THE PhD THESIS

Creation and evaluation of the genetic variability for obtaining semi-determined tomato hybrids and adequate behavior to the pedoclimatic and technological conditions in Romania

(SUMMARY OF Ph.D. THESIS)

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INTRODUCTION

Global climate change and control over recent abiotic factors are a major challenge for farmers around the world. The need to grow high quality, value-added tomatoes is essential. The transition from conservative breeding to creative breeding was a major step towards creating new generation hybrids (LIU et al., 2021).

At the beginning of modern breeding, tomato breeding was largely focused on increasing plant productivity and resistance to disease and pest attack. The contribution of new creations has become significant with the special attention paid to the taste, sensory (aroma, taste, juiciness, consistency) and nutritional qualities (lycopene, vitamin C, β-carotene, organic acids, phenolic compounds and volatile compounds) of fruits. Such fruits are increasingly recommended both for current consumption and for processing in the agri-food industry. (KHAN et al., 2021; FELFÖLDI et al., 2021).

Tomatoes rich in bioactive phytochemicals are these effects are beneficial to human health due to their antioxidant (free radical scavenging), anti-inflammatory, anti-cancer and anti-atherogenic properties. Therefore, new varieties of tomatoes with a high level of bioactive compounds (lycopene, β-carotene and polyphenol content) are considered "functional foods" of high quality, nutritional characteristics you can get (CHAUDHARY et al., 2018; KHAN et al., 2021).

Based on these considerations, the present study aimed at the analysis and complex evaluation of some tomato genotypes in order to enrich the genetic background with as many cultivars as possible, including promoting traditional genotypes or new tomato cultivars, to be cultivated and appreciated for fruit quality, physico-chemical, nutritional components, as well as for their taste and sensory attributes.

The research was aimed at analyzing the variability of qualitative, nutritional and organoleptic characteristics of tomato genotypes represented by commercial hybrids created abroad but well listed in our country, as well as new commercial hybrids, recently obtained from the improvement works carried out in our country, at the Agrosel Research Station (Câmpia Turzii, Romania).

WORKING HYPOTHESIS AND SCOPE OF THE RESEARCH

The main purpose of the research proposed in the doctoral thesis was to

obtain useful information for genetics and tomato breeding, as well as the importance of genotype and capitalization of the genetic potential of new commercial hybrids, in relation to environmental and cultural factors, to achieve high production and very good commercial, food and taste quality.

The research was initiated on genotypes of tomatoes with semi-determined growth, grown in protected areas, in tunnel-type solariums. The genotypes were represented by two commercial hybrids validated and appreciated in the tomato culture in our country, used as references, or control, for two new commercial hybrids, created at Agrosel SRL, Turda, Romania.

Because consumer demands and market demand for fresh fruit quality are increasing, an important goal of the research was to identify genotypes with very good quality fruits, with attractive commercial appearance, nutritional value and high content of chemicals useful to the human body, as well as with a very good taste quality and a taste to the liking of most consumers.

OBJECTIVES PROPOSED IN RESEARCH

In order to achieve the proposed goal, three distinct experiments were designed, in which the main objectives pursued were the following:

- Analysis of the variability of some characteristics of great agronomic interest in tomatoes, regarding plant growth, productivity and fruit quality in new commercial hybrids of tomatoes created in Romania (at Agrosel), compared with their parental lines and commercial hybrids from the international assortment.

- Determination of the main morpho-physiological peculiarities of tomatoes that contribute to the productive capacity and quality of fruits. The nutritional or nutritional value of fruits and their content in chemical elements useful and of interest for ensuring the health of consumers.

- Evaluation of the potential of F7 generation parental lines used in artificial hybridizations in order to show hybrid vigor in F1 hybrids (heterosis). Determination of genetic parameters of interest (eg absolute and relative heterosis, heterobeltiosis) for useful chemical compounds in tomatoes that also contribute to the organoleptic quality and taste value of fruits.

