S U M M A R Y

of the doctoral thesis entitled:

COMPARATIVE STUDY OF CONVENTIONAL AND ORGANIC CULTIVATION SYSTEMS FOR RASPBERRY AND ARONIA

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In this doctoral thesis, entitled "*Comparative study of conventional and ecological cultural systems for raspberries and chokeberries*" developed by PhD student Dragomir Damian under the scientific coordination of Prof. Univ. Dr. Dorel Hoza, within the Doctoral School of Plant and Animal Resources Engineering and Management of the University of Agronomic Sciences and Veterinary Medicine in Bucharest, we have included the results of the experimental research in fruit plantation conditions carried out during the years 2020 – 2023 within the Moara Domnească Experimental Base of the Research and Development Station for Fruit Growing Băneasa Bucharest.

The theme of the doctoral thesis is one that focuses on current concerns, of global and national interest, namely the production of fruits in organic and conventional system, regarding also to the aronia and raspberry species as important and novel fruit species.

Given the current context of climate change crises coupled with the need for food production that meets the needs of consumers, farming systems need to aim at achieving several objectives. Thus, greatly influenced by the urgent problems generated by climate change, as well as by environmental degradation and the need to ensure food security, the EU has developed a series of strategies underlining the urgency and need to address at Member State level, on a wider scale, new farming

systems aimed at protecting and expanding biodiversity and ensuring or rebalancing the environment.

Organic farming and especially organic fruit growing is a production system that has as its ultimate goal the creation of a sustainable balance within the ecosystem, with a direct positive effect on the prevention of problems caused by specific diseases and pests, as well as on the maintenance and improvement of soil fertility.

On the other hand, the demand and need for high-quality fruit products and berries is constantly growing at global, European and national level, hence the need to develop cultivation technologies that are capable of leading to sustainable and economically efficient production. In this sense, the fruit growing systems must pursue several objectives, such as: ensuring consumption, ensuring the quality of production, environmental protection and last but not least a fair income for the producer

In this context, the purpose of the research in the thesis was to study, evaluate and compare the efficiency and sustainability of chockberry and raspberries cultivation technologies, in organic and conventional system, especially by studying the effect of mulching, used as the main method used in organic and conventional farms for production factor management at the plant level aiming also at achieving the sustainability of the production.

As for the species chosen to be studied in this doctoral thesis, the documentary studies showed that there are two categories of fruits that have a wide search, having food and nutraceutical properties chokberry and raspberry.

The chosen experimental factor, namely mulching the land with a protective organic origin layer, placed in the direction of the fruit shrubs rows, was identified and selected as a technological method capable of contributing to the achievement of sustainability objectives and principles, respectively having positive effects on soil health and biodiversity, being last but not least a renewable resource that leads to reducing the farm's dependence on external resources.

The specific research objectives were aimed at:

- evaluation of the influence of the cropping system (organic and conventional) as well as mulching, on the main parameters of growth and fruiting, on the productivity and quality of three varieties of chokberry;
- evaluation of the influence of the cropping system (organic and conventional) and mulching on the main fruiting, productivity and quality of three raspberry varieties;
- making recommendations on the appropriateness of using mulching technique in fruit shrub farms.

The doctoral thesis is structured in eight chapters.

The first three chapters are made up of information that contains and substantiates the theme of the scientific study, describing all the arguments identified

in the literature in the field of organic agriculture and fruit growing. The following five chapters make up the part relating to the own research carried out during the study period.

Part I is dedicated to the bibliographic study necessary to substantiate the research topic, being made up of three chapters.

In chapter one, specific elements of organic farming are introduced with in an integrated and exhaustive way, by presenting the history of organic farming, the advantages and disadvantages of this production system. Also, this chapter presents the bases and principle of sustainable ecological agriculture, European and national regulations for organic farming, and its role within the strategies that aim to put into practice the European Green Deal, through the Biodiversity Strategy and the "Farm to fork" Strategy. Based on the bibliographic study, the current level of development of the organic production system is detailed as well as its trends, including the approaches contained in the Action Plan for Organic Farming.

Next, in a subchapter dedicated to the evolution and trends of organic agriculture and fruit growing in Romania, the importance of organic fruit growing is presented, respectively of the production of quality berries, without pesticide residues, with minimal negative impact on the environment.

