Research regarding phenotypic expression and agronomic value of the 'Hera' tomato variety at Plant Genetic Resources Bank - for Vegetables, Floricultural, Aromatic and Medicinal Plants Buzău, Romania

C. VÎNĂTORU[1], B. MUȘAT[1] , C. BRATU[1] , G. NEGOȘANU[1], M. POPESCU[1] and D. HOZA[2]

[1] Plant Genetic Resources Bank - for Vegetables, Floricultural, Aromatic and Medicinal Plants Buzău, Romania [2] University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania

Abstract

The Plant Genetic Resources Bank - for Vegetables, Floricultural, Aromatic and Medicinal Plants Buzău possess for *Solanum lycopersicum* species an outstanding germplasm collection which is composed of over 2000 genotypes structured on various breeding stages. 'Hera' tomato variety was approved and patented in 2018. The variety showed distinct phenotypic expressiveness of long and red pepper shaped fruits, preserving the taste and aroma of the traditional tomatoes. Starting with 2019, it was included in the conservative selection program and intensively evaluated regarding the phenotypic expressiveness, the variability of the main characters as well as its yield capacity and fruit quality. The research was carried out both in greenhouse, on an area of 300 m² and open field, on 600 m². It was applied a specific crop technology for undetermined growth tomatoes. During the vegetation period, biometrical and phenological measurements were elaborated during 3 years of cultivation. The variety is intended for fresh consumption and a high yield potential. In greenhouse conditions was obtained an yield of 3.6 kg per plant and 2.4 kg / plant in open field. In greenhouse conditions was registered an average fruit weight of 289 g and 268 g in open field.

Keywords: breeding, conservative selection, fresh consumption, traditional, germplasm, yield potential

INTRODUCTION

Spanish conquistadors were the first to record seeing tomatoes being cultivated for food in Mexico in the 16th century. Tomato seeds were then dispersed to the Philippines, the Caribbean, Italy, and Spain and from there to the rest of continental Europe and Southeast Asia (Bland, 2005).

Over time, although it is a crop introduced relatively recently in Romania, in the nineteenth century, tomatoes have gained popularity among growers and consumers, thus writing history in the cultivation and use of this species. If at the beginning were cultivated trans-generational preserved local populations that were inherited from family-to-family, after 1990, concomitantly with the development of research in the area of crop plant breeding, high-performance varieties and later top hybrids were created. Heirloom vegetables are nonhybrid varieties that have been preserved from generation to generation as seeds (Coolong 2009). Over time, these organic creations have replaced the traditional classic tomato due to their superior production and quality characteristics. Heirloom tomatoes are defined as varieties, which have been passed down through multiple generations of a family (Rowland, 2019).

However, the process of breeding and obtaining new varieties and high-performance hybrids had as main objective to increase productivity, uniformity, and stability of varieties at the expense of the traditional Romanian taste and flavor. This aspect was neglected, being cultivated varieties whose fruits had a pleasant commercial aspect, uniform color and size, without green shoulders or characteristic defects in the peduncular or apical area. Later, consumer interest and desire to return to traditional tomatoes with a specific taste and aroma increased considerably, thus identifying the reason why these characteristics disappeared. Many consumers now demand tomatoes of higher organoleptic and nutritional quality that, at the same time, maintain a high standard of external quality (Gómez et al., 2001).

The selection and promotion of varieties with perfectly uniform fruit, a characteristic transmitted by the *u* gene, to the detriment of those with green shoulders (*U* gene), has also led to the inactivation of a complex of SGLK2 genes with a role in the absorption of sugar and other substances that confer flavor and aroma to tomatoes. The high degree of genetic uniformity in tomato cultivars is not only strongly influenced by domestication far from the center of origin, but above all by genetic improvement which, per se, culminated in the achievement of uniform forms, apart from the fact that only a limited number of genotypes were used for breeding (Saavedra et al., 2001). Moreover, due to the replacement or disappearance of wild and local species, countless genomic forms with genes that could be of high interest for future actions of breeders were lost due to pests and diseases (Bai and Lindhout, 2007).

