INTRODUCTION

Consumer expectations towards agricultural products are increasing, the demands of the society are higher and higher: they expect not only good flavor, but favorable nutritional values of the product as well. By the segregation of consumer levels, the importance of the segment, which ignores the environmental impact of industrialized agriculture, has revulsions against uniformed products and is mistrustful with food additives and chemical residues, is constantly growing. As a consequence, the products of alternative, extensive –including organic- farming systems, have an increasing marketing role.

The main principle of organic farming systems is to endeavor to the harmony with nature, which has to be represented in every elements of the firm, including variety use. The landraces, the extensive balanced populations, which are greatly adapted to the production region, can fit to such production systems.

In the past century, when the tomato became an industrial crop in Hungary, landraces were excluded from intensive production, being unable for mechanic harvesting, and having difficulties with transportability and storage. The point that can save landraces from total vanishing could be their extremely rich flavor and advantageous nutritional value.

Since the abandonment of big-scale production of landraces the production technology has undergone significant changes. The ripening process of most of the modern tomato varieties is influenced, which has an effect on cell wall decomposing enzymes as well as on other

biochemical processes. The green houses, post ripening, artificial fertilizers have an important role in nutritional and flavor parameters. Farmers disappointed in today's agriculture mention the re-introduction of landraces as the solution of the issues mentioned above.

AIMS OF THE WORK

The main aim of my thesis is to investigate the landraces as technological elements fully compatible with the principles of organic farming and to judge the applicability of them in the light of today's agricultural nutritional and marketing expectations. For this aim, the following investigations will be designed:

1. In a three-year open field experiment, yield quality and quantity parameters of 16 indeterminate type tomato accessions, most of them collected from the Central-Hungarian Region, will be investigated, in comparison with three commercially available varieties.
2. The samples collected through the three years will be analyzed (BRIX^{o}, titratable acidity, dry matter, antioxidant capacity (FRAP and DPPH), total polyphenol content, vitamin C and lycopene content) to compare the parameters of landraces and commercial varieties.
3. As a part of my study, based on Hungarian and foreign literature sources, I discuss the meaning of the phrase "landrace" and similar names, as being controversial in Hungary. The outcome is a suggestion for the translation of foreign phrases, discussing the similar and different characteristics of them.

The hypothesis of my study is to investigate the statements available in scientific and popular sources, i.e. the landraces can be characterized by lower yield and more valuable nutritional value in comparison with commercial varieties.

MATERIALS AND METHODS

Location of the experiment. The experiment was implemented at the Soroksár Experimental and Educational Station of Corvinus University Budapest, Faculty of Horticultural Science, Department of Organic Farming. The department is situated in 17 hectares of organically certified plain area, surrounded by hedges. The soil is chernozem type calcareous sand. The experiment was implemented between 2012 and 2014.

Meteorological data. The summer of 2012 was average with a long late summer. The summer of 2013 was rather arid, without any precipitation until late August. in 2014, the summer was extremely humid and relatively cold, which resulted in an air temperature lower than average.

Accessions and commercial varieties selected for investigation. The selection of the landraces for the experiment (Table 1) was done by the Center for Plant Diversity, Tápiószele. Based on the results of the pre-experimental year of 2011, accessions were divided into variety groups according to the fruit size and utilization type. All of the accessions were of indeterminate type. The control of the experiment was provided by the commercial varieties (Table 2), which selected by

the adaptability to extensive organic production, the past experiences of the experimental site and the relative popularity of them.

Table 1. The RCAT code, origin, and basic fruit properties of accessions involved in the experiment.

RCAT code	Registration		Variety group	Fruit shape	Fruit color
	Origin	year			
030268	Bugac	1976	Cherry	circular	red
030731	Máriapócs	1983	Cherry	circular	red
030271	Kozárd	1976	Salad	obovate	red
031255	Soltvadkert	1976	Salad	obovate	red
031257	Gyöngyös	1977	Salad	obovate	red
060349	Nagykáta	2006	Salad	obovate	red
030275	Cegléd	1977	Fresh cons.	circular	orange
031012	Veresegyház	1987	Fresh cons.	circular	red
031095	Cigánd	1986	Fresh cons.	flattened	red
054422	Jánoshalma	2001	Fresh cons.	elliptic	red
031091	Pácin	1986	Caning	oblate	pink
031174	Monor	1987	Caning	circular	red
056060	Újszilvás	2001	Caning	oblate	red
057664	Kaskantyú	1987	Caning	oblate	red
060348	Nagykáta	2006	Caning	cordate	red
029837	Táplán (Tápláni konzerv)		Caning	circular	red

Table 2. Name and basic fruit characteristics of commercial varieties involved in the experiment.