- Application of organoleptic tests and evaluation of fruit quality with the help of sensory descriptors, correlations and multivariate analysis. Identifying consumer preferences based on age, gender, etc. and issuing forecasts for new improvement works and targeting them to meet future market and consumer requirements, as they evolve.

- Analysis of the possibilities to increase tomato production and fruit quality by using mycorrhization, respectively MFA (Arbuscular Mycorrhizal Fungi), depending on the response of the genotype to inoculation with AMF.

STRUCTURE OF THE DOCTORAL THESIS

The doctoral thesis entitled "**Creation and evaluation of the genetic variability for obtaining semi-determined tomato hybrids and adequate behavior to the pedoclimatic and technological conditions in Romania**" includes 52 figures, 19 tables and is structured according to the rules of word processing in two parts: **Part I - Current state of knowledge and Part II - Personal contribution.**

Part I of the thesis, includes two chapters that present information about the current study of research on tomato morphology, respectively the evolution of genetics and tomato breeding.

Chapter I is entitled "The current state of research on tomato improvement" and contains 5 subchapters.

Chapter II is entitled "Evolution of genetics and tomato breeding" and includes 4 subchapters entitled respectively 8 subchapters.

Part II contains 4 chapters and represents the personal contribution. These chapters include the working hypothesis and objectives of the research, the material and methods used, the results obtained, the general conclusions, the recommendations derived from the research and elements of originality of the thesis.

Chapter III is entitled "The purpose and objectives of research" and presents the motivation of the paper and the objectives pursued to meet the purpose of this thesis.

Chapter IV is entitled "Location of experiments, biological material and research methods" and is structured and systematized in 10 subchapters.

Chapter V is entitled “Results and Discussions” and includes the discussions and results obtained from the research. This chapter is in turn structured in three subchapters, in which the three ISI articles.

Chapter VI is entitled “General conclusions and recommendations” and summarizes the conclusions of the studies conducted and the recommendations, which improved the basic research.

Chapter VII summarizes the unique and original elements of the thesis.

RESEARCH RESULTS

Results obtained in Experience I

The results of research conducted in the first experiment (I), published in the article entitled "**Physico-Chemical, Nutritional, and Sensory Evaluation of Two New Commercial Tomato Hybrids and Their Parental Lines**" in the journal Plants [ISI, IF = 4,658, Q1 in Plant Sciences], revealed the existence of significant differences

between the genotypes tested for the physico-chemical, nutritional and sensory elements of the fruits.

The amplitude of the variation for the glucose content of the fruits in eight genotypes varied between 5.75 mg / g (AS 300 F1) and 12.52 mg / g (AS 10 ♂ (F7)). The lower limit was recorded for the newly created commercial hybrid at Agrosel AS 300 F1, with lower values compared to the Precos F1 and Addalyn F1 control hybrids, as well as its own parental lines. In contrast, in the other newly created commercial hybrid (AS 400 F1), the glucose content was almost double (11.37 mg / g). Significant differences between the eight genotypes were also recorded for the fruit content in malic acid and citric acid. Malic acid had limits between 0.61 mg / g (Precos F1) and 1.73 mg / g (Addalyn F1), and citric acid ranged between 1.73 mg / g and 3.39 mg / g (FELFÖLDI et al., 2021).