A new direction of improvement is thus required with the aim of rehabilitating old, valuable populations, which have a specific traditional taste and aroma but also high quality and productivity. Therefore, breeding programmes aimed at developing new cultivars should include internal quality as a main objective (Rodriguez-Burruezo et al., 2005).

In addition, traditional varieties are of great interest to plant breeders because they have a larger fruit size than wild materials and thus represent an elite germplasm with a pre-selected genetic background, which reduces the time required to develop a new cultivar (Rodriguez-Burruezo et al., 2005). Some varieties remained genetically unaltered, while others led to new strains as a consequence of natural and artificial selection, hybridisation, genetic mutation or drift, and adaptation to local conditions (Rodriguez-Burruezo et al., 2005).

Heirloom tomatoes typically lack shape uniformity and have thinner skins compared with more modern varieties, making them difficult to pack and transport over long distances.

The rapid popularity of tomatoes has pushed the commercial tomato producer to develop cultivars that are designed to withstand considerable physical stress imposed by the industry's picking, packing, and shipping techniques (Vavrina et al., 2003)

Given the impact of weather on tomato fruit production, heirloom tomato flavor and appearance are significantly impacted by high temperatures, and a variety of fruit defects can occur, such as blossom-end scar, catfacing, cracking, grey wall, and odd shapes that may make them unmarketable by commercial standards. The target audience of this publication includes conventional and organic producers as well as home gardeners (Ozores-Hampton et al., 2012)

"Heirloom" is a botanical classification that entered the culinary lexicon in the 1940s; it was first used in relation to plants in 1981 (Wilkins 2002). "Heirloom" here refers to any open-pollinated variety that is particularly treasured or has a known heritage (Harland and Larrinua-Craxton 2009). To be classified as an heirloom, a variety should meet three criteria: (a) it can reproduce itself from seed; (b) it was introduced more than fifty years ago; and (c) it has a history of its own, such as being grown and passed on in a specific family or region for a long period (Jordan 2007).

However, in the course of improvement, not much attention was paid to the study of flavor characteristics (Petro-Turza, 1987). Tomato research has mainly focused on the selection of new varieties to increase firmness of the fruit and storage regimes to increase their shelf life (Boukobza et al., 2002)

Heirloom tomato varieties are typically open pollinated, and many were released more than 50 years ago (DeMuth, 1998). Heirlooms are open pollinated, which means that the fruit is similar to the fruit of the previous generation (Flomo, 2010).

Many open pollinated, heirloom tomato varieties have an indeterminate growth habit, simultaneously producing new vegetative growth and fruit over time, in contrast to determinate varieties that produce most of the fruit within a discrete time period (Rogers et al., 2012).

Both in Europe and in Romania, there are local populations with a long tradition, very appreciated, including the famous" Inima de Bou" and the long pepper-shaped tomato, popularly called "tata vacii". Heirloom tomatoes (*Solanum lycopersicum* L.) such as 'Cuore di Bue' are highly appreciated by consumers for their outstanding quality and flavour (Di Gioia,2010)

With the rehabilitation and reactivation of these old populations, consumers as well as producers have contributed to their promotion and expansion in culture. The growing taste for heirloom tomatoes among elites opens up new spaces of consumption (high-end restaurants, farmers' markets and grocery stores) and production (whether in smaller organic c to farmers' markets and gourmet stores. Heirloom tomatoes are much the rage today. A resurgence of interest in and demand for these delicate fruits began in the early 1980s (Joseph et al., 2017). From both gustatory and production perspectives, the heirloom's resurgence is best appreciated in the context of the overall fresh tomato market (Joseph et al., 2017).

Mouthfeel, like aroma, is an inherent part of perceived taste and the overall sensory eating experience. Heirlooms also display a range of textures, but the better ones are noted for consistencies such as meaty, juicy, and creamy; the worst are thin and watery. While hybrids are bred for durability, the typically softer, field-ripened heirloom tomatoes have thinner skins that are sensitive to handling, but this also contributes to a more consistent overall texture best appreciated at the height of ripeness, albeit relatively short-lived. In turn, they are easily damaged, hard to ship when fully ripe, and designed for quick consumption after harvesting (Joseph et al., 2017).

Tomato has assumed the status of a functional food when one considers the overwhelming epidemiological evidence for tomato and tomato product consumption in prevention of chronic diseases such as cancers and cardiovascular diseases (Kuti et al., 2005).

