



ABSTRACT

Keywords: *Foeniculum vulgare* Mill., foliar fertilization, plant density, production, chemical composition, antioxidant activity, antimicrobial activity

Foeniculum vulgare Mill. is an aromatic and medicinal plant species, being part of *Apiaceae* (*Umbelliferae*) botanical family. Since ancient times, this plant has been used as medicine, and can be used as a remedy for a wide range of medical conditions.

Volatile oils extracted from various species of aromatic and medicinal plants form a certain category of raw materials of high interest both in food industry and in cosmetics or perfumery. The chemical compounds from essential oils composition are much more appreciated, compared to synthetic substances, whereas natural extractions are associated with a much lower number of risk factors for population health.

The thesis research is topical at an international level, because there is a lack of scientific data that would highlight as clearly as possible the influence of some factors on the production and quality of the essential oil obtained from aromatic and medicinal plants.

The experience of the doctoral thesis "*Research on the influence of some technological factors on the production and its quality on Foeniculum vulgare Mill. species*", was carried out in the period of 2020-2022, on the experimental field of Phytotechnology discipline and in Research Station – Ezareni Farm, USV Iași.

The analyzes were carried out in the laboratories of the Phytotechny and Phytopathology disciplines of Faculty of Agriculture, from University of Life Sciences "Ion Ionescu de la Brad", Iași. Also, part of the qualitative analyzes were carried out at the National Research and Development Institute for Chemistry and Petrochemistry – ICECHIM, Bioresources department.

The aim of this doctoral thesis is to determine the influence of some technological factors on production, analyzed in quantitative and qualitative terms, of *Foeniculum vulgare* Mill. species, in the pedoclimatic conditions of the Iași county.

In order to attain the aim of the research, the following objectives were suggested:

- ✓ establish the influence of technological factors on plant growth and development;



- ✓ highlight the effect of technological factors on the mass production of plant and seeds per hectare on two fennel varieties (*Foeniculum vulgare* var. *vulgare* and *Foeniculum vulgare* var. *dulce*);
- ✓ specify the influence of the experimental factors on the plant volatile oil content;
- ✓ determine the impact of the experimental factors on the main chemical compounds from the essential oil composition;
- ✓ establish the influence of researched factors on some secondary metabolites in fennel varieties;
- ✓ determination of the antimicrobial activity of the essential oils obtained from the two fennel varieties.

Two experiments were established: one experiment for the analysis of *vulgare* variety, and the second experiment, using the same experimental factors, for studying var. *dulce*. The research was carried out using randomized block design with three replications. Each plot within the 2 experiments had 3x3 m (9 sq m).

The analyzed experimental factors were:

Factor A – row spacing:

- a1 - 50 cm - control
- a2 - 75 cm
- a3 - 100 cm

Within each plot, different row spacings and 30 cm between plants per row were used. Both variants and repetitions were separated by 1 m wide access ways.

Factor B – foliar treatments:

- b1 - unfertilized - control;
- b2 - Aminosol[®] (Lebosol) – organic foliar fertilizer with animal protein hydrolysate;
- b3 - Total Care[®] (Lebosol) - NPK foliar fertilizer, trace elements (Cu, Mn, Fe, Zn) and amino acids;
- b4 - Nutriplant 160³[®] (Lebosol) – foliar fertilizer NPK 12-12-12 and trace elements (Zn, Cu, Mn);

Structurally, the doctoral thesis comprises two parts, counting up eight chapters and 195 pages, 42 figures and 47 tables.



The first part, termed "The current stage of research", includes three chapters, summing up 53 pages, with 27.46% percentage and inscribes the history of aromatic and medicinal plants usage, the importance and systematics of *Foeniculum vulgare* Mill. species, morphological and biochemical peculiarities of this species.

The second part, termed "Personal Contributions", includes five chapters, totting up 142 pages, with a percentage of 72.54%. In this part, is highlighted information regarding the climatory conditions in which the research was carried out, the aim and objectives suggested in the doctoral thesis, the plant material and the research methods used, results related to the phenological observations, the production of seeds, herb and essential oil, the chemical composition of the volatile extracts, the antioxidant and antimicrobial activity of the volatile oil, of two varieties of fennel, *Foeniculum vulgare* var. *vulgare* and *Foeniculum vulgare* var. *dulce*.

The bibliography includes 157 titles from specialized, national and international literature.

In **the first chapter**, the history of the aromatic and medicinal plants usage is briefly presented.

The second chapter concerns the systematics of *Foeniculum* genus, as well as the importance of *Foeniculum vulgare* Mill. species. In this chapter, the divisions and subdivisions of the genus are briefly described, with the presentation of the species and the possibility of using them for aromatic, therapeutic purposes as well as in other areas of interest.

In **the third chapter**, the morphological and biological peculiarities of the two fennel varieties are described. In this chapter, the morphological differences between sweet and bitter fennel are highlighted; the chemical composition of the two varieties is presented, as well as the main chemical compounds in the essential oil extracted from the seeds.

In addition, this chapter presents information regarding the secondary metabolites identified in the composition of the two fennel varieties and their ability to capture free radicals, achieving a reduction in oxidative stress. Aspects regarding the inhibitory effects of volatile extracts from fennel on fungi are also described.

