



MICROBIOLOGIC, AGROCHEMICAL AND ALLELOPATHIC SOIL STATUS UNDER *LAVANDULA* L. PLANTS SPECIES IN FOREST-STEPPE ZONE

Yunosheva Olena*, Ellanska Natalia

M. M. Gryshko National Botanical Garden, National Academy of Sciences of Ukraine, Kyiv, Ukraine

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The article reports the results of microbiological, agrochemical and allelopathic studies of the influence of *Lavandula angustifolia* Mill. and *Lavandula hybrida* Rev. introductive plants on the soil status. The aim of this study was to analyze the effect of hydrothermal and soil conditions of Forest-Steppe zone on the microbial cenosis formation and dynamics of taxonomic and ecology-trophic groups of microorganisms, the soil allelopathic activity and the ratio of biogenic elements. The analysis of the functional structure of microbial cenosis in the rhizosphere of lavender and lavandin shows a decreased quantity of micromycetes and an increase in the amount of spore-forming bacteria. The allelopathic activity of soil under lavender is characterized by a low level of toxicity. The processes of mineralization of organic matter in the soil were quite balanced. The influence of allelochemicals on the distribution of macro and microelements in the soil during lavender cultivation has been studied. The obtained results prove the positive effect of the studied plants on the microbiocenose and physical-chemical soil state that should be taken into account for their gardening.

Keywords: *Lavandula*, microbiocenosis, micromycetes, bacteria, soil allelopathic activity.

Introduction

Nowadays the disturbingly increasing anthropogenic effect on natural ecosystems leads to the reduction of the biological diversity of plant, animal and microbial world. The problem of preservation of phytobiodiversity can be solved out by means of sinecologic methods of plant introduction into the artificial phytocoenosis.

Aromatic plant species are characterized by polyfunctional properties as they are resistant to various anthropogenic pollutants and phytopathogenic microorganisms and do not accumulate phytotoxic substances in their environment, causing the phytosanitary effect on the ecosystem (Yurchak, 2005; Kovtun-Vodyanytska, 2017).

The species of *Lavandula* L. genus are known for their ability to influence the environment because of their high allelopathic activity. Moreover, the plants of *Lavandula* genus are popular

Corresponding author: Yunosheva Olena, Gryshko National Botanical Garden, National Academy of Sciences of Ukraine, 1, Timiriazevska str., Kyiv 01014, Ukraine

✉ vandae@ukr.net

horticultural species as they are characterized by long flowering period, high ionizing sanitary effect and do not require special growing conditions.

The role of biologically active substances and the associated microbiota of culturphytocoenosis of *Salvia sclarea* L., *Lavandula angustifolia* and *Mentha piperita* L. aromatic plants were studied by Yurchak (1999, 2005). We had earlier characterized the formation of the microbiocenosis in the soil samples under *Monarda didima* L., *Hyssopus officinalis* L. *Dracocephalum moldavicum* L., *Vitex agnus-castus* L. plant species of Lamiaceae family (Ellanska, 2010, 2013)

This way, the aim of this study was to characterize the main taxonomic and ecotrophic groups of microorganisms and to estimate the allelopathic activity of soil under the plants of *Lavandula* genus under the conditions of Forest-Steppe zone.

Material and methodology

Locating plants and data collection

This experimental study was carried out in the Department of Allelopathy of M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine (Kyiv). *Lavandula angustifolia* Mill. and *Lavandula hybrida* Rev. plants were donated by the Botanical garden collection fund.

Microbiological researches

The bacterial abundance was quantified on meat-peptone agar (for ammonifiers), on ammonium starch agar (for inorganic nitrogen-immobilizers and actinomycetes), on Mishustin medium (spore-forming bacteria), on Hetchenson medium (cellulose decomposing bacteria), on Eshbi medium (for nitrogen-fixing bacteria by the application method), while the microscopic fungi were incubated on Capek medium. The ratio of certain ecological-trophic groups of microorganisms (mineralization-immobilization index) was calculated according to Andreyuk (2001), the index of organic matter transformation was analyzed by the method of Mucha (1980). We calculated the number of colony-forming units (GFU/g) of soil bacteria, taking into account the dilution of soil samples according to standard- accepted methods (Tepper, 2004).

Analysis of soil allelopathic activity

The estimation of soil allelopathic activity was carried out by direct bioassay method (Grodzinskij, 1990). Garden cress (*Lepidium sativum* L.) and winter wheat (*Triticum aestivum* L.) plants were used as test cultures. The soil samples with no influence of exometabolites of the studied plants were considered control ones.

Agrochemicals analysis

The content of macro- and trace elements in the root-soil soil was determined by the method of Rink's (1982) spectrometer with inductively coupled plasma ICAR 6300 DUO (USA). The obtained results were statistically processed using Microsoft Office 2007 software suite.