The main objective of the Buzau Plant Genetic Resource Bank is to enrich the germplasm base of this species, to rehabilitate old and neglected local populations in culture and to preserve them in the medium and long term, Accessions in gene banks need to be characterized and evaluated to determine their genetic diversity (Gonçalves et al., 2009).

The need for the preservation of wild species, local varieties and traditional genotypes in gene banks is evident, which have become an important form of gene maintenance (Gepts, 2006). The diversity found in heirloom tomato cultivars could be a rich source of germplasm for quality and functional attributes (Alonso et al., 2011). Commercial tomato (*Solanum lycopersicum*) is one of the most widely grown vegetable crops worldwide. Heirloom tomatoes retain extensive genetic diversity and a considerable range of fruit quality and leaf morphological traits (Rowland, 2019). The challenge of feeding a growing population is exacerbated by climate unpredictability, with drought and temperature increases, leading to decreased crop yield (Matiu et al., 2017).

The wild relatives of tomato have the genetic ability to adapt to extreme habitats, and many heirloom cultivars also retain this ability as a result of directed breeding with wild species, and less selection for commercially valuable traits (Sim et al., 2012). Local populations can be cultivated with success in the field, but preferably in greenhouse, which offer the necessary protection against pathogens and extreme environmental conditions, as their resistance is not so high compared to that of high-performance varieties and hybrids. The economic viability of high tunnels relies on achieving improved productivity and quality of high-value crops (Sydorovych et al., 2013).

Protected systems also provide crops with an indeterminate growth habit with a longer harvest season as compared with field production (Wittwer and Castilla, 1995). High tunnels create a microclimate that impacts abiotic and biotic factors and influences plant growth and development (Rogers et al., 2012)
Greenhouse cultivation of tomato in this area is mainly based on F1 hybrids (Rodriguez-Burruezo et al., 2005)

MATERIALS AND METHODS

'Hera' variety description

The material used in the rehabilitation of the local population over 150 years old, 'Hera', line 28. Four biotypes were selected that had similar characteristics to the traditional population, of which 12% had intermediate forms that were eliminated, and 88% were chosen as typical plants with characteristics specific to the old local population (Figure 1).

Figure 1. Biotypes identified

The 'Hera' variety is a tomato line (L 28) with elongated, long pepper-like fruit.

In terms of morphological characterization, the line shows indeterminate growth and a plant height of 215 cm in protected areas on average. The stem section is cylindrical and densely pubescent. Leaf colour is medium green with medium gloss and medium embossing. Leaf length averages 36 cm in protected areas and 28 cm in the field. The leaflets are of medium size and the leaf insertion on the stem is pendulous. The number of inflorescences per plant is 8, inflorescences. The colour of the flower corolla is yellow and the style is positioned at the same level as the stamens and does not show pubescence (Figure 2). The immature fruit shows green shoulders, a characteristic transmitted by the *U* gene. The colour of the fruit at maturity is red, with yellow epidermis, and in section the fruit is red. The ease of fruit removal is intermediate. The number of fruits per plant is 9 on average in the field and 15 fruits in protected areas. The fruit has a stellate pistillate point with a diameter of 1.4 mm on average. The shape of the fruit is long pepper-like, with medium veins in the peduncular area and medium gloss. Fruit height averages 8.5 cm in protected areas and 10.6 cm in the greenhouse, and the diameter averages 3.7 cm in the greenhouse and 3.2 cm in the field. The abscission zone averages 3.5 mm. Pericarp thickness reaches 7 mm on average. Fruit weight averages 289 g in protected areas and 268 g in the field. The number of seed lobes is 2. The fruit contains very few seeds.

Figure 2. Immature fruit, leaf insertion and flower detail

The variety is characterized by a growing season of 117 days, falling in the semi-wild season. Fruits are large, red, have a commercially pleasing, long pepper shape. The strong character of this variety is given by the taste and aroma of the fruit but also the thickness of the flesh (Figure 3).

The yield potential/plant ranges from 3.6 kg in the greenhouse to 2.4 kg in the field.

Tomato fruits have a dry matter content of 5.54%. The sugar content is 5.7 °Brix on average. Firmness is poor.

