S U M M A R Y

of the doctoral thesis entitled:

STUDY OF THE BEHAVIOR OF SOME KIWIFRUIT HYBRID GENOTYPES (*ACTINIDIA* SPP.) IN THE CONDITIONS OF THE BUCHAREST AREA

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Worldwide, kiwi fruits are appreciated, especially due to their taste and nutritional properties. Over time, numerous studies have been carried out internationally, regarding the development and improvement of cultivation technology, improvement of the variety assortment, health benefits of fruits, storage capacity, using possibilities etc.

For Romania, *Actinidia* represents a relatively new species. However, the creation, testing, and introduction of new varieties adapted to Romanian climatic conditions is a priority in our national pomology programs. Research and cultivation of kiwi plants in our country began in 1993, and the most important studies have been carried out in a joint Romanian-Italian breeding program, initiated at the Faculty of Horticulture of the University of Agronomic Sciences and Veterinary Medicine in Bucharest in partnership with Vitroplant Cesena, Italy.

The research topic "**Study of the behavior of some hybrid kiwi genotypes (*Actinidia* sp.) in the conditions of the Bucharest area**" **aims** at a detailed examination of the behavior of intra and interspecific hybrids from the collection located in the Didactic-Experimental Fields for Pomology of the Faculty of Horticulture, Bucharest. The hybrid collection can be considered the beginning point for the expansion of *Actinidia* species cultivation in our country, as these hybrids are adapted to the area's conditions and have greater frost resistance compared to the original species. Thus, the research undertaken in this doctoral thesis aimed at the following main **objectives**:

- studying the morphological and productive characteristics of kiwi plants;
- observing and describing the main phenological stages of kiwi plants based on local climatic conditions;
- studying male hybrid genotypes to select valuable pollinators;
- studying the physical and chemical quality parameters of the fruits of some kiwi hybrid genotypes at harvest time and at consumer maturity;
- determining the storage capacity of the fruits of some kiwi genotypes;
- studying the possibilities for marketing and processing kiwi production;

- analyzing consumer preferences regarding the consumption of Romanian kiwi fruits and some products obtained from them;
- studying the behavior of some kiwi genotypes regarding grafting propagation;
- description of the selected elite varieties for cultivation expansion.

This doctoral thesis consists of two parts, a first part that includes the documentary research on the current state of knowledge in the field, entitled "**Bibliographic study**" and a second part of experimental research entitled "**Personal Research**", which contains the research conducted, the results obtained, the conclusions of the work, and the original contributions to the development of the research topic.

In order to achieve the aim of the doctoral thesis and establish the research plan, the **first part** of the work, which includes 9 chapters, a detailed documentary study was carried out based on the specialized literature in the field that highlights aspects regarding:

- **Chapter I** - The current state of knowledge regarding the genus *Actinidia*;
- **Chapter II** - The current status of *Actinidia* breeding worldwide and in Romania;
- **Chapter III** - The importance and health benefits of consuming kiwi fruits;
- **Chapter IV** - The current state of knowledge regarding the morphology and biology of the main species of *Actinidia* genus;
- **Chapter V** - The current state of knowledge regarding the propagation methods of *Actinidia* species;
- **Chapter VI** - The current state of knowledge regarding the cultivation technology of *Actinidia* species;
- **Chapter VII** - The current state of knowledge regarding the harvesting and storage technologies for kiwi fruits;
- **Chapter VIII** - The current state of knowledge regarding the utilization of kiwi fruits and processing methods;
- **Chapter IX** - The current state of knowledge regarding the taste and consumer preferences.

In the **second part** of the doctoral thesis, which comprises 9 chapters, the research conducted and the original contributions made over the three years of study are described.

Chapter X. S*tudy of morpho-productive characteristics of some hybrid kiwi genotypes (Actinidia sp.) in the conditions of Bucharest area* includes a brief introduction, materials and methods, results and discussions, as well as some partial conclusions. The main objectives of this study are: determining the overall yield of some kiwi varieties and hybrids under the climatic conditions of the Bucharest area; observing morphological characteristics of the leaves, shoots, flowers, pollen, fruits, and bark of *A. arguta*, *A. chinensis* and *A. deliciosa* plants, as well as the seeds, young roots, and leaves from some *A. arguta*, *A. chinensis*, *A. eriantha* and *A. macrosperma* plants; determining the degree of species influence on the studied hybrids by observing the pubescence of the leaf surface and defining a simple algorithm for identifying the gender of Actinidia plants.