The total phenolic components, as the sum of all the individual phenolic compounds, fluctuated strongly within the eight genotypes, with limits between 38.4 and 96.3 μg / g at the parental lines AS 30 ♀ (F7) and AS 09 ♀ (F7). The new commercial hybrid AS 300 F1 had a total content of phenolic compounds close to the control hybrids Precos F1 and Addalyn F1, but lower than the newly created hybrid AS 400 F1. The calculation of the phenotypic correlation coefficients allowed the identification of very significant positive correlations ($p < 0.001$) between carbohydrates (total, glucose, fructose), and separately, between organic acids (total, malic, citric), and carbohydrates were closely correlated with acids organic. The results of the calculated heterosis (absolute, relative and heterobeltiosis) illustrated the complexity and difficulty of tomato breeding (LIU et al., 2021), as the negative heterosis in new commercial hybrids had the largest share. Regardless of the type of calculated heterosis (absolute, relative and heterobeltiosis), the common feature identified was the high share of negative heterosis in the new commercial hybrids. Of all the values of heterosis, calculated on the basis of 17 analyzed chemical elements and the four parental lines, in three types of heterosis the negative values predominated. The content of fruits in glucose, citric acid and malic acid + citric acid showed only negative values of heterosis, in all combinations of parental lines. The relationships between the parameters analyzed by correspondence analysis (CA), principal components analysis (PCA) and hierarchical grouping in pairs (UPGMA) and similarity index (Euclidean) confirmed that the hybrids used as a control were very well chosen for testing the new commercial hybrids: Addalyn F1 for AS 400 F1, and Precos F1 for AS 300 F1.

Results obtained in Experience II

The results of the research carried out under Experiment II, published in the article entitled “Analysis of Physico-Chemical and Organoleptic Fruit Parameters Relevant for Tomato Quality”, in the journal Agronomy [ISI, IF = 3,949, Q1 in Plant

Sciences], particularly highlighted the in which the quality elements of the fruit contribute to the overall value of the tomatoes and to their taste value or to the final flavor of the tomatoes.

In this study, performed on four tomato genotypes, the two recently created F1 commercial hybrids at Agrosel, Romania (AS 300 and AS 400) and the two F1 commercial hybrids used as control variants, Precos (Geosem, Bulgaria) and Addalyn (Hazera Seeds, France), the analysis of the physical-morphological, chemical and organoleptic properties of the fruit provided relevant and original information on the relationships between morphological, chemical and sensory parameters that influence the final quality of tomatoes.

The analyzes performed integrated the quality elements of the fruits with those that contribute to the productive capacity of the cultivars (eg the number of fruits per plant, the weight of the fruits, the production per plant, etc.). Fruit production was extremely different within the four genotypes, the most productive hybrid being AS 400, followed by Addalyn and AS 300 (FELFÖLDI et al., 2022a).

Significantly different values between commercial hybrids were also recorded for the following chemical components in fruit: dry matter ranged from 3.77% (AS 300) to 6.88% (AS 400); total acidity (expressed in mg NaOH 100 g-1 FW) ranged from 100.11 to 184.87, extremes identified in the two control hybrids; the ascorbic acid content varied between 20.65 and 28.03 mg 100 g-1 FW, the highest value being recorded for the hybrid AS 300, closely followed by Precos and AS 400; lycopene ranged from 7.4 to 15.4 mg 100 g-1 FW; carotenoids between 8.91 and 16.64 mg 100 g-1 FW; β-carotene between 1.10 and 1.74 mg 100 g-1 FW (the lowest value was recorded at AS 300, and the highest at Precos).

The results of the test of organoleptic hierarchy of fruits, using the hedonic scale (grades 1-9), based on 12 sensory descriptors framed in four distinct attributes (according to VINDRAS et al., 2018), highlighted qualitative differences between hybrids. With the results of multivariate analyzes, the information obtained provided a particularly interesting view of the relationships between different attributes that contribute to the taste and organoleptic quality of tomatoes. The analysis of the main components (PCA), the hierarchical grouping in UPGMA pairs, and the dendrogram highlighted the hierarchical relationship between genotypes, confirming the closeness between the two commercial hybrids created in Romania (even if AS 300 and AS 400 do not have a common genetic origin or a very high degree). strongly related) and, at the same time, their distance from Addalyn and especially from Precos. (FELFÖLDI et al., 2022a).

Results obtained in Experience III

The results of the research conducted in Experiment III, published in the article entitled “Arbuscular Mycorrhizal Fungi and Fertilization Influence Yield, Growth and

Root Colonization of Different Tomato Genotype", in the journal Plants [ISI, IF = 4,658, Q1 in Plant Sciences], contributed important information on the possibilities of using mycorrhizal fungi in tomatoes according to genotype, increasing fruit production and helping to ensure a growing environment with superior ecological and economic value.