The fruit can be eaten both fresh and preserved. They have a shelf life of about 10-20 days.

Figure 3. L 28: plant detail, immature fruit, fruit group, longitudinal and cross section of fruit

Field crop technology

The field crop was established on an area of 600 m^2.

Land preparation was carried out in autumn with the dismantling of the previous crop, levelling of the land and basic fertilization. 30-40 t/ha manure, 250-300 kg/ha superphosphate and 100-150 kg/ha potassium sulphate were applied, and fertilizers were incorporated into the soil by deep ploughing at 29 cm. In spring, as soon as it was possible to enter the field, 150 kg/ha ammonium nitrogen was applied, then the land was prepared by disc harrow followed by tilling and shaping the land into furrows 140 cm wide with a 94 cm crown.

The tomato crop was established by planting seedlings. Seedlings were produced in the heated greenhouse. Seedling production was carried out on honeycomb pallets with 70 holes using peat as substrate. Seedlings were planted 45 days after sowing. Throughout the seedling production period, purification was carried out by eliminating atypical, diseased, or non-proliferating plants. Treatments were applied to prevent seedling drop (*Pythium spp*.). Field planting was carried out in the first decade of March.

The crop was staked with strings using the metal structure of an uncovered plot and planted 180 cm between strips, 60 cm between rows and 35 cm between plants per row. This crop establishment scheme allowed easy, mechanized maintenance of the strip spacing (Figure 4).

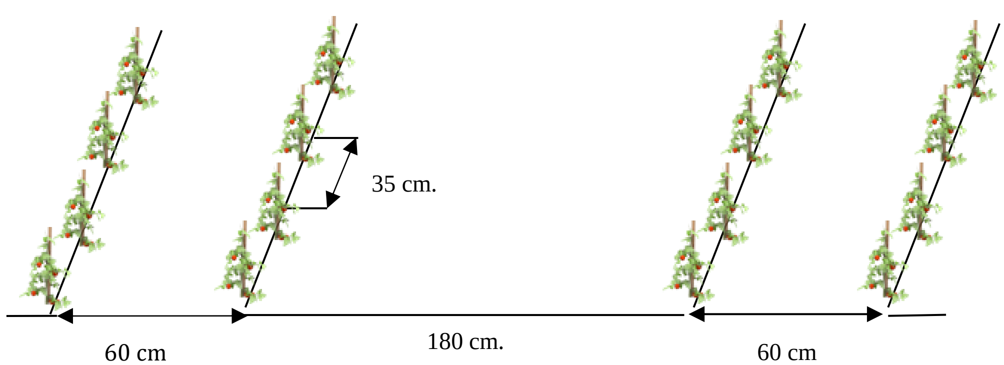

Figure 4. Scheme for the establishment of tomato cultivation in the field in strips in a palisade system

Planting was done by hand and watering was done with 0.5-1 l/plant. Five days after planting, the gaps were filled in manually with quality seedlings of the same cultivar and age as the original planting. For weed control and soil loosening, mechanical hoeing was carried out, supplemented by manual hoeing in turn. Irrigation was carried out with lower watering norms at the beginning of 200 m^3 water/ha then increased to 400 m^3 water/ha.

Greenhouse crop technology

For the comparative study, the crop was also cultivated in the greenhouse, a protected space, without technological heating, on an area of 300 m2.

Both years, the tomatoes were planted in high tunnels 1 month earlier and harvested 3 weeks earlier than the field (O'Connell, S. et al., 2012).

Greenhouse preparation was carried out with great care: the removal of previous crop debris, disinfection of the soil in the greenhouses being the most effective method of disease and pest prevention was done chemically. Before the crop was established, organic fertilizers were applied to the soil (80-100 t/ha).

Planting was done by hand at 70 cm between rows and 30 cm between plants per row and 120 cm between strips. The crop establishment scheme is the same as previously used. Immediately after planting the gaps were filled in. Soluble chemical fertilizers were used for fertilization, which were administered with irrigation water through the drip irrigation system. The special works used were the staking of the plants with string to the greenhouse support system at a distance of 200 cm, the pruning of the plants, the removal of the leaves below the first inflorescence, the shearing of the inflorescences when required (Figure 5).