Name	Maintained by	Variety group	Fruit shape	Fruit color
San Marzano	Sunseed Genetics (UK)	Canning	ovate	red
Hellfrucht	Hild Samen GmbH (DE)	Fresh cons.	circular	red
Marmande	Semillas Fito SA (ES)	Canning	oblate	red

Production technology. The forecrop of the experiment was corn in every year. No fertilization was performed throughout the three years. Seedlings were grown in unheated plastic tunnel. The spacing of the plans were (45+90)*45 cm, in a twin row, with agrotextile ground cover and drip irrigation. One plot consists of ten plants of the same accession/variety in four replicates. The side-shoots were removed.

Investigations on yield quality and quantity. Ripened fruits were harvested weekly separated by accession/variety, regardless to the repetition. The fruits were divided into intact, cracked and infected fractions and weighted on the spot.

Nutritional investigations. A representative sample of 1,5 kg intact fruits were separated from every accession/variety for laboratory investigations. Homogenization of samples were performed at BCE Faculty of Food Science, Department of Applied Chemistry, Department of Canning Technology and at SOTE Faculty of Health Sciences, Department of Dietetics and Nutrition Sciences. The dry matter of

samples was measured by drying in an oven. Total soluble solids were measured by a digital refractometer according to Codex Alimentarius 558/93. Titratable acidity was measured by titration (ISO 750:2001). The FRAP methodology was used according to Benzie and Strain (1996) DPPH measurement was applied according to Molyneux (2003). The polyphenol content was measured by the methodology of Singleton and Rossi (1965). The lycopene content was measured according to Fish et al (2002). The ascorbic acid content was measured by reverse-phase HPLC methodology.

Statistical analysis. In case of the comparison of the yield of traits and of years, the data of the continuous five harvests with the highest yields were used. For this, two-way MANOVA tests were used, with Games-Howell, or Tukey post-hoc tests. In case of nutritional data analysis, the values of the peak harvest of every trait were used. For this, two-way MANOVA tests were used, with Games-Howell, or Tukey post-hoc tests. The correlations between weather, yield, and nutritional parameters were analyzed by the calculation of Pearson coefficients (n=285). In contrast with the previous analyses, the data of both five peak harvest were used as well. In order to structure the information of the correlating variables, a dimension reduction was performed with Principal Component Analysis, based on yield (T), weather (I), and nutritional (B) parameters. Using the nutritional data and the amount of intact fruits, the utility value of the investigated accessions and varieties was identified. Rank values of 1 to 6 were ordered to the nutritional parameters (sugar-acid ratio, FRAP, TPC, DPPH, lycopene) and

weighed with yield parameters. The values of the accessions and varieties were compared by ANOVA test. Based on the calculated utility values, cluster analyses were performed with Ward- and K-means methods.

RESULTS

Yield results of investigated tomato accessions and varieties. The **biological potential** of traits was highly weather-dependent. In case of every trait the highest results were given in 2012. The following two years took a notable decrease. Generally speaking, the results of the second year was the lowest. In case of most traits, the third year was more favorable, than the second year. The extreme weather conditions of the three years were not tolerated by any accession or variety.

The weather of the first year was the most favorable for the **intact fraction**. The arid second year meant more intact fruits, than the humid third year. In the first year the highest results were given by Cigándi and Jánoshalmai landraces, and Hellfrucht and San Marzano varieties. The lowest results were given by Nagykátai, Kozárdi, and Pácini accessions, respectively. In the second year the highest results were reached by Hellfrucht, Bugaci, Jánoshalmai, Tápláni konzerv, and Máriapócsi accessions. The lowest results were measured in case of Monori, Gyöngyösi, and Újszilvási landraces. In the third year the landrace Pácini reached an outstanding result, which exceeded the results of the previous year as well as the yearly data of the other accessions and varieties. It was followed by Gyöngyösi, Hellfrucht and Bugaci traits.

The lowest values were given by Monori, Kozárdi, and Újszilvási landraces.

With regards to the **cracked fraction**, similarly to the intact one, the first year showed the highest values. Throughout the first year an outstanding amount of cracked fruits were harvested from Pácini landrace, followed by Marmande, Kaskantyúi and Bugaci. The lowest amounts were produced by San Marzano and Jánoshalmai landrace. In the second year the amount of cracked fruits decreased. The landraces Pácini and Újszilvási, and Marmande gave the highest amounts. The San Marzano was followed by Gyöngyösi, Máriapócsi and Jánoshalmai, in the row of traits with lowest amounts. In the third year the highest resuts were reached by Tápláni konzerv, Újszilvási and Pácini landraces. The lowest results were given by San Marzano, Máriapócsi and Nagykátai landraces.