A special sub-chapter, with an innovative character, is the one that brings up-to-date information on the adoption trends in organic farming, namely the integration of Agriculture 4.0 and Hortivoltaics in organic farms. Thus, the technologies used in Agriculture 4.0 such as: IoT, agricultural robotics, drones, GPS technologies, soil sensors and satellite images, digital weather stations equipped with multiparameter sensors, can facilitate sustainable production, in order to manage the activities of fruit farms. Also, the new trend of integrating agrivoltaic or Hortivoltaic systems into fruit farms is presented, representing an innovative system that offers the opportunity to simultaneously use land dedicated to fruit production, both for fruit production and for the generation of photovoltaic solar energy, a system that can bring benefits to farmers in the context of the energy crisis, correlated with the climate crisis.

Chapter two, the stage of research on organic fruit growing and details regarding the cultivation of fruit shrubs in organic and conventional systems, substantiates the selection for study within the thesis, of a technological link that can determine the reduction of the impact of fruit technologies on farm biodiversity as well as soil fertility. This technological link refers to the covering (mulching) of the soil with a layer of material of organic origin, a technological method that also has a direct impact on the productivity and quality of the fruits obtained in fruit shrub plantations.

Chapter three presents the species selected in the study, in terms of origin, cultivation area and importance of the crop, along with the growth and fruiting particularities of each species, as well as elements regarding the requirements regarding the environmental conditions and cultivation technology of each species.

Part 2, consisting of own research, consists of 5 chapters in which the purpose and objectives of the research are presented, the organizational framework of the experience, the results of the determinations regarding the influence of experimental systems and variants on the main indicators of growth and fruition as well as a chapter with general conclusions and recommendations.

The fourth chapter presents the purpose and specific objectives of the doctoral thesis, namely studying the influence of organic and conventional cropping systems, as experimental factor mumming and the evaluation of the influence of the cropping system and mulching on the main parameters of growth and fruiting, on the productivity and quality of aronia and raspberry varieties, all in order to substantiate and formulate recommendations on the opportunity to use the mulching technique in farms. of fruit shrubs (this being the practicality element of the thesis).

Chapter five presents the material and method as well as the natural setting in which the studies were carried out. The experimental lot was established in 2020, within the Moara Domnească Experimental Base belonging to SCDP Băneasa, Bucharest, in Afumaţi commune, county. Ilfov. For a solid foundation of the response of fruit plantations to biotic and abiotic factors, in addition to climatic, pedological, morphological and agrochemical characterizations, in this chapter we have also carried out a *multiannual analysis on the evolution of the main climatic factors affecting the area*. From this study it emerged very clearly that the period 2020–2023 was characterized by large amplitudes and climate changes, especially due to global climate variability and change. To highlight these trends, multiannual average climate data for the period 1961-2007 were used, which were compared with weather data collected during the period of the study. The conclusion was that, at the level of the Moara Domnească Experimental Base, significant trends of increasing annual average temperatures and rainfall deficits are highlighted. These factors are increasingly present especially in the spring and autumn, affecting significantly the growth and development of fruit shrubs. The general trend is of increasing the average temperature, as average the difference between multiannual temperature and actual ones, being of one increased by 1.5 to 2°C. This phenomenon, in conjunction with insufficient or unevenly distributed rainfall, adding the level of evapotranspiration, has a significant negative effect on plants, by compromising the essential physiological processes, such as photosynthesis, respiration and transpiration, with a direct effect on growth and fruiting.

The biological material subchapter describes the varieties used in the experiment, for each species, three varieties with distinct characteristics and requirements being chosen. For chokberry varieties chosed were Galicjanka, Melrom and Nero, and for raspberries Polka, Laszka Sokolica. Those varieties are described, along side with the main elements related to growth and fruiting, as well as the

characterization from the point of view of the habitus of the plants but also from the point of view of the characteristics of the fruits.

In order to highlight the technology applied during the study, so from experimental plot establishment to the maintenance works, the technological methods are described. Considering the typology of the species as well as the way they are managed, each species is characterized by specific requirements, the aronia crop being maintained as a bush, and the raspberry crop being supported by a system consisting of support poles and wires.