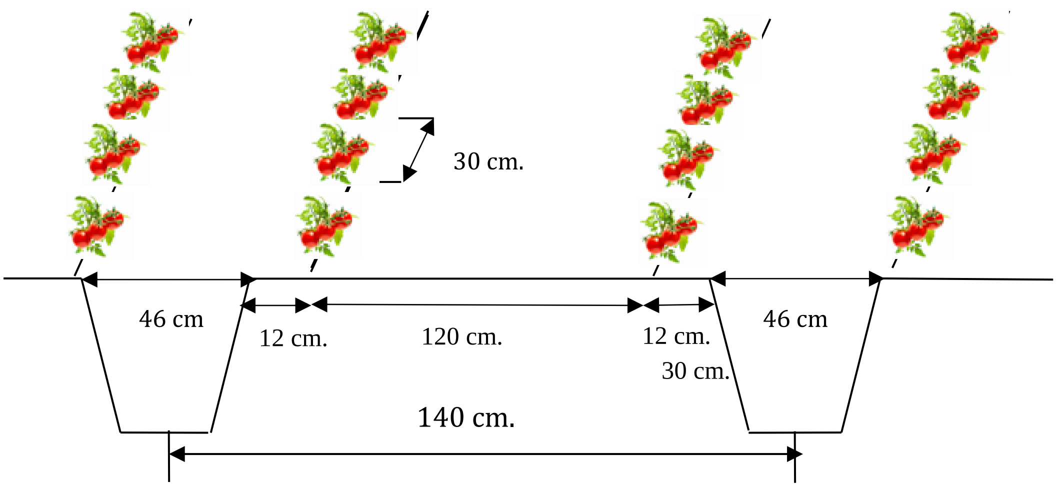

Figure 5. Scheme for the establishment of tomato cultivation in greenhouses in a palisade system

Phenological and biometric measurements were carried out over a period of 3 years, 2019-2021 and the results were statistically interpreted using SPSS software. ANOVA analysis was performed, followed by Duncan's post-hoc test with 95% confidence interval and $p<0.05$.

RESULTS AND DISCUSSION

To determine the quality and production potential of 'Hera', it was studied in 3 years of culture, from 2019 to 2021, following the main morphological characteristics of the plant and the fruits, as well as the aspect of productivity in the two culture environments, greenhouse and field.

There are two crop variants: L 28C- open field crop and L28S- greenhouse crop.

Thus, significant differences are observed between the values recorded in 2019 and 2021, as opposed to 2020, a year characterized by a prolonged drought that affected plant growth, development, and productivity (Table 1).

Table 1. Main plant features

Characteristic	Variant	2019	2020	2021	Mean (2019-2021)
Plant height (cm)	L28C	123.4 ±2.42[b]	127 ± 3.66[b]	125 ± 1.85[b]	125 ± 2.19[b]
	L28S	216 ± 3.8[a]	213 ± 3.0[a]	215 ± 1.5[a]	215 ± 1.3[a]
Leaf lenght (cm)	L28C	29.2 ± 4.4[b]	27.8 ± 4.4[a]	27 ± 3.8[b]	28 ± 2.7[b]
	L28S	36.6 ± 2.4[a]	35,4 ± 6.7[a]	36 ± 4.0[a]	36 ± 4.0[a]
No. leaves/plant (buc)	L28C	23 ± 3.7[a]	23.2 ± 1.5[a]	23,4 ± 3.6[a]	24 ± 3.0[a]
	L28S	35 ± 13.0[a]	29 ± 6.3[a]	32 ± 11.0[a]	32 ± 7.3[a]
Leaves distance/plant (cm)	L28C	16.8 ± 2.7[a]	17.6 ± 4.0[a]	17,6 ± 4.0[a]	17 ± 3.2[b]
	L28S	19.8 ± 3.3[a]	20.8 ± 8.1[a]	20 ± 5.4[a]	20.2 ± 5.2[a]

* Letters represent Duncan test results with confidence interval of 95% and p<0,05

During the early growth of the tomato plants their stem elongation rates are not constant, but after they have reached a length of about 50 cm., they have a constant growth rate under constant growing conditions (Went et al., 1945).