Depending on the trait, the highest amount of **infected fruits** were produced in the first or the third year. The second year resulted the lowest values in case of most of the accessions and varieties. The traits less sensitive to seasonality were San Marzano variety, Újszilvási, Soltvadkerti, and Ceglédi landraces. The cherry group gave the lowest values among the others. The highest amount of infected fruits were provided by the members of canning group. In the first year Kaskantyúi, Nagykátai ökörszív and Újszilvási landraces performed the worst. The lowest amount were harvested from Máriapócsi, Jánoshalmai, Bugaci landraces and San Marzano variety. In the second year the lowest amounts were measured in the case of Máriapócsi, Bugaci and

Jánoshalmai landraces. The most infected were Újszilvási, Kaskanytúi landraces and Marmande variety. In the third year the results were close to those of the first year. The lowest amounts were measured in case of Máriapócsi followed by San Marzano and Nagykátai. The first two produced the lowest amount in every year. The landrace Újszilvási gave scored in the top three every year. Similarly unfavorable results were given by Kaskantyúi and Marmande.

Results of the nutritional analyses of accessions and varieties.

Total soluble solids. The ^{o}Bx value of the investigated traits ranged between 3,13-7,06 throughout the three years. Lower results were given in the case of fresh consumption and canning group. The values of commercial varieties were average or lower. The highest values were given by Máriapócsi, Ceglédi, Nagykátai ökörszív, and Gyöngyösi landraces.

Titratable acidity. The values ranged between 0,27-0,81 g/100cm^3 in the three years. Lower values were measured in the second and third year. No outstanding differences were found, higher values were given by Bugaci and Ceglédi landraces. No clear distinction was possible between varieties and accessions. The salad group generally gave lower acid values.

Sugar-acid ratio. Due to weather changes the second year showed higher sugar-acid ratio values. Landraces and varieties did not divide significantly in any year. Lower values were given by Cigándi landrace and Hellfrucht variety.

Dry matter content. The impact of seasonality was strong, the highest values were given by cherry group in every year. In the fresh consumption group the landraces Ceglédi, Cigándi, and Jánoshalmai scored among the best every year. Hellfrucht gave weaker results. From the canning group, the landraces Monori and Nagykátai ökörszív are promising; the control varieties reached good values, similarly to or slightly overcoming the landraces.

Vitamin C content. The results were extremely low and seasonality-influenced in both two years. The high standard deviance make the accuracy of the data questionable. The cherry types scoring the best in 2013 had values lower than the average in 2014. The landraces Jánoshalmai, Veresegyházi, Monori, Kaskantyúi, and Újszilvási gave better results in both years. San Marzano can be characterized by low vitamin C content both years, similarly to Tápláni konzerv, while Marmande gave the third highest value of its group in 2014.

Lycopene content. A moderate seasonality characterizes the lycopene content of the investigated accessions and varieties. The highest results were given by the members of the salad group; in the first and last year Soltvadkerti and Gyöngyösi reached 12-14 mg/100g. Kaskantyúi landrace, independently from changing weather conditions, showed 8 mg/100g in every year. Hellfrucht has a lower lycopene content.

Antioxidant capacity (FRAP, DPPH, TPC). In case of FRAP, the results of the three years changed in the same range. Higher results were shown in the second year. The TPC values changed according to

the season, the values of the first year were six times, while those of the second year were two times higher, than those of the third year. In case of DPPH, no seasonality was detected; the values in the second year were 8-10 % lower, in comparison with the data of the other years. The cherry types showed high FRAP and TPC results in every year. Except the first year, Hellfrucht had one of the highest FRAP and DPPH Values. In case of TPC, the landraces showed better results.

CONCLUSIONS AND SUGGESTIONS

Due to major differences in weather conditions of the three years, it was possible to observe the susceptibility of accessions to extreme weather conditions, which had a significant impact on yield quantity and quality as well. The first year with a hot late summer was the most ideal for every landrace and variety from the point of yield potential, although in some cases –e.g. Gyöngyösi, Nagykátai, Ceglédi, and Veresegyházi accessions- the highest amount of cracked fruits were given in the very same year.

In case of some landraces a certain degree of independence from weather extremities was observed with regards to yield potential, these were Veresegyházi, Pácini and Újszilvási accessions. Other landraces could give better results despite of a certain weather extremity, therefore it can be assumed, that Gyöngyösi and Ceglédi landraces can wear higher amounts of precipitation, though it demands further research.

Based on my results, the influence of the amount of precipitation and of the genetic background on cracking and infection can be assumed. The

third year took an increase in the ratio of cracked fruits in case of Versegyházi, Cigándi, Jánoshalmai, Monori, and Tápláni konzerv accessions, which can be attributed to the extremely humid season. However, the landraces Nagykátai, Ceglédi, Pácini, Újszilvási, Kaskantyúi, Nagykátai ökörsziv, and Marmande variety, the amount of cracked fraction was the same in every year, therefore it can be referred to genetic background. In order to decrease the ratio of cracked fruits, further research is needed.