Regarding fruit production per hectare, the hybrids R0P12 (40.083 t/ha) and R3P6 (36.997 t/ha) stood out with higher yields compared to the other studied genotypes, with the control

varieties Hayward and Bruno registering 51.169 t/ha and 39.684 t/ha, respectively. The other hybrids recorded average, small, or very small yields, below 20 t/ha.

Numerous morphological characteristics of kiwi hybrids are influenced by the parent species. Most interspecific hybrids between *A. deliciosa* x *A. chinensis* exhibited characteristics similar to *A. deliciosa*, while the hybrids between *A. chinensis* x *A. arguta* were similar to *A. arguta*. Observations under a stereo microscope on the pubescence of the lower side of kiwi leaves indicate that the density of stellate hairs can provide information about the degree of parental species influence on the hybrids, and the number of arms or branches of a stellate hair can offer information about the gender of the plants. Although there are some worldwide studies on kiwi leaf pubescence (*Huang et al., 1999*; *Huang and Ferguson, 2007*; *Huang, 2016*; *Zhixue et al., 2002*), this hypothesis has not been previously proposed. Given the practical importance in the process of genetic breeding, in the selection of hybrids, as well as the advantages of this method (reduced analysis time and low costs), this technology for identifying the genus of kiwi plants can be considered an innovative and very useful one. In order to verify this algorithm for identifying the genus of kiwi plants based on the morphological analysis of leaf pubescence, further observations are needed on the morphology of leaf pubescence of different species of *Actinidia* from different climatic conditions and zones.

Chapter XI. ***Phenology of Actinidia genotypes in the climatic conditions of the Bucharest area*** includes a brief introduction, materials and methods, results and discussions, as well as some partial conclusions. Given that *Actinidia* is a relatively new species in Romania, characterizing the main stages of growth and fruiting can optimize and refine some horticultural practices and operations regarding the maintenance of kiwi plantations, such as frost protection, pruning, fertilization, pollination techniques, irrigation, or pest and disease control. In this context, the main goal of this research was to define the phenological stages of Hayward and Bruno varieties and some intra specific and interspecific *Actinidia* hybrids. The phenological stages were described under the environmental conditions of the Romanian Plain (Bucharest area), according to the BBCH code (*Meier, 2001*) and the nomenclature used by *Salinero et al., (2009)* for the species *A. deliciosa*, variety Hayward. Data were recorded over three consecutive growing seasons (2017-2020).

Actinidia species have specific requirements regarding temperature, humidity, wind, soil, etc. In addition, commercial crops require special maintenance practices to be productive. These horticultural practices influence the size and dry matter content of the fruits, as well as their market acceptance by consumers. An accurate understanding of the phenological stages of kiwi plants is essential for proper plantation maintenance. In conclusion, this study can improve the cultivation of this new crop in Romania, contribute to the Romanian breeding program, and also aid in the zoning of the main *Actinidia* species under the climatic conditions of our country.

Chapter XII. ***Study of some male hybrid kiwi (Actinidia sp.) genotypes for the selection of some valuable pollinators*** includes a brief introduction, materials and methods, results and discussions, as well as some partial conclusions. For kiwi pollinator (male) plants, breeding programs involve selecting elites with a long flowering period and a high pollen germination rate.

It is also very important that the flowering period coincides with that of the selected female plants and that they have the same degree of ploidy as the female plants (*Li et al., 2010*). The aim of this study was to evaluate the pollen grains from 15 kiwi hybrids to identify the most suitable pollinators for the female kiwi elites selected in the current breeding program. The anthers with pollen grains were collected in Petri dishes and kept for 12 hours after collection at room temperature, then placed for germination in a 15% sucrose solution. The following observations and measurements were made: shape index of viable and non-viable pollen grains, viability percentage (%), germination rate (%), and pollen tube length (µm) after 4, 8, 12, and 24 hours.

Regarding the study of the flowering period of the male plants, it can be mentioned that most kiwi hybrids flowered between the first decade of May and the first decade of June. The R0P7 hybrid reached the BBCH 60 stage in the last decade of April, recording the earliest development. The longest flowering period was recorded in the R2P8 hybrid, lasting from the second decade of May to the second decade of June. The pollen germination rate and pollen tube length varied depending on the genotype and incubation period. The highest germination rate (93%) was recorded after 24 hours of incubation for R2P8 and R3P9.