When presenting the results we have also taken into account the number of precipitations throughout the plant vegetation period (I group – the years characterized by the lower level of precipitations, II group – the years characterized by the higher level of precipitations).

Results and discussion

Microorganisms are considered an important consortium of agrophytoceneses and an indicator of fertility, biological activity and allelopathic state of soil (Yunosheva and Ellanskaya, 2015; Ellanskaya and Gorelov, 2017).

A distinctive feature of the aromatic plants is their production of essential oils. The lavender's soil microbiota forms under influence of its plant's excretions, in particular, essential oils, that have a specific effect on the functional structure of the microbiocenosis and organic matter decomposition (Vokou, 2002; Hassiotis, 2010).

Here we firstly analyzed the abundance and the ratio of basic taxonomic and eco-trophic microorganism groups of lavender rhizosphere microbial cenosis and inter-row soil under soil conditions of Forest- Step zone. The number of micromycetes was shown to decrease during the flowering period especially for the years characterized by the lower level of precipitations when comparing to the control samples (Figure 1).

At the same time, the abundance of these microorganisms was 1.5–2.0 time-lower in case of the rhizosphere samples of the studied plants than for the ones of the inter-row soil.

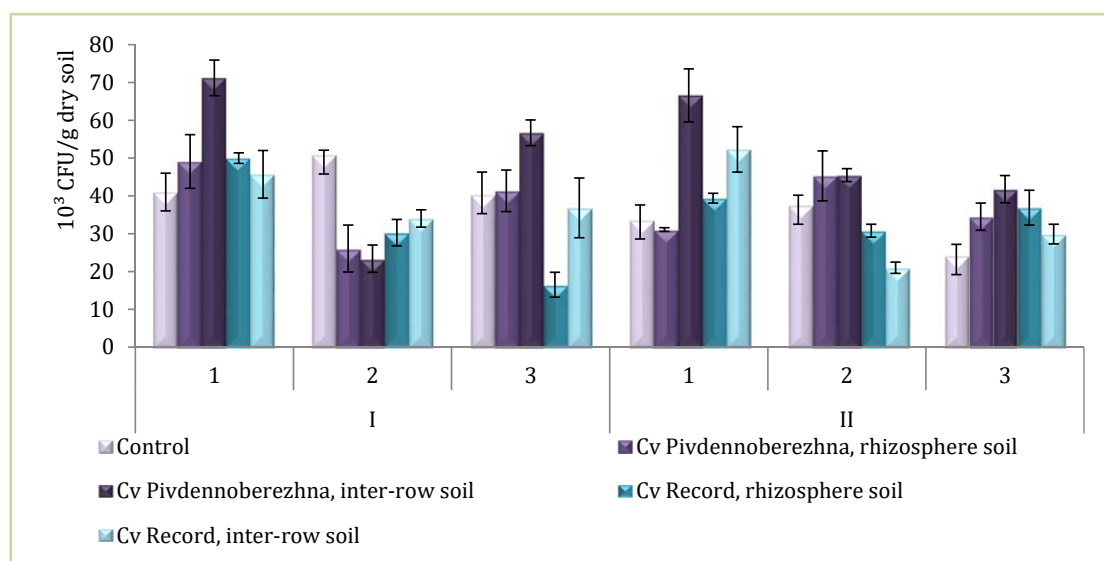


Figure 1 Micromycetes abundance in the soil samples under *Lavandula angustifolia* plants: 1 – growing stage; 2 – flowering stage; 3 – seed formation stage; I group – the years characterized by a lower level of precipitations; II group – the years characterized by higher level of precipitations

Lavender rhizosphere was characterized by a wider spectrum of micromycete species of *Penicillium* and *Trichoderma* genera comparing to the control ones (mostly the mucoral

forms). The noteworthy fact is that *Aspergillus* species were found in the studied soil samples probably due to the species-specific secretions of lavender plants. The quantitative parameters of spore bacteria growth were 1.4–2.4 times higher compared to control ones throughout all the phases of plant development. The abundance of ammonifiers, cellulose-destroying microorganisms and actinomycetes appeared to be increased in the studied soil samples. The development of nitrogen-fixing microorganisms was inhibited by up to 80% throughout the entire period of lavender plant vegetation during the years characterized by lower water availability, whereas such an inhibition did not exceed 16–19% for the years characterized by more precipitations.

Ammonifiers were shown to develop more intensively during the lavender emergence and flowering periods, their abundance declining by the end of vegetation period (Table 1).

The general abundance of nitrogen-fixing bacteria was descending throughout the vegetation period mostly in rhizosphere zone. During the years characterized with the higher water availability the abundance of microorganisms can be stated as relatively high, this parameter decreasing being observed only during the plant flowering period.