In **the fourth chapter**, is described the natural environment in which the experiments were carried out, pointing to:

- geographical location of the experimental field;
- geomorphology, hydrography and hydrology of the area;



- climatic conditions recorded during the research period, with reference to thermal and rainfall data recorded in the experimental years.

In **the fifth chapter**, the aim and objectives of this doctoral thesis, the biological material used and the methods used are presented.

The material used was the seeds of the two fennel varieties and the foliar fertilization, using three products from Lebosol portfolio: Aminosol[®] – organic foliar fertilizer with animal protein hydrolysate, Total Care[®] – NPK foliar fertilizer with trace elements (Cu, Mn, Fe, Zn) and amino acids, Nutriplant 160^{3®} – foliar fertilizer NPK 12-12-12 and trace elements (Zn, Cu, Mn), and the control plot was untreated.

Within the same chapter, field research methods and laboratory analysis methods are described.

The laboratory analysis methods used are:

- essential oil extraction by hydrodistillation;
- chemical composition of volatile extracts by gas chromatography coupled with mass spectrometry (GC/MS);
- spectrophotometric methods to determine the antioxidant activity, the total content in polyphenols and flavonoids;
- the diffusion method in agar to identify the antimicrobial activity of fennel oils;
- statistical methods for data processing.

In **chapter six**, the results regarding the phenology and biometric measurements of the two fennel varieties are highlighted. The research results regarding:

- phenological observations made during the vegetation period;
- biometric measurements;
- the influence of experimental factors on the height of the stems at harvest, the degree of branching and the number of umbels.

These parameters were followed throughout the vegetation period in the experimental years, presenting the results obtained for each year separately, as well as the average of the years.

The two varieties of fennel, although they have Mediterranean origins, have habituated to the specific climatic conditions of Iași area, which are favorable for the growth and development of the plants.



Var. *dulce*, showed a lower number of umbels than var. *vulgare*. A significant influence of the foliar fertilization factor is also observed, increasing the number of umbels by up to 62%, in case of foliar treatments with macronutrients, micronutrients and amino acids.

It can be assumed a resultant influence of the factors row spacing and foliar treatments on the dynamics of plant growth and their development.

In **the seventh chapter**, the results regarding the production of *Foeniculum vulgare* Mill. are presented. The productivity of the two varieties was analyzed from the standpoint of the amount of fresh grass and seeds obtained per hectare, as well as the production of volatile oil stocked at the level of seeds and grass in fennel plants.

A genetic influence (the variety) can be distinguished, the productions of grass/ha and seeds/ha being much higher in case of *Foeniculum vulgare* var. *vulgare*, compared to *Foeniculum vulgare* var. *dulce*.

Regardless the row spacing and foliar fertilization, the most important grass and seeds productions were reached in 2021, followed by 2022, and the lowest values were stated in 2020.

Foeniculum vulgare var. *vulgare* can reach yields up to 11 t of fresh grass/ha and 828.5 kg of seeds/ha, when plants are grown with 50 cm between rows and a complex foliar treatment is applied (amino acids, macroelements, microelements), whereas *Foeniculum vulgare* var. *dulce* can achieve a yield of 7.8 t grass/ha and 675.8 kg seeds/ha.

Regarding the accumulation of volatile components in seeds, var. *vulgare* stored higher concentrations between 2.13% and 2.43%, whereas var. *dulce* presented values between 1.65% and 2.01%.

The yield and the production of volatile oil from both fennel fruit and grass is significantly influenced by the experimental factors tagged in the doctoral thesis. Also, the genetic characters specific to each fennel variety have a major influence.

In **the eighth chapter**, the results regarding the quality of *Foeniculum vulgare* Mill. species are presented. On this basis, the influence of the experimental factors on the chemical composition of the volatile oil, the secondary metabolites content, as well as the ability of the essential extracts to inhibit the development of microorganisms are highlighted.

Following the GC-MS analysis, 15 chemical components were identified in the volatile oil extracted from sweet fennel and bitter fennel fruits.



The main components of the essential oil from *Foeniculum vulgare* var. *vulgare* are: anethole (70.49% - 76.21%), fencone (12.03% - 14.25%), estragole (3.45% - 4.19%), anisaldehyde (1.05% - 5.51%) and α -pinene (2.08% - 3%).

The major components of the volatile extract of *Foeniculum vulgare* var. *dulce* are: anethole (64.89% - 74.65%), fencone (12.43% - 15.34%), estragole (5.69% - 7.79%) and α -pinene (2.14% - 5.61%).

The data obtained in this research showed a significant influence of foliar treatments on the major essential oil components of bitter fennel and sweet fennel seeds.

Foeniculum vulgare var. *vulgare* showed a lower capacity to discharge free radical reactions, compared to *Foeniculum vulgare* var. *dulce* where the antioxidant activity listed higher values by over 50%.

A pellucid influence of foliar treatments is identified, in the case of sweet fennel, where all antioxidant activity values were improved by using the foliar nutrients. The synthesis of phenolic and flavonoid components in plants from both fennel varieties was significantly influenced by the use of foliar treatments.

The doctoral thesis accomplish with a chapter assigned to conclusions, developed from the research data obtained in the research.

Certain useful recommendations can be deduced from the results, to sustain potential studies in other researches, alongside to outline new assessments in the cultivation of aromatic and medicinal plants.

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