Since the evaluation of pollen germination percentage is an essential criterion for characterizing pollinator plants, out of the 15 male kiwi hybrid genotypes, 4 of them - R0P3, R0P6, R2P8, and R3P9 (which recorded over 90% germination rate after 24 hours), were selected for further testing in experimental fields. In addition to compatibility tests with selected female plants, other studies such as determining ploidy levels are necessary. Most of the analyzed kiwi hybrid genotypes were obtained through interspecific crosses (*A. deliciosa* x *A. chinensis*) and probably have different ploidy levels. According to the specialized literature, for a good pollination rate, male and female plants must have the same ploidy level.

The R2P8 hybrid has a long flowering period, from the second decade of May to the second decade of June, a large number of flowers in the inflorescence - 4, 6, or 8, over 90% pollen viability, and over 90% germination rate. The R3P9 hybrid has a medium flowering period, from the second decade of May to the first decade of June, a large number of flowers in the inflorescence - 3 or 5 flowers, over 95% pollen viability, and over 90% pollen germination rate. Given the longer flowering period, among the two genotypes, the R2P8 hybrid was chosen for homologation and registration with ISTIS. Thus, in 2021, application number 669/29.04.2021 was submitted for testing the R2P8 hybrid (*A. deliciosa*) as a pollinator for the selected female elites in the current breeding program. In 2023, the R2P8 hybrid was registered with ISTIS under the name Kiflor.

Chapter XIII. ***Study of physical and biochemical quality parameters of fruits of some kiwi hybrid genotypes (Actinidia sp.) at harvest and at consumption maturity*** includes a brief introduction, materials and methods, results and discussions, as well as some partial conclusions. To achieve the objectives of this study, two control varieties (Hayward, Bruno) and 27 intra- and interspecific *Actinidia* hybrids were used.

The pomological description of the hybrids in terms of average fruit weight, shape index, and peduncle length was carried out after harvest. The qualitative evaluation of the fruits was determined both after harvest and at the consumption maturity of the fruits by analyzing several

parameters such as pulp firmness, soluble dry matter content, fructose, glucose, total dry matter, citric, malic and tartaric acid, as well as ascorbic acid.

The conclusions of this study show that genetic variations between the analyzed kiwi genotypes have a significant impact on fruit quality, both at the technological maturity of harvest and at the maturity of consumption. Regarding the pomological description of the analyzed hybrids, it can be concluded that there is considerable variability concerning average fruit weight, shape index, and peduncle length. The hybrids R1P12 stood out for their very large fruit size and R1P9 for their spherical shape.

The results indicate that proper management of the plantation can significantly improve the production and quality of kiwi fruits. A positive correlation was observed between the average fruit weight and the average number of fruits per plant, suggesting that optimal agricultural practices can lead to superior yields. The most productive genotypes were R0P2, R0P12, R2P6, R3P6, and R3P8.

At the end of the three-year study, it can be concluded that certain genotypes demonstrated greater stability of physico-chemical characteristics, making them more suitable for consumption and long-term storage. Based on the study of the physical quality parameters of the fruits of some kiwi hybrid genotypes, it can be concluded that pulp firmness is an extremely important and decisive indicator in establishing the technological maturity of harvest and the optimal consumption period, with the studied genotypes reaching optimal consumption maturity at different times. From the qualitative evaluation of the fruits by analyzing several biochemical parameters, the hybrids R0P13 stood out for their high content of soluble dry matter, fructose, glucose, and balanced taste, R1P12 for their very high ascorbic acid content, and R0P12 for their special aroma and considerable total dry matter content.

Chapter XIV. ***Study of the storage capacity of fruits of some kiwi hybrid genotypes (Actinidia sp.)*** includes a brief introduction, materials and methods, results and discussions, as well as some partial conclusions. To achieve the objectives of this study, two control varieties (Hayward, Bruno) and 26 intra- and interspecific *Actinidia* hybrids were used. The fruits were harvested at technological maturity from the Didactic-Experimental Fields for Pomology within the Faculty of Horticulture, then sorted and stored under four different conditions. The pomological description of the hybrids in terms of average fruit weight, shape index, and peduncle length was carried out after harvest and is presented in Chapter XIII. The storage capacity of the fruits of some kiwi hybrid genotypes (*Actinidia* sp.) was evaluated under normal storage conditions (2-3°C and 90-95% relative humidity) and under three controlled atmosphere conditions with 1.5% O_2, 2% CO_2, and 5% CO_2, at 1-2°C and 95% relative humidity. Physical and biochemical quality parameters were analyzed after harvest and monthly, in dynamic.