Basing the obtained results the processes of mineralization of organic matter in the soil appeared quite balanced. The mineralization-immobilization ratio during active plant vegetation period proved the accumulation of organic compounds, whereas the mineralization processes became more active at the end of the growing season.

The development of microorganisms in the soil samples under lavandin plants was characterized by analogical peculiarities to that of lavender ones (Figure 2). The representatives of *Penicillium*, *Trichoderma*, *Fusarium*, *Gliocladium* genera dominated. Spore-forming bacteria were developing much active during the flowering and seed formation periods. The actinomycete abundance prevailed in lavandin rhizosphere throughout all its vegetation periods. The positive development of nitrogen-fixing microorganisms was observed with only its slight inhibition during the flowering period for the years characterized by low precipitation level.

The results of our study correspond the developmental characteristics of the microbiocenosis of the other representatives of aromatic plant species of Lamiaceae family. The similar trends of the micromycete ratio was reported for the soil samples of *Monarda didima* та *Dracocephalum moldavicum*, their abundance declining in 2–5 times during germination and flowering periods comparing to the control ones. The decreasing of micromycete abundance in the rhizosphere samples was also observed for the flowering period of *Salvia sclarea* L. and representatives of *Vitex* genera (Yurchak, 1997; Ellanska, 2013). The root and volatile exometabolites of lavender may inhibit this group of microorganisms. The increasing abundance of spore-forming bacteria, actinomycete, ammonifiers was reported for microbiocenosis of the soil under the *Salvia sclarea*, *Monarda didima* and *Mentha piperita* plants (Yurchak, 2005; Ellanska, 2010).

Consequently, the formation of microbiocenosis depends on several factors of climatic and soil conditions and plant species. The allelopathically active plant substances (essential oils, phenolcarboxylic acids) may become one of the microbe biomass regulators.

Table 1 Functional structure of microbocenosis and mineralization indexes in the soil samples under *Lavandula angustifolia* Mill. Plants

Variant	Ammonifiers (106 CFU/g dry soil)			Inorganic nitrogen-immobilizers (106 CFU/g dry soil)			Mineralization / immobilization ratio			Organic matter transformation index		
	1*	2	3	1	2	3	1	2	3	1	2	3
Control	2.9 ± 0.1	5.0 ± 0.3	8.6 ± 0.9	6.7 ± 0.7	11.0 ± 1.6	15.2 ± 0.8	2.3	2.2	1.8	4.3	7.3	13.2
Cultivar	6.0 ± 0.1	2.8 ± 0.3	9.6 ± 1.1	7.9 ± 0.8	9.3 ± 0.6	4.7 ± 0.7	1.3	3.3	0.5	0.7	3.7	28.6
Pivdennoberezchna, rhizosphere	6.0 ± 0.7	13.4 ± 0.4	4.2 ± 0.1	3.5 ± 0.6	14.2 ± 1.5	12.6 ± 1.6	0.6	1.1	3.0	15.8	25.1	5.6
Cultivar	8.8 ± 0.5	5.9 ± 0.7	4.3 ± 0.8	11.3 ± 0.6	6.2 ± 0.2	9.6 ± 0.7	1.3	1.1	2.2	15.5	11.0	6.2
Pivdennoberezchna, inter-row	6.5 ± 0.7	7.2 ± 0.8	3.4 ± 0.2	3.9 ± 0.6	11.7 ± 0.2	10.7 ± 0.6	0.6	1.6	3.1	17.3	11.8	4.6
Cultivar	12.1 ± 0.5	4.4 ± 0.3	3.7 ± 0.9	9.8 ± 1.4	9.3 ± 0.4	4.7 ± 0.6	0.4	1.6	1.3	54.8	8.6	6.5
Cultivar Record, rhizosphere	2.9 ± 0.4	6.5 ± 0.9	4.0 ± 0.8	3.4 ± 0.4	6.6 ± 1.8	8.0 ± 0.1	1.2	1.0	2.0	5.3	13.1	6.0
Cultivar Record, inter-row	6.1 ± 0.3	4.6 ± 0.4	3.2 ± 0.9	14.7 ± 0.6	6.9 ± 0.6	3.9 ± 0.5	2.4	1.5	1.2	8.7	7.7	5.9
	4.2 ± 0.6	6.1 ± 0.3	4.9 ± 0.5	4.5 ± 0.5	8.1 ± 1.7	10.9 ± 1.3	1.1	1.3	2.2	8.0	10.9	7.2
	5.7 ± 0.5	5.6 ± 0.6	2.0 ± 0.4	7.7 ± 0.7	9.6 ± 0.1	6.7 ± 0.5	1.3	1.7	3.4	10.3	8.9	2.6

Note: * Sampling periods: 1 – growing stage; 2 – flowering stage; 3 – seeds formation stage; numerator – the years characterized by a lower level of precipitations; denominator – years characterized by higher level of precipitations.

