medicinal plants. *AgroLife Scientific Journal*, *11*(1). <https://doi.org/10.17930/AGL2022125>
- Yadikar, N., Bobakulov, K., Li, G., & Aisa, H. A. (2018). Seven new phenolic compounds from *Lavandula angustifolia*. *Phytochemistry Letters*, *23*, 149–154.