ABSTRACT

Keywords: microgreens, seeds, nutrient substrate, innovation.

The research carried out in order to develop the doctoral thesis with the title "Research on the foundation and practice of vegetable crops in the microgreens system" was carried out between 2016 and 2019, in the greenhouse of the Research Institute for Agriculture and the Environment of the University of Life Sciences. Ion Ionescu from Brad" from Iasi.

Research motivation

The culture of vegetable plants of the microgreens type, being at the beginning of the road in our country, presents a considerable need to learn information about the technological process. Therefore, the first step in this process is the quality of the seeds that will be used. A viable seed, with optimal germination rates, leads to the success and profitability of the culture, especially in the case of the microgreens culture, where the quantities of seeds used for establishment are very large.

The aim of the work is to evaluate the possibilities of practicing microgreens type vegetable culture in our country, in protected spaces, and to improve knowledge about cultivation technology in optimal conditions. The realization of a cultivation technology for those who are interested in this new type of culture, actually helps vegetable cultivation, through the scientific input and the diversification of the technological material and the vegetable production system.

In order to achieve the proposed goal, the following objectives were established:

1. The study of the germination of the seeds of the vegetable species chosen for the culture of microgreens;

2. The study of the influence of the species and the substrate in the realization of the culture of microgreens;

3. The study regarding the attitude and preferences of consumers towards the microgreens vegetable product.

In order to carry out the studies and research of the doctoral thesis, it was necessary to use three categories of biological, biotechnical and technical material. The biological material used was represented by seven species of vegetable seeds, as follows: garden pea, moon red radish, summer radish, early white cabbage, red cabbage, red basil and green basil.

The biotechnical material used in the study was made up of the vegetation pots (18/11/6 cm trays and special cellulose cups for seedlings) and the substrates used in the experiments (coconut waste, peat 80 % + 20 % coconut, peat 80 % + 20 % perlite, peat 80 % + 20 % sand, as well as non-woven fabric.

For the first proposed objective, namely ***the study of the germination of the seeds*** of the vegetable species chosen for the culture of microgreens, observation, analysis, documentation and determination of germination indices were used as the working method. The experiment was carried out in the Laboratory of Vegetables, within USV Iasi, using the SANYO MLR-35 1H germinator, regulated with three temperature graduations, namely 15°C, 20° C and 25° C. For all seven vegetable species analyzed, observation and determinations regarding the germination rate, germination dynamics, germination speed and germination coefficient, the observations were made daily. In order to achieve the second proposed objective, in addition to the documentation necessary to choose the best types of substrates, observation, comparison and biometric determinations were the most important work methods. Two experimental factors were used, represented by the type of substrate with the four variants (1 - coconut waste, 2 - peat 80 % + 20 % coconut, 3 - peat 80 % + 20 % perlite, 4 - peat 80 % + 20 % sand) and the seven vegetable species chosen (garden pea, moon red radish, summer radish, early white cabbage, red cabbage, red basil and green basil).

Regarding the last proposed objective, in addition to analysis and observation, I also used the interview method (survey method). The questionnaires were addressed to consumers in the area of Iasi county, between August and September 2019.

The thesis is structured in two parts and seven chapters

Part I – **The current state of knowledge**, includes two chapters:

Chapter 1 - The importance of growing vegetable plants in the microgreens system

Chapter 2 - General considerations regarding the technological flow of growing vegetable species in the microgreens system

Part a - II - **Results of own research**, includes five chapters:

Chapter 3 - The purpose and objectives of the research. The material used and the general working methodology

Chapter 4 - Study of natural and administrative-organizational framework conditions

Chapter 5 - Results regarding the study of seed germination depending on the temperature

Chapter 6 - Results regarding the influence of the species and the substrate on the culture

Chapter 7 - Results regarding the attitude and preferences of consumers towards microgreens vegetable products. The bibliography includes a large number of bibliographic references, both from Romania and from abroad.

Chapter 1. The importance of growing vegetable plants in the microgreens system, includes four subchapters, namely:

- 1.1. The importance of growing vegetable plants;
- 1.2. Cultivation of vegetable plants in the microgreens system;
- 1.3. Cultivation system of vegetable plants;
- 1.4. The main risk factors of microgreens culture.

In the first subchapter, emphasis is placed on the food and economic importance of plants.

With regard to the nutritional importance, reference is made to the energetic importance (through the intake of carbohydrates, proteins and lipids), to the importance as a source of fibers, catalytic importance (through the intake of vitamins), mineralizing importance (through the intake of mineral salts). Along with these components, vegetables also contain substances with a sanogenic role, seasoning and aromatic substances, antibiotic substances, etc.