Significant differences are observed between the two culture environments, the values recorded for all parameters measured in the field are much lower compared to those recorded in the greenhouse. For the measurable parameter Plant height, in the field, an average value of 125 cm was obtained compared to the protected area, the greenhouse, where an average value of 215 cm was obtained.

Concerning the characters distance between leaves/plant and number of leaves/plant, there were no significant differences in the 3 years of culture, being characters that kept their relative homogeneity. The characters that varied significantly were leaf length and plant height, these recording significantly higher values in years 2019-2021 and lower in 2020.

As for the fruit, it varied in weight, recording a value of 268 g on average in the field and 288 g on average in the greenhouse.

Also, the number of fruits per plant varied from 9 fruits on average in the field to 15 fruits on average in the greenhouse (Table 2).

Table 2. Main fruit features

Characteristic	Variant	2019	2020	2021	Mean (2019-2021)
Fruit weight (g)	L28C	272,4 ± 54.1[a]	264,.8 ± 4.1[a]	267.4 ± 13.4[b]	268 ± 17.4[a]
	L28S	280 ± 11.0[a]	283.4 ± 24.7[a]	303 ± 12.3[a]	288.8 ± 12.5[a]
Fruit no./plant (piece)	L28C	8.4 ± 2.30[b]	9.2 ± 3.19[a]	9.2 ± 2.17[b]	9 ± 2.64[b]
	L28S	17 ± 1.52[a]	12 ± 2.30[a]	16 ± 2.39[a]	15 ± 1.14[a]
Fruit height (cm)	L28C	8.28 ± 0.8[b]	8.48 ± 0.4[a]	8.8 ± 1.9[a]	8.54 ± 0.7[a]
	L28S	13.2 ± 2.9[a]	9.6 ± 2.3[a]	9 ± 2.0[a]	10.6 ± 2.0[a]
Fruit diameter (cm)	L28C	4.48 ± 1.6[b]	2.96 ± 0.2[a]	3.9 ± 1.8[b]	3.78 ± 0.9[b]
	L28S	3.5 ± 13.0[a]	2.9 ± 6.3[a]	3.2 ± 11.0[a]	3.2 ± 7.3[a]

* Letters represent Duncan test results with confidence interval of 95% and p<0,05

In terms of agronomic value, a maximum yield was recorded in the greenhouse in 2020, with a value of 4848 g/plant compared to the minimum value recorded in 2019, under field conditions, of 2284 g/plant. (Figure 6.).

Usually one or two weeks after a plant produced its first fruit a heavy crop is harvested, then a marked drop occurs, followed by one or more waves of fruit production (Went et. Al, 1945).

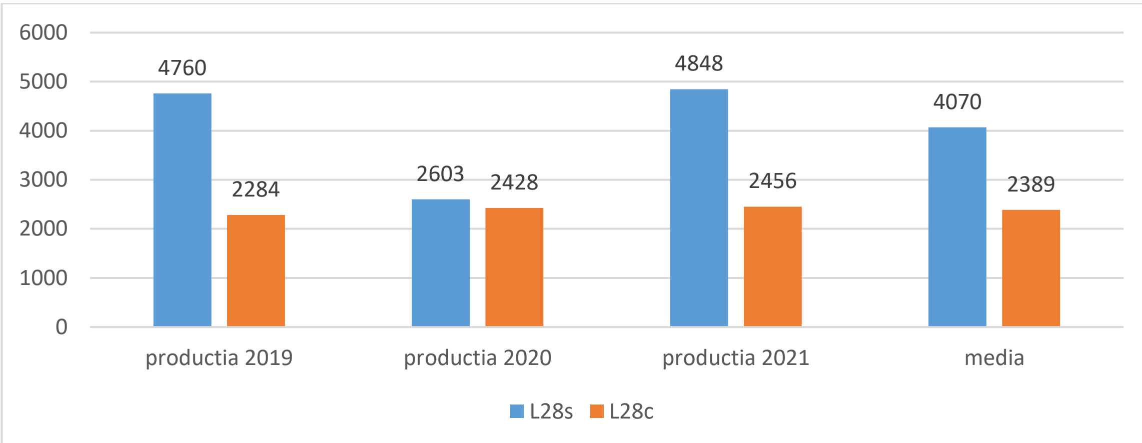

Figure 6. Yield/plant (g) in 2019-2021

The lowest yield values of 2603 and 2428 g/plant were recorded in the dry year 2020. The prolonged drought affected the field crop directly exposed to the stress caused by high temperatures but also in protected space conditions, generating temperatures that were too high and could not be controlled, as the greenhouse was not automated. On average, the yield obtained in the greenhouse during the 3 years of study was 4070 g/plant and in the field, 2389 g/plant.