In order to implement the experimental factor, in accordance with the experiment scheme, a layer of mulch in a layer of 10 – 15 cm was applied on the rows of fruit shrubs, the material used being of organic origin, namely wood chips. This experimental factor, together with the conventional and organic cropping system, represents the factors that have been studied, namely the way in which it influences the growth and fruiting parameters of the chosen species as well as the main fruit quality indicators.

Another important activity carried out within the experimental plot was the taking of soil samples for detection and analysis of multipesticides residues, furthermore in order to comply with the principles of separation and spatial delimitation of the organic plot, it was decided and executed the preparation and establishment thorugh sowing with wheat ofe perimetral plots. Also theis surface was administered in an organic system. This chapter also describes the activity as well as the purpose of the organic certification of the experimental plot, so in order to validate the production process and confirm the research carried out, the entire organic certification process has been completed. In 2020, the procedures for organic conversion the land and the plantation were started, so in 2023 the organic certification was obtained, after completing the 3 years of conversion (aronia and raspberries being considered perennials).

The experimental lot consists of two species, chokberry and raspberry, for each species 3 experimental factors are designed, respectively Factor A: cropping system, conventional and organic; Factor B: the variety with three grades, three varieties for each species and Factor C: the treatment with two grades, mulched and non-mulched. The rows of shrubs studied were made up of 10 plants of each variety and on each variant. The experimental group was placed in randomized blocks, with 3 replicates on each variant. In choosing the plants subject to the determinations, the avoidance of the end effect was taken into account, respectively plants 2, 3 and 4 of each row and variety were determined.

The research methods and methodologies used aimed to determine the influence of the conventional and organic cropping system, as well as the other experimental factors, on the main parameters of growth and fruiting of the chokberry and raspberry varieties. In this chapter, the main indicators followed as well as the

material, equipment and methods used in making the specific determinations are presented.

In order to determine the influence of the cultivation system and the experimental factors on the growth and fruiting of the species under study, specific determinations were made, in aronia the determinations were the growth and fruiting parameters including: the number of shoots per plant, the number of clusters per plant and the number of fruits per bunch, these being determined by counting, in each year of the study and on each variant and treatment. As far as the quality parameters are concerned, on a sample bases of 60 fruits from each experimental variant (cultivation system, variety, treatment), fruits were analysed within the SCDP Băneasa laboratory, and determinations regarding the average fruit mass, height and diameter of the fruit (by weighing and measuring), subsequently for each fruit the quality indicators were determined, soluble dry matter, pH and titratable acidity respectively, were performed.

For raspberries, the determinations included the fruit quality parameters such as morphological characters of the fruits: average weight, fruit content in phenols, vitamin C, anthocyanins and antioxidant capacity. The chemical determinations were made in the laboratory using the specific methods and methodology for each type of analysis.

In order to statistically sustain the obtained results, the data was processed with using statistical analysis programs, applying the mono or bidirectional ANOVA test, followed by the Duncan test with a significance level of 0.05. The results obtained are presented within thesis in the form of tables and graphs.

In chapter six , own research and determinations results related to aronia, are extensively presented, pursued the specific objectives set:

- ***The influence of the cropping system on the vegetative growth parameters*** was determined by quantifying the number of shoots per plant, the average and total number of fruits per plant. This indicator was calculated by multiplying the number of bunches/plant by the average number of fruits/bunch. It was concluded that during the three years of the study, the indicators on vegetative growth and fruiting show significant variations, both related to the crop system factor (organic and conventional) and to the experimental factor (mulched and non-mulched). Regarding the number of shoots per plant, in 2021, the maximum value was reached by the non-mulched organic variant, and the minimum number by the conventional non-mulched variant. In 2021 and 2022, Melrom variety produced the highest average number of shoots per plant in the non-mulched organic system, and the lowest was recorded in Galicjanka variety, also in the organic mulched system. It has ben observed that Galcijanka variety shows a very high variability between the organic and conventional mulched and non-mulched variants. In 2023, the maximum number of shoots was reached by Nero variety in the conventional non-mulched variant, and the lowest number Galicjanka in organically mulched variant.