Regarding the economic importance, it is shown that, through the cultivation of vegetable plants, an intensive use of the land is ensured and it is possible to obtain consistent incomes, compared to other crops, some horticultural crops and especially agricultural ones (cereals and technical plants). Moreover, the culture of vegetable plants allows a high intensification compared to the system of protected culture and especially forced culture (in greenhouses and solariums).

The intensive system and modern technologies ensure a high economic efficiency of vegetable culture, comparable to that of flowers.

In the second subchapter, reference is made to the importance of growing vegetable plants in the microgreens system, two structural elements being addressed - the food importance and the economic importance of these crops.

Regarding the nutritional importance of microgreens type vegetable products, it is shown that the main chemical components of these products are several times higher in concentration than in current products.

At the same time, it shows that the products are much easier to digest and give the food a more appetizing appearance. Of great importance is the fact that microgreens are products that ensure a new diversification of food regimes, especially for vegetarian or vegan consumers.

The economic importance results from the innovative character of the product, from the relatively high prices, but justified by the nutritional and sanogenic value. In the circumstances of advanced technologies, technically and economically optimized, the efficiency of such products is ensured, in this sense there are enough examples from countries where the technology is performing well, and the consumer market is sufficiently developed.

In subsection 1.3. a synthesis of the main cultivation systems of vegetable plants is made. This synthesis helps to make comparisons between this and especially with modern, innovative, economically efficient systems with chances of being promoted.

The two big systems are presented in order - the system of conventional crops (in unprotected land and in protected system) and the system of non-conventional crops (in ecological system and microgreens system).

Finally, the last subchapter is presented, which presents and discusses the main risk factors of microgreens culture. It is emphasized that the production of the microgreens harvest is subject to many dangers or risk factors, because the biological material (seeds and germs) is very vulnerable and can be attacked by particularly dangerous agents, and chemical treatments are prohibited, because the harvest is carried out in a few days and cannot be polluted by pharmaceutical substances.

Chapter 2. General considerations regarding the technological flow of cultivating vegetable species in the microgreens system

This chapter concretely presents how a culture of microgreens is made under standard working conditions, based on the information from the specialized literature. In this chapter, the following technological links are presented, systematized in eight subchapters:

2.1. The choice of vegetable species
2.2. Preparation of seeds for establishing the crop
2.3. The choice and preparation of cultural spaces
2.4. Choosing and preparing culture vessels
2.5. The choice and preparation of culture substrates
2.6. The establishment of culture
2.7. Maintenance of microgreens cultures. Regulation of culture factors
2.8. Harvesting and post-harvesting

In the first subchapter, attention is drawn to the fact that not every vegetable species is suitable for the culture of microgreens, because the small plants must have a pleasant taste (sweet - sour, sour, sweet - hot, etc.), solanaceae vegetables are not used, for example, which produce bitter plants (toxic, poisonous).

In the second sub-chapter, the method of seed preparation is presented and includes the following elements of content: selection and preparation of seeds, emphasizing their quality. This quality of the seeds is assessed based on the following quality indices: purity, twining, vigor and state of health (fitosanatara).

The next subchapter refers to the choice and preparation of culture spaces. Here the difference is made between the production of microgreens in a familiar system (relatively simple, but with compliance with phytosanitary hygiene rules) and the production of microgreens in an industrial or commercial system, where the culture vessels must be arranged in such a way as to ensure optimal conditions of light, air, humidity atmospheric, current care, etc.

In the next subchapter, 2.5., reference is made to the culture substrate, its nature and how to use it. The substrate must be sterile (hygienic), present optimal qualities for seed germination and optimal conditions for the growth and development of microgreens plants. Two more commonly used substrates are presented - peat and coconut shell.

In the next chapter, the way of establishing the culture is presented. There are informative data about 14 species of plants recommended for microgreens culture, as well as some technical elements such as: seed soaking time, seed quantity, time of establishment (season), sowing depth and number of days until harvest.

A very important aspect of the technological flow refers to the maintenance of culture, which is presented in a separate subchapter. The maintenance is relatively simple, but it is particularly demanding, regarding the regulation of vegetation factors: temperature, humidity, light and nutritional regime.

The temperature must be 18 - 28° C, the ambient humidity must be around 50 %, the light is provided with different sources, the most suitable ones seem to be those with LED diodes; the nutrition regime is usually ensured before sowing, by incorporating it into the culture medium, using different fertilization recipes, recommended by specialized companies.

Harvesting and post-harvesting are dealt with in subchapter 2.8. In this chapter, some important aspects are discussed - harvesting method and post-harvest storage.

The harvesting method refers to the time of harvesting and the method of harvesting (cutting a few millimeters above the substrate).