Research conducted over the three-year period showed that the dynamics of the physico-chemical characteristics of kiwi fruits are significantly influenced by storage conditions. The best results in terms of storage duration were obtained under P4 conditions - 5% CO_2, 1-2°C, 95% RH. Due to the high concentration of CO_2, the fruits slowed down their physiological processes, thus ensuring optimal quality maintenance over a longer period. During storage, observations showed

that the R1P9 kiwi hybrid presented better biochemical quality parameters and the lowest weight loss compared to the other studied hybrids.

Chapter XV. ***Possibilities of utilization and processing the kiwi production*** includes a brief introduction, materials and methods, results and discussions, as well as some partial conclusions. Kiwi fruits are valued both for fresh consumption and processed forms such as juice, nectar, syrup, jam, marmalade, compote, jellies, liqueur, cider, vinegar, dehydrated, candied, or freeze-dried fruits. In the food industry, kiwi fruits can also be used in the preparation of various pastry products, as well as ice cream, fruit yogurt, or different types of chocolate. Cultivated in both the Northern and Southern hemispheres and having a storage duration of over 6-8 months, fresh kiwi fruits are available throughout the year if harvested at the correct maturity and stored under optimal conditions (*Hennion, 2003*).

For fresh consumption, specialists recommend that the fruits be consumed at optimal maturity, when they reach a soluble dry matter content of 12-15%. At this stage, organoleptic characteristics are at their peak, and the taste presents a perfect balance between acidity and sugars (*Hennion, 2003*). The optimal harvest period, consumer maturity, and storage capacity of the studied kiwi genotypes are detailed in Chapter XIV. This chapter presents several options that can bring additional economic benefits to local kiwi producers, offering niche products that are not yet available on store shelves.

Chapter XVI. ***Research on consumer behavior regarding kiwi fruits and products*** includes a brief introduction, materials and methods, results and discussions, as well as some partial conclusions. This chapter presents the results obtained from the study of consumer preferences regarding the consumption of Romanian kiwi fruits and several products derived from them (dehydrated fruits, jam, honey, cider). Sensory analysis was performed using various panels of consumers selected by gender, age, and origin. Consumer perception of some kiwi hybrids was assessed at different maturity stages. The overall appearance, shape, and size of the fruits, the color and firmness of the pulp, juiciness, taste, and aroma were evaluated by assigning scores from 1 to 5. At the time of consumer maturity, analyses were conducted regarding the average fruit weight, pulp firmness, soluble dry matter content, and acidity for each genotype. Different evaluation sheets were used for assessing the products derived from kiwi fruits, with criteria adapted for each product. The results showed that consumer preferences are influenced by the kiwi hybrid genotypes as well as by the fruit maturity stage.

The new selected kiwi elites were highly appreciated, and most interspecific kiwi hybrids (*A. deliciosa* x *A. chinensis*) receiving higher scores than the control varieties (Bruno, Hayward) or intraspecific hybrids.

Consumer education regarding the optimal maturity for kiwi fruit consumption and the promotion of consuming Romanian fruits was carried out over the three years of study through numerous events, interviews, participation in scientific sessions, and conferences.

Consumer preferences and attitudes are factors that influence the acceptance or rejection of new foods and products (*Fischer and Frewer, 2009*). These preferences can be formed as a result of the consumer's personal experience with the respective foods, being relevant, and in some

cases even decisive, for the product's market acceptance (*Stan et al., 2017*). Additionally, for the selection of hybrids, it is important to consider consumer preferences alongside the biochemical characteristics of the fruits. As many researchers point out, taste is one of the most important criteria in the sensory evaluation of fruits. However, depending on personal experience, consumers may value the appearance of fruits more than taste or aroma.

Correlating the criteria evaluated by respondents with the analyzed parameters, it can be concluded that the new selected kiwi elites were highly appreciated, and most interspecific kiwi hybrids (*A. deliciosa* x *A. chinensis*) receiving higher scores than the control varieties (Bruno, Hayward) or intraspecific hybrids. The results showed that consumer preferences are influenced by both the kiwi hybrid genotypes and the fruit maturity stage, similar conclusions reported by *Giuggioli et al. (2019)* in their studies.