The values obtained indicate that 'Hera' can be grown both in protected areas and in the field for fresh consumption as well as for processing. The research was completed with approval and patenting, being registered in the Official Catalogue of Cultivated Plants in Romania under the name 'Hera'.

CONCLUSIONS

1. The germplasm base of the Buzau Plant Genetic Resource Bank was exploited through the rehabilitation of a traditional local population.
2. From the genetic material used in the rehabilitation and breeding process of this local population, 4 biotypes with similar characteristics to the studied variety were chosen.
3. Of these, Line 28 was the one with high typicality and genetic stability and was then tested both in protected areas and in the field to establish quality and productivity parameters.
4. The research was completed with the determination of the agronomic value of the variety in the two growing environments of the rehabilitated and improved local population.
5. In the 3 years of culture, lower values of measurable parameters were observed in the field as opposed to the greenhouse.
6. The year 2020, characterized by severe drought conditions, was the period with the lowest values of the main plant and fruit characteristics, both in the field and in the greenhouse.
7. The research was completed with approval and patenting, being inscribed in the Official Catalogue of Crop Plants in Romania under the name of 'Hera'.

Literature cited

Alonso, A., Salazar, J.A., Arroyo, A., Grau, A., García-Martínez, S., Serrano, M. and Ruiz, J.J. (2011). Screening A Diverse Collection Of Heirloom Tomato Cultivars For Quality And Functional Attributes . Acta Hortic. 918, 551-555.

Bai Y and Lindhout P (2007). Domestication and breeding of tomatoes: what have we gained and what can we gain in the future? Ann. Bot. 100: 1085-1094.

Bland, S.E. (2005). Consumer Acceptability Of Heirloom Tomatoes, pp. 4-43

Boukobza, F. And Taylor, A.J. 2002. Effect of postharvest treatment on flavor volatiles of tomatoes. Postharvest Biol. and Tech. 25, 321-331

Coolong, T. (2009) Heirloom vegetables. Cooperative Extension Service, College of Agriculture, University of Kentucky. Accessed September 26, 2011.

DeMuth, S.P. 1998. Vegetables and fruits: A guide to heirloom varieties and community-based stewardship, U.S. Dept. Agr. Spec. Reference Brief Ser. 98–05. 20 Nov. 2012.

F. Di Gioia, F. Serio, D. Buttaro, O. Ayala & P. Santamaria (2010) Influence of rootstock on vegetative growth, fruit yield and quality in ‘Cuore di Bue’, an heirloom tomato, The Journal of Horticultural Science and Biotechnology, 85:6, 477-482.

Flomo, S. T. (2010) Investigation of yield and quality of grafted heirloom and hybrid tomatoes.Master’s thesis, Western Kentucky University.

Gepts P (2006). Plant genetic resources conservation and utilization. Crop Sci. 46: 2278-2292.

Gómez, R., Costa, J., Amo, M., Alvarruiz, A., Picazo, M. And Pardo, J.E. (2001). Physicochemical and colorimetric evaluation of local varieties of tomato grown in SE Spain. Journal of the Science of Food and Agriculture, 81, 1101–5

Gonçalves, L. S. A., Rodrigues, R., Amaral Júnior, A. D., Karasawa, M., & Sudré, C. P. (2009). Heirloom tomato gene bank: assessing genetic divergence based on morphological, agronomic and molecular data using a Ward-modified location model. Genetics and molecular research, *8*(1), 364-374.

Harland, Gail and Larrinua-Craxton, S., (2009) The Tomato Book: A Guide to the Pleasures of Choosing, Growing, and Cooking. 1st ed. London: Dorling Kindersley

Hugh, J., Nink, E., McCarthy, A., Ellen Messer and Sean B. Cash (2017) “The Heirloom Tomato is ‘In’. Does It Matter How It Tastes?”, Food, Culture & Society, 20:2, 257-280.