The mineral substances are known for their key role in plant functioning and development as well as in the increasing of their resistance to abiotic and biotic environmental factors. The analysis of the content of biogenic elements in the soil samples under lavender and lavandin plants proved the tendency of decreasing of ammoniac nitrogen content starting from the blossoming period and increasing of nitrate-nitrogen concentration at the end of vegetation period. The phosphorus concentrations didn't significantly differ for the studied samples. The beginning and the end of the vegetation periods were characterized by rising of potassium amounts. The maximum magnesium concentration was detected for lavender rhizosphere during the seed formation period. The end of vegetation period was characterized by the 40% increase of magnesium concentration in the studied soil samples while its twice decreasing was shown for the control ones. The declining of iron content (up to 33%) was observed for all the rhizosphere soil samples of the studied plants during the growing season. The obtained results prove the positive effect of the studied plants on the physical-chemical soil state that should be taken into account for their gardening.

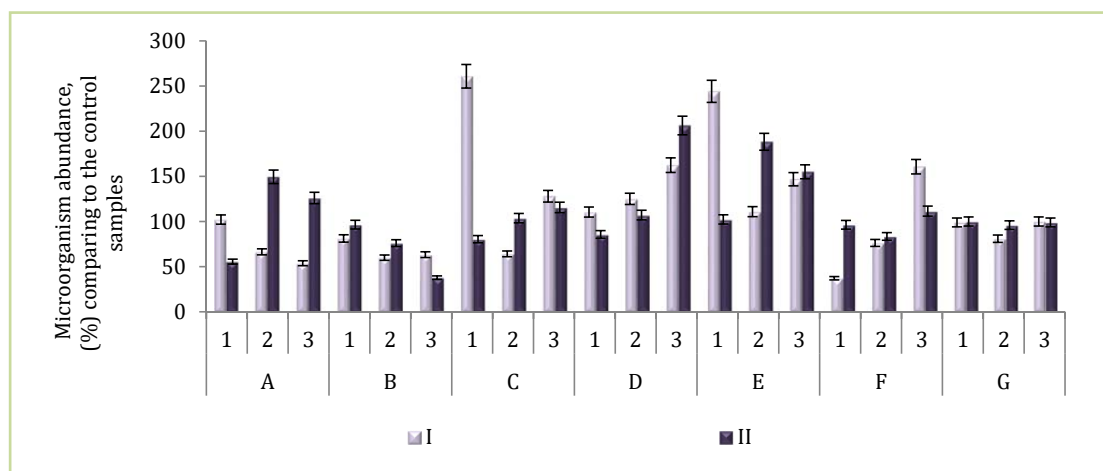


Figure 2 Microbial abundance in the soil samples under *Lavandula hybrida* Rev. plants: 1 – growing stage; 2 – flowering stage; 3 – seed formation stage; A – ammonifiers; B – inorganic nitrogen-immobilizers; C – micromycetes; D – spore-forming bacteria; E – actinomycetes; F – cellulolytic; G – nitrogen-fixing; I group – the years characterized by the lower level of precipitations; II group – the years characterized by the higher level of precipitations

The toxicity of the lavender rhizosphere was considerably lower under the Forest-Steppe conditions compared to the conditions in the southern regions of Ukraine (Yurchak, 2005). The soil allelopathic activity depended on the water balance, as its effect appeared (basing the analyzed parameters) lower for the years characterized by high precipitation level and higher one for the arid years. The obtained data corresponding to the hypothesis that the level of soil toxicity depends on the intensity of essential oil adsorption, which is influenced by the precipitation level.

Conclusions

Therefore, the exometabolites of lavender and lavandin plants caused the 1.7–1.9 time decreasing of micromycete abundance in the rhizosphere. We also report the significant (in 1.4–2.4 times) increasing of spore-forming bacterium abundance and the improved development of actinomycetes, ammonifiers, cellulolytic microorganisms. Basing the obtained results the processes of mineralization of organic matter in the soil appeared quite balanced. The allelopathic activity of the soil samples under lavender and lavandin plants was characterized by low toxicity level for the biotests. The soil allelopathic activity was proved to depend on the water availability: its characteristics were lower for the years of higher precipitation level and higher ones for the arid years. The microbiological analysis of the soil samples under the studied plants proved the variable microorganism biodynamics in the rhizosphere and inter-row samples of the aromatic plants as the periods of increasing or decreasing of microbiota abundance can be logically explained by the plant taxonomy, the geographical and climate conditions, the phases of plant development, the intensity of their physiological processes. Microbiologic, agrochemical and allelopathic soil status under *Lavandula angustifolia* Mill. and *Lavandula hybrida* Rev. plant species under the Forest-Steppe zone conditions was found out favourable for the successful introduction of these plants.

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