Experience in a multifactorial design with 12 tomato genotypes and three different treatments (T1, control, without fertilization and colonization with mycorrhizae; T2, with fertigation, NPK and microelements, without colonization with mycorrhizae; T3, seedling roots inoculated with mycorrhizal fungi arbusculare - AMF), in completely randomized blocks with three repetitions, allowed to obtain original results, with scientific and applied value. A first result of great importance and practical utility in tomato cultivation by using MFA was obtained by analyzing soil samples and various chemical elements in the soil composition before planting seedlings and after completion of cultivation, after the last fruit harvest and extraction of plants from the soil. Analyzing the changes that took place in the soil in the three treatments, and the differences between the values of the 27 soil elements at the end of the crop, compared to those at the beginning of the crop, the t-pair test showed higher values, significantly positive (α <0.05), for the phosphorus content, in the variant treated with AMF (FELFÖLDI et al., 2022b).

The two experimental factors (genotype and treatment) and their interaction significantly influenced the main characteristics of plants and fruits. The results for biomass accumulation, represented by root length, plant height and number of leaves per plant, indicated significant differences both between genotypes and treatments and between genotype × treatment combinations. The unilateral analysis of the effect of the genotype on the analyzed characteristics, regardless of the treatment, highlighted a real influence of the hereditary dowry of the cultivar, on the elements that contribute to the growth of tomatoes.

The variation of the colonization frequency allowed the separation of genotypes in four classes: with high potential for native acceptance; with a high level of inoculum acceptance; with increased fertilizer acceptance rate; with a low inoculum acceptance rate. The multivariate analysis distributed the parental lines of the new commercial hybrids obtained at Agrosel, Romania, closely grouped in pairs, confirming that the phenotype represented by the 19 analyzed parameters accurately reflects their genotype. The grouping in distinct pairs of the same line in the F6 and F7 generation reflected their high degree of homozygosity and phenotypic uniformity, resulting from the selection process. In contrast, the effect of heterosis due to the pronounced heterozygosity of F1 commercial hybrids was very well reflected by the PCA, especially in the F1 hybrid AS300 (FELFÖLDI et al., 2022b).

CONCLUSIONS

Chemical analyzes indicated significantly different values between genotypes, depending on the particularities of the cultivars tested and the genetic differences between them. These differences were manifested both between the new commercial hybrids and the reference (control) hybrids, as well as between the parental lines and the improved commercial hybrids.

The analysis of physico-chemical and organoleptic parameters indicated that the analyzed genotypes showed that the modern improvement of tomatoes in terms of commercial appearance, bioactive properties and organoleptic parameters is in a good direction. Improved commercial hybrids showed characteristics of much higher agronomic interest than the hybrids used as controls, instead the quality and sensory analysis are on an equal footing.

The use of beneficial fungi without the administration of fertilizers can have a beneficial and important effect on the quality and yield of tomato fruits**.**

ORIGINALITY, INNOVATIVE CONTRIBUTIONS AND RECOMMENDATIONS

The results confirmed previous research on tomatoes, according to which the overall quality of the fruit is influenced by many quality elements, but provided new, original information on their different contribution and interaction in determining taste quality and guidance of new improvement works. for obtaining cultivars with high sensory quality.

Following the sensory evaluations, it was shown that for consumers it is important both the general, commercial appearance of the fruit and specific elements, such as the color of fresh tomatoes, the texture of the pulp, the juiciness, the taste and aroma, etc. In our study, based on proximity and distance from the origin, an analysis of the correspondence provided a relevant picture of the relationships between physical-morphological and chemical attributes, as well as descriptors used in organoleptic assessments of tomato quality.

In the research carried out within the doctoral thesis, the importance of qualitative analyzes on tomatoes for consumers, users, processors, but also for tomato producers and growers was highlighted. Therefore, the success of tomato breeding programs is closely linked to the adequate knowledge of the market and the requirements of consumers, but also of users, processors, as well as the preferences and needs of growers.