Post-harvest storage is a very important operation, due to the fact that the harvest is very vulnerable. This is determined by the harvesting method, the ambient temperature and the storage temperature after harvesting. Some modern preservation methods are

also presented. The storage temperature is around 0° C, provided that the humidity does not cause the formation of drops on the plants.

Chapter 3. The purpose and objectives of the research. The material used and the general working methodology

In this chapter, the entire strategy for the realization of the thesis is presented, as follows:

3.1. The purpose and objectives of the research

3.2. The material used

3.3. General working methodology

In the first subchapter, the purpose and objectives of the research to be carried out within the thesis are presented.

The purpose of the work is to evaluate the possibility of practicing microgreens vegetable culture in our country, in protected spaces and to improve the knowledge about this type of culture in optimal conditions.

The general objectives of the research aim to achieve the proposed goal. The following objectives were proposed in the research program:

- The study of seed germination in the vegetable species chosen for the culture of microgreens;

- The study of the influence of the species and the substrate in the realization of the microgreens culture;

- The study regarding the attitude and preferences of consumers towards microgreens vegetable products.

In subsection 3.2. the material used to carry out the research is presented. Three categories of material were used: biological, biotechnical and technical.

The biological material is represented by seven vegetable species: garden pea, moon radish, summer radish, early white cabbage, red cabbage, red basil and green basil.

As technical material, they were used: filtered water, drinking water, labels, knives, sprinklers, foil of different types, etc.

The main biotechnical materials were represented by vegetation vessels and culture substrates.

In subsection 3.3. the general work technology is presented, methods specific to research work were used: experiment, observation, comparative analysis, case study and the interview method, corresponding to the research objectives.

The research protocol includes the following stages:

- Verification of the germinability of the biological material, respectively of the seeds from the seven vegetable species

- Verification of the readiness of vegetable species for cultivation in the microgreens system
- The study of the influence of the growth substrate for this type of culture
- The study of consumer attitudes and preferences towards microgreens products

Chapter 4. The study of the natural and administrative organizational framework conditions

This chapter is justified by the purpose and objectives of the study, the material and the working method. The results of this study are presented below, as follows:
- geographical location;
- climatic characterization (temperature, precipitation, humidity, cloudiness);
- the meteorological characterization of the experimental years (2017, 2018 and 2019);
- organization of the work space and environmental conditions (temperature, humidity, light intensity).

Chapter 5. Results regarding the study of seed germination depending on the temperature

The main purpose of the research presented in this chapter was to establish the optimal temperature regime for the realization of the microgreens culture, at the standards accepted by consumers.

The study is complex and has the following objectives specific to this chapter: the cultural value of the seeds, the dynamics of seed germination depending on the temperature, the establishment of the germination rate, the establishment of the germination speed depending on the temperature and the establishment of the velocity coefficient depending on the temperature.

The seeds specified in the general part of the work methodology were used as biological material: garden peas, red moon radish, summer radish, early white cabbage, red cabbage, green basil and red basil.

A bifactorial experiment was used as the basic method, in which factor A was represented by the seven types of seed, and factor B was represented by three temperature graduations: 15° C, 20° C and 25° C.

The final goal of the experiment was to establish for each species of seeds what is the optimal temperature based on the germination indicators, as presented in the objectives of the experiment.

The results are structured according to the methodology, regarding the cultural value, the germination indicators at the three temperature steps: 15° C, 20° C and 25° C.

Regarding the cultural value, all seeds have the limits presented in the quality standards for seeds. The germination had values between 95 % (for peas) and 99 % (for red cabbage and green basil).

The indicators of geminability had the most favorable values at a temperature of 20° C. Regarding the dynamics of germination at all three degrees of temperature, in the first days it increases significantly, after which a plateau phase follows. The germination rate is the most relevant indicator that directly influences the other indicators and primarily the germination speed.

From the obtained results, the most balanced values regarding germination dynamics, germination rate and germination velocity were obtained for all species (relatively cryophilic species), at a temperature of 20° C.

Chapter 6. Results regarding the influence of the species and the substrate on the culture

The researches whose results are presented in this chapter are interesting, necessary and useful. The information obtained as a result of these researches is very interesting due to their novelty, because such researches are carried out for the first time in the circumstances of the presented research protocol. Such research is necessary, because only in this way can technical solutions be found that ensure the success of the culture. To the same extent, the information obtained based on the technologies for the realization of this type of culture.

The purpose of the research is to establish the suitable species, as well as the best substrates, which will ensure successful crops, in the natural and technical conditions of our country.