From the analysis of the fruiting indicators (average number of clusters per plant and average number of fruits per cluster), they showed a very high variability, indicators being significantly influenced by the crop system factor and the mulched vs. non-mulched variant. In 2021, Nero variety, in the organically mulched variant, performed better than the other varieties analyzed, the lowest number of fruits being recorded by Melrom in the conventional non-mulched variant. In 2022, a higher productivity was achieved than in 2021, Galcjanka in the non-mulched organic variant being the most productive, and the lowest result was achieved by Melrom variety in the conventional non-mulched version.

In order to achieve one of the specific objectives of the doctoral thesis, namely the formulation of recommendations regarding the opportunity to use the mulching technique in fruit shrub farms, the effect of the cropping system on the productivity indicators was analyzed, respectively the average fruit weight, corroborated with the total number of fruits/plant, were factors to determine the total amount of fruits per plant.

As for ***the average fruit weight,*** determined according to the variant and cropping system, in 2021, Galicjanka variety recorded the highest average fruit weight in the conventionally non-mulched variant. In 2022, Galcjanka recorded the highest average fruit weight in the conventional mulched variant, followed by Nero in the organically non-nulched variant. Compared to the average fruit weight and the mulched/nonmulched system, the data analysis showed that the mulched variant produces a positive effect on this indicator, indicating that mulching had a significant positive effect on productivity. In 2023, the data analysis highlighted the differences in the average fruit weight between the varieties and cultivation methods, with the highest average fruit weight being recorded by Melrom variety in the conventional non mulched variant, and the lowest by Galicjanka variety in the organically mulched variant. The highest variability in fruit weight was recorded by Nero in organic mulched variant, and the lowest variability by Galicjanka, in conventional system. Melrom variety, tends to produce on average the heaviest fruits, and Galicjanka with the lowest mass. In conclusion, cultivation methods had a different impact on fruit weight depending on the variety. By applying post-hoc statistical tests, it has been concluded that in 2023, there are no statistically significant differences between conventional mulched and non-mulched variants.

The productivity calculations were made based on estimated average productions. In the calculation of the average productivity, was considered a planting scheme of 3 m x 1m, resulting in a number of 3,333 plants/ha, as well as a constant average productivity during the years of study. By extrapolating and interpreting the data, it has been calculated that Nero variety was the most productive in all cultivation variants, organic and conventional, obtaining a production of 9,463 kg of fruits/ha in mulched variant and 8,735 kg/ha in the non-mulched variant. Galicjanka and Melrom

varieties had variable yields, with a minimum reached by Galicjanka in conventional non-mulched system- 3,645 kg/ha. All varieties generally performed better in organic variants compared to conventional ones. From this data has been concluded that it is recommended to cultivate the Nero in organic system by applying mulch cover.

In conclusion, the study demonstrated that the cropping system and mulching technique significantly influence the vegetative growth parameters and production of the chokberry crop. During the three years of the study, the organic and conventional systems, with mulched and non-mulched variants, were marked by significant variations in the number of shoots and fruits per plant. The data suggest that mulching has a significant positive effect on fruit weight as well as productivity and in order to maximise productivity, it is recommended to use mulching technique, especially in organic cropping systems.

Chapter seven, is dedicated for the **results of raspberry**, thus in order to determine the influence of experimental factors, the morphological characteristics of the fruits, the antioxidant activities and the content of bioactive compounds in raspberries were determined and studied for each variety chosen in the study.

Regarding the weight and size of the fruits, it emerged that organically grown fruits, in general, had a higher weight compared to conventional ones, but the qualitative parameters vary significantly depending on the years of study. In relation to the cultivation system, conventional and organic and mulched/non-mulched, in 2023, fruits grown in conventional mulched system showed the highest level of °Brix, while fruits grown without mulch in the organic system had a lower Brix level. The pH values of raspberry fruits did not show major variations, in general, the pH of conventional fruits being higher than that of organic ones. The mulched culture system produced positive influences on fruit weight as well as on soluble dry matter (°Brix) content, compared to the non-mulched system. From the point of view of the organic vs. conventional system, the soluble dry matter content (°Brix) and pH of conventional fruits in 2023 achieved the best results, while the titratable acidity was slightly higher on organic fruits, which may indicate a more intense flavor and a higher resistance potential of organic fruits.