The new commercial hybrids created at Agrosel, Romania, have characteristics of agronomic interest at a higher level than those used as a reference (control), and

the commercial and sensory qualities are not inferior to them. The importance of the analyzed components ('descriptors' or 'attributes', according to VINDRAS et al., 2018) and their contributions to the quality of tomatoes, the relationships between them, as well as the possible use of such information in order to obtain new quality cultivars superior and added value.

Results on the response of tomato plants by genotype to mycorrhizal fungus (AMF) treatment provided original data and showed that the success of tomato cultivation using arbuscular mycorrhizal fungi is significantly influenced by hereditary dowry of cultivars and the reaction of each genotype to inoculation.

Research has shown an improvement in the quality of tomato fruit and an increase in production following the application of shrub mycorrhizal fungi (AMF), which are beneficial for biodiversity and ecosystem. Given the growing consumer demands for healthy products, as well as current policies on organic farming systems, the use of these beneficial micro-organisms can be an efficient and environmentally friendly way to reduce the application of chemical fertilizers. Improving production results, production quality, economic and ecological efficiency, etc. in tomato cultivation it can also be achieved by using genotypes that capitalize on new cultivation technologies, including the use of AMF.

SELECTIVE BIBLIOGRAPHY

1. CHAUDHARY, P., SHARMA, A., SINGH, B., NAGPAL, A.K., 2018. Bioactivities of phytochemicals present in tomato. J. Food Sci. Technol. 55, 2833–2849.
2. FELFÖLDI, Z., RANGA, F., SOCACI, S.A., FARCAS, A., PLAZAS, M., SESTRAS, A.F., VODNAR, D.C., PROHENS, J., SESTRAS, R.E., 2021. Physico-Chemical, Nutritional, and Sensory Evaluation of Two New Commercial Tomato Hybrids and Their Parental Lines. Plants, 10, 2480.
3. FELFÖLDI, Z., RANGA, F., ROMAN, I.A., SESTRAS, A.F., VODNAR, D.C., PROHENS, J., SESTRAS, R.E., 2022 a. Analysis of Physico-Chemical and Organoleptic Fruit Parameters Relevant for Tomato Quality. Agronomy, 12(5), 1232; https://doi.org/10.3390/agronomy12051232
4. FELFÖLDI, Z., VIDICAN, R., STOIAN, V., ROMAN, I.A., SESTRAS, A.F., RUSU, T., SESTRAS, R.E., 2022 b. Arbuscular Mycorrhizal Fungi and Fertilization Influence Yield, Growth and Root Colonization of Different Tomato Genotypes. Plants, 11(13), 1743; https://doi.org/10.3390/plants11131743.
5. KHAN, U.M., SEVINDIK, M., ZARRABI, A., NAMI, M., OZDEMIR, B., KAPLAN, D.N., SELAMOGLU, Z., HASAN, M., KUMAR, M., ALSHEHRI, M.M., 2021. Lycopene: Food Sources, Biological Activities, and Human Health Benefits. Oxidative Medicine and Cellular Longevity, 2021 2713511, doi:10.1155/2021/2713511.
6. LIU, Z., JIANG, J., REN, A., XU, X., ZHANG, H., ZHAO, T., JIANG, X., SUN, Y., LI, J., YANG, H., 2021. Heterosis and Combining Ability Analysis of Fruit Yield, Early Maturity, and Quality in Tomato. Agronomy, 11(4), 807. https://doi.org/10.3390/agronomy11040807.
7. VINDRAS, C., SINIOR, N., COULOMBEL, A., TAUPIER-LETAGE, B., REY, F., 2018, ITAB. Tasting guide: Tools to integrate organoleptic quality criteria into breeding programs, technical booklet. Diversifood Project. ed.; Institut de l'Agriculture et de l'Alimentation Biologiques.