To achieve the proposed goal, the following objectives were established:

1. The study of the influence of the vegetable species used on the culture of microgreens;

2. Study of the influence of the substrate used;

3. Study of the influence of the combinations of the two factors.

Seeds from the seven vegetable species and four types of substrate were used as working material: coconut waste, peat 80% + coconut waste 20%; peat 80% + 20% perlite and 80% peat + 20% sand.

In summary, the research method was a bifactorial experiment: factor A - the species mentioned in the biological material and factor B - the culture substrate mentioned in the biotechnical material.

The results of the experiments were structured according to the established objectives.

The results regarding the influence of the species on the culture of microgreens show: the average number of days required for seed germination, the number of days required for the period of growth and development, the length of the harvest period, the uniformity of the crop, the phenological and morphological characterization of the crop.

Germination duration varied within relatively wide limits: from 2.58 days for summer radish, to 5 days for red basil, with an experimental average of 4,01 days.

The duration of the growth and development period varied from 6,41 days for summer radish, to 9.33 days for green or red basil, with an average of 7,33 days.

The duration of the harvest period varied between 9,29 days for the moon radish, up to 11 days for the green basil with an experimental average of 10,19 days.

The uniformity of the culture is appropriate and approaches the commercial standards. Cabbage is the crop with a lower uniformity (77,1 – 75,4 %), and the best results were obtained with radishes (87,5 – 89,2 %).

The phenology of the crop is determined by the germination indicators: the average germination days are between 2 - 4 days for radishes, up to 4 - 6 days for green basil. Harvesting can take between 7 - 11 days (for red radish) and 9 - 14 days (for basil).

Microgreens plants have a height between 2,15 cm for green basil and 7,33 cm for garden peas, and the mass of a plant varies between 0,01 g for basil and 0,7 g for peas.

The results regarding the influence of the culture substrate are evaluated according to the duration of the germination days, the duration of the growth and development period, the duration of the harvest period, the uniformity of the culture.

The germination time varied between 3,76 days (on the coconut culture medium) and 4,47 days (on the peat and perlite medium), in conclusion the general average was 4,01 days.

Between 7,16 days (on the peat and coconut culture medium) and 7,61 days (on the peat and perlite medium) were needed for growth and development.

The harvesting period lasted between 9,94 days (on the coconut medium) and 10,61 days (on the peat and perlite medium).

The uniformity of the culture was better, 92,5 %, (on the medium consisting of coconut waste) and the lowest 72,3% (on peat and perlite).

The combinations of factors (species x substrate) showed values that exceed the individual values of the two factors, which shows that the optimal grading for the substrate factor must be found.

The production results, expressed by the number of plants per culture tray and the weight of the plants, show that the highest amount of harvest, as a number of plants, was 1449 plants/tray for the red basil species, and the lowest amount of harvest the number of plants was 149.7 plants/tray, for the pea species.

Expressed in g/cm², the values that obtain the amount of harvest vary between 0,11 g/cm² (for basil) and 0,56 g/cm² (for peas).

Chapter 7. Results regarding the attitude and preferences of consumers towards microgreens vegetable products

The motivation of the research in this chapter results from the fact that it is necessary and useful to know the consumer's interest in this vegetable product in order to establish the development strategy of the microgreens product.

The purpose of the research presented in this chapter is represented by the knowledge of the relationship between the consumer and the producer, based on the consumer's attitude and preferences, depending on his socio-professional profile.

To achieve the proposed goal, the following objectives were established:

- Realization of the socio-professional profile of the respondents;
- Questioning the respondents regarding the attitude towards microgreens products;
- Questioning the respondents regarding their preferences for microgreens.

The research methodology is based on the face-to-face interview method based on a questionnaire.

The questionnaire has three parts: elaboration of the socio-professional profile (gender, age, family members, education, family income, place of origin), the relationship with the microgreens product (if it is consumed, how often, what criteria are used to choose the product, which are the species used), preferences compared to microgreens products (preferred species, consumption rate, appreciation of the microgreens product).

The methodology continues with the pilot phase in which the questionnaire is analyzed by a panel of respondents to clarify the aspects regarding the attitude and preference towards the microgreens product.

Next comes the establishment of the survey sample and the conduct of the interview. The recorded data are processed using a specialized software program - SPSS - Statistical Package for the Social Sciences Statistical Analysis for Social Studies.

The results of the research reported in this chapter can be summarized as follows:

- The microgreens vegetable product is little known among the respondents;
- The types of microgreens most known among the respondents are: cabbage, peas and radish;
- The population of consumers participating in the interview is concerned about the level of pesticides in vegetable products;
- Microgreens vegetable products are not currently known to consumers, but through serving in restaurants;
- Microgreens products are still little accessible to consumers, because they are really expensive products;

- Microgreens are vegetable products with great nutritional potential and that deserve to be promoted, especially because they have a relatively simple production technology.