Regarding the products, jam and honey can be considered promising products. However, other recipes can be easily improved and later promoted as innovative products from Romanian kiwi fruits.

Chapter XVII. ***Results on the grafting propagation of some hybrid kiwi genotypes*** includes a brief introduction, materials and methods, results and discussions, as well as some partial conclusions.

Kiwi plant grafting is an increasingly used method of vegetative propagation due to soil issues such as high calcium content or high pH, drying or apoplexy of plants ('*Kiwi Moria'*) etc. A solution may be the use of the rootstock - Z1 from Vitroplant (an interspecific hybrid between *A. deliciosa* x *A. arguta*, obtained at Vitroplant Italy) which shows good resistance to cold, iron chlorosis, low soil permeability, and water deficit. In this study, the Hayward and Bruno varieties were used, along with some valuable hybrid genotypes obtained through intra and interspecific crossings. The Z1 rootstock was planted in pots and grafted in a cold greenhouse in April, where temperatures varied from 20 to 24°C. The scion branches were taken from mother plants in dormancy in January and stored at 2-3°C. The improved cleft grafting method was used, and Flexiband-type special tape was used as binding material. Arborinn mastic was used to reduce dehydration and oxidation. After 4 months from grafting, the graft takes rate, rootstock and scion diameters, main shoot diameter, total shoot length, total number of shoots, and average main shoot length were analyzed and determined.

The results show highlighted significant differences between the studied genotypes for most parameters. Based on the observations and measurements, we can conclude that most of the studied kiwifruit genotypes grafted on the rootstock Z1 from Vitroplant showed good results. R1P1 recorded the highest graft take rate (90%) and showed good growth vigor. The highest values of total vegetative growth were recorded by the Vip Red variety (654.20 cm) and the R0P9 hybrid (610.31 cm). The rootstock Z1 from Vitroplant demonstrated good graft compatibility with all tested varieties and kiwifruit hybrid genotypes.

Chapter XVIII. ***Description of the selected elites for cultivation expansion*** includes a brief introduction, materials and methods, results and discussions, as well as some partial conclusions.

Following the research conducted from 2017 to 2020 on the study of hybrid kiwi genotypes (*Actinidia* sp.) in the Bucharest area, four hybrid elites of *Actinidia* sp. were selected (three females – R0P13, R1P9, R1P12 and one male – R2P8) and two elites of *A. arguta* (one female – R8P1 and one male – R9P16), for testing for registration in the Official Catalogue of Crop Plant Varieties in Romania, by ISTIS (State Institute for Variety Testing and Registration). Thus, following the technical examination during 2021-2022, at the conclusion of the experimental cycle, the following varieties were registered: Kisweet (R0P13), Kiball (R1P9), Kigiant (R1P12), Kiflor (R2P8), Ariana (R8P1), Andros (R9P16), and these can be cultivated in favorable areas of the country starting from 2023.

The four varieties of *Actinidia* sp. can be successfully cultivated in Romania in areas favorable for growing peaches and apricots, while the two varieties of *A. arguta* can be cultivated in areas suitable for plum cultivation.

The thesis continues with the general conclusions of the experimental research carried out, in Chapter XIX "General Conclusions and Recommendations".

At the end of the thesis, the bibliography chapter is presented, which includes all the bibliographic titles consulted and all the authors cited in the text of the thesis.

The work is structured into 19 chapters and contains a total of 392 pages. Of these, 163 pages comprise the two parts, with 50 pages representing the bibliographic study (30.68%) and 113 pages presenting the original contributions (69.32%). The thesis comprises 73 figures and 43 tables presented in the two main parts. The 20 annexes of the work were carried out on a number of 134 pages. A total of 659 bibliographic sources were consulted and cited, including specialized books, research papers, and articles, as well as other recent sources of information.

The results obtained were utilized by registering 6 kiwi varieties – Kisweet (R0P13), Kiball (R1P9), Kigiant (R1P12), Kiflor (R2P8), Ariana (R8P1), and Andros (R9P16) – in the Official Catalog of Cultivated Plant Varieties in Romania and publishing 13 scientific articles (11 published in ISI-indexed journals and 2 in BDI-indexed journals), 10 as the first author and 3 as a coauthor.