Regarding each variety reaction to the experimental factors, it has been observed that Polka variety has had a positive response in organic system compared to the conventional one, both in mulched or non-mulched variants, the fruits morphological parameters as well as the fruits contents in phenols and anthocyanins being higher in the organic system.

Laszka variety also responded positively in organic mulched cropping system, the weight of the fruits being higher compared to the conventional production system. The fruit height and diameter indices did not vary significantly by cropping system, but the mulched and non-mulched variants have influenced the fruit pH. It has been registered values between 3.00 and 3.87 for the organic mulched fruits and 3.15 and

4.06 for conventional mulched fruits. As for the total acidity, the results showed that fruits from non-mulched variants, compared to mulched ones, have a lower acidity. Soluble dry matter (SUS) is positively influenced by the cropping system, especially for organic fruits compared with conventional ones. As far as vitamin C content is concerned, a similar trend can be observed, with the organic fruits registering higher values compared to conventional ones. The amount of anthocyanins is also higher in organic fruits compared to those from the conventional system.

Sokolica variety showed a yearly significant variation regarding average weight values, but it was noted that generally organic fruits registered a higher weight than the conventional ones. The amount of SUS, was influenced by the cropping system, in general organic system fruits registering higher values than the conventional ones. Regarding the fruit pH, as well as the amount of acids, during the three years of study there were no significant differences regarding the mulched and non mulched variants, but for organic fruits higher acid content was recorded comparing to conventional fruits. The same results were obtained in terms of anthocyanin content, the main compounds responsible for the color of raspberry fruits, the phenol content and the antioxidant capacity of the fruits. Regarding the comparison between mulched and non-mulched variants, in general, the non-mulched variant recorded higher values.

In conclusion, the results of the raspberry study showed that the genotype, cultivation method and year had a significant effect on the weight of all three raspberry varieties studied. Cultivation method, is not influencing the fruit size (fruit height and fruit diameter) due to the fact that this is a variety characterstic. Organic and conventional system of production did not significantly influence the fruit pH, during the 3 years of testing, but the fruit soluble dry matter content and total acidity increased slightly in organic fruits compared conventional ones. Regarding the total anthocyanins and total phenols content, it has been observed that cropping system as well as variety, affect strongly the level of bioactive compounds in raspberry fruits. The vitamin C content and the antioxidant capacity, were significantly influenced by the cultivation system practiced.

The raspberry study demonstrated that the genotype, cultivation method and year had a significant effect on the weight of the fruits. Generally, organically grown fruits weighed more than conventional, and mulching factor had a positive impact on weight and soluble dry matter (°Brix) content. Although the fruits size (height and diameter), was not significantly influenced by the cultivation method, the organic system led to a slight increase in total acidity and vitamin C content, compared to the conventional system. In addition, anthocyanins and total phenols had higher levels in organic fruits, indicating superior nutritional quality and increased antioxidant capacity. The conventional non-mulched system showed a significant impact on the averages of indices, emphasizing the importance of using mulch to reduce variations

induced by external conditions. Thus, mulching technique is recommended to be adopted by shrub farms, especially practicing organic systems, with the aim to maximize fruit weight, bioactive substance content and nutritional quality.

In chapter eight, conclusions and recommendations, it is highlighted that cultivation techniques (organic and conventional) and mulching versus non-mulching system, significantly influence vegetative growth and plant productivity. For both species studied, the growth and fruiting indicators as well as the quality of the fruits varied significantly between conventional and organic systems, with mulched and non-mulched.

For aronia, Nero variety has had organic highes productivity especially in organic mulched variant, and the Galicjanka variety recorded the highest average fruit weight in the conventional non-mulched variant.

For the raspberry species, the organic fruits generally showed higher weights and contents of bioactive substances compared to conventional ones, indicating the fruit higher nutritional quality. Mulching has contributed positively to increasing the weight and productivity of fruits.

Having in mind the obtained results, the recommendations addressed to fruit shrubs farmers refer to the positive influence of the organic farming system on the productivity and quality of fruits in both species, but especially on raspberries, due to the higher content of bioactive substances and the higher nutritional quality. Also, given climate change and its influence on plants, the general recommendation, is that farmers should adapt continuously their technologies and practices, so that maximum yields can be obtained from their crops.