Jordan, J. A. (2007). The heirloom tomato as cultural object: Investigating taste and space. Sociologia Ruralis, *47*(1), 20-41.

Kuti, J. O., & Konuru, H. B. (2005). Effects of genotype and cultivation environment on lycopene content in red-ripe tomatoes. Journal of the Science of Food and Agriculture, *85*(12), 2021-2026.

Matiu M, Ankerst DP, Menzel A. (2017). Interactions between temperature and drought in global and regional crop yield variability during 1961–2014. PLoS ONE 12: e0178339

O’Connell, S., Rivard, C., Peet, M. M., Harlow, C., & Louws, F. (2012). High Tunnel and Field Production of Organic

Heirloom Tomatoes: Yield, Fruit Quality, Disease, and Microclimate, HortScience horts, *47*(9), 1283-1290.

Ozores-Hampton, Monica, Charles S. Vavrina, and Aline Coelho Frasca (2012). Growing heirloom tomato varieties in Southwest Florida. EDIS 2012.3.

Petro-Turza, M. 1987. Flavor of tomato and tomato products. Foods Review International. 2(3), 309-351.

Rogers, M. A., & Wszelaki, A. L. (2012). Influence of High Tunnel Production and Planting Date on Yield, Growth, and Early Blight Development on Organically Grown Heirloom and Hybrid Tomato, HortTechnology hortte, *22*(4), 452-462.

Rowland, S. D., Zumstein, K., Nakayama, H., Cheng, Z., Flores, A. M., Chitwood, D. H., … Sinha, N. R. (2019). Leaf shape is a predictor of fruit quality and cultivar performance in tomato. New Phytologist. doi:10.1111/nph.16403

Saavedra G, Spoor W and Harrier L (2001). Molecular markers and genetic base broadening in Lycopersicum spp. Acta Horticulturae 546: 503-507

Sawsan RodrÍGuez-Burruezo, J. Prohens, J. RosellÓ & F. Nuez (2005) “Heirloom” varieties as sources of variation for the improvement of fruit quality in greenhouse-grown tomatoes, The Journal of Horticultural Science and Biotechnology, 80:4, 453-460.

Sim SC, Durstewitz G, Plieske J, Wieseke R, Ganal MW, van Deynze A, Hamilton JP, Buell CR, Causse M, Wijeratne S et al. (2012). Development of a large snp genotyping array and generation of high-density genetic maps in tomato. PLoS ONE 7: e4

Steven D. Rowland, Kristina Zumstein, Hokuto Nakayama, Zizhang Cheng, Amber M. Flores, Daniel H. Chitwood, Julin N. Maloof, Neelima R. Sinha. (2020) Leaf shape is a predictor of fruit quality and cultivar performance in tomato. New Phytologist 226:3, pages 851-865.

Sydorovych, O., Rivard, C. L., O’Connell, S., Harlow, C. D., Peet, M. M., & Louws, F. J. (2013). Growing Organic Heirloom Tomatoes in the Field and High Tunnels in North Carolina: Comparative Economic Analysis, HortTechnology hortte, *23*(2), 227-236.

Tregear, A. (2003) From stilton to vimto: using food history to re-think typical products in rural development. Sociologia Ruralis 43 (2) pp. 91–107

Vavrina, C.S., Armbrester, K., And Pena, M. 2003. Growing Heirloom Tomato Varieties in Southwest Florida. Univ. of Fla. IFAS, Extension fact sheet HS921.

Went, F. W., & Cosper, L. (1945). Plant Growth Under Controlled Conditions. VI. Comparison Between Field and Air-Conditioned Greenhouse Culture of Tomatoes. American Journal of Botany*, 32(10), 643.* doi:10.2307/2437619

Wilkins, Jennifer L. (2002). “Consumer Perceptions of Seasonal and Local Foods: A Study in a U.S. Community.” Ecology of Food and Nutrition 41 (5): 415–439.

Wittwer, S.H. and N. Castilla. 1995. Protected cultivation of horticultural crops worldwide. Hort Technology 5: 6-2