The ratio of infected fraction can indicate the resistance of landraces to infections. Based on this, more vigorous are those with smaller fruit size: - Bugaci, Máriapócsi- , and Ceglédi landrace. Despite of the increased cracked fraction ratio in the first year, the extent of infections did not increase in the case of Gyöngyösi, Jánoshalmai, and Tápláni konzerv accessions, which could indicate stronger resistance, and can be the starting point of further plant protection trials. With the increase of cracked fruits, the ratio of infected fruits increased in the case of Cigándi, Hellfrucht, Pácini, Monori, Újszilvási, Kaskantyúi, Nagykátai ökörszív and Marmande traits, here the application of an appropriate plant protection technology is reasonable.

In general, it can be concluded, that in the case of landraces with bigger fruit size, the ratio of cracked and infected fruits was higher. Due to their special pepper shape fruit, salad types were extremely susceptible to blossom end rot, which was the most severe in the second year. In the case of big, ribbed fruits, serious radial cracking, as well as irregular fruit shape and blossom-end closing irregularities were common, which

resulted significant yield losses, for example in the case of Újszilvási and Kaskantyúi accessions, the producing of which is not suggested with the same technology.

It is important to note the high ratio of cracked fruits of the investigated accessions, as a general characteristic of these landraces. The consumers seeking for organic products lay the emphasis on nutritional values, and can tolerate moderate visual defects of the products. The impact of cracking on nutritional values should be investigated further on.

According to my results, it can be concluded, that general statements are not applicable – certain parameters of the control varieties were exceeded, while others were under-achieved by the landraces. Therefore it is reasonable to investigate each accessions in order to explore their advantages and shortcomings and to enhance their utilization in breeding and agricultural production systems.

The comparison of landraces and varieties can be interpreted within their group. However, it can be concluded, that general statements were not justified by my results, as it showed controversial results on the level of accessions and varieties. In the fresh consumption group Hellfrucht and Cigándi landrace had roughly the same yield potential throughout the three years, as well as those of Veresegyházi and Jánoshalmai in the second year. Therefore it cannot be declared clearly, that the yield of landraces is low. The two control varieties of the canning group, San Marzano and Marmande, have origins from landraces. San Marzano was positioned into the canning group due to its utilization as canning raw material, as it is demonstrated by its results: the yield potential is lower,

but the intact fruit ratio is outstanding. However, the variety Marmande was rather similar to the group member landraces in performance. The accessions Pácini, Újszilvási, and Tápláni konzerv had favorable yield performance, though only the latter is reasonable due to its acceptable intact fruit production. No accession could be marked as outstanding from the point of low cracked or infected fraction ratio.

With regards to the nutritional value of landraces no clear and significant differences were found, in comparison with varieties. This can be partly justified by the same production technology, as well as by the applicability of control varieties to extensive production. A comparison with intensive hybrids presumably ended up with more radical differences.

It was observed in case of the landraces, that its sugar and acid content is similar to or higher than those of the control varieties. In case of certain accessions it can be concluded, that its lycopene and polyphenol-content is higher, than those of the commercial varieties. This difference can be regarded to genetic differences.

In order to summarize the results of the investigated accessions, and to provide a practical result for farmers, I calculated the utility value (HÉ) of each landrace and variety. For this value we used sugar-acid ratio, FRAP, TPC, DPPH, vitamin C and lycopene values, which were transformed into rankings and weighed by the quantity of intact fruits (kg/m2). The results were averaged and analyzed statistically. The differing weather conditions resulted an extremely high standard deviation. Significant differences were found only between Hellfrucht

and the group of Kozárdi and Nagykátai ökörszív landraces. It is true for most of the landraces, that their possibly higher nutritional values could not compensate their less favorable intact fruit results, therefore the utility values of them were lower than those of the commercial varieties in most cases.

The data composed of the utility values (HE_atl, HE_max, HE_comp) were the basis for a cluster analysis in order to further refine the grouping of the investigated accessions. The results are shown on Figure 1., which demonstrates the values representing the accessions in a two-dimensional space of HE_átl and HE_max values. The two methods applied gave a consensual result in case of most of the accessions and varieties, except Máriapócsi, Veresegyházi and Pácini landraces, and San Marzano variety. It might be due to the differences of years, which made the grouping variable. Based on these results, Jánoshalmai and Cigándi accessions ae clearly distinct from Hellfrucht in utility value, which could be a good reason for the re-introduction of them in production. The moderately high values of Bugaci, Veresegyházi, Pácini, Gyöngyösi, Máriapócsi and Ceglédi are considerable, with special regards to their unique characteristics (fruit color, shape, size). The production of certain accessions, i.e. Kozárdi and Nagykátai ökörszív is not suggested with the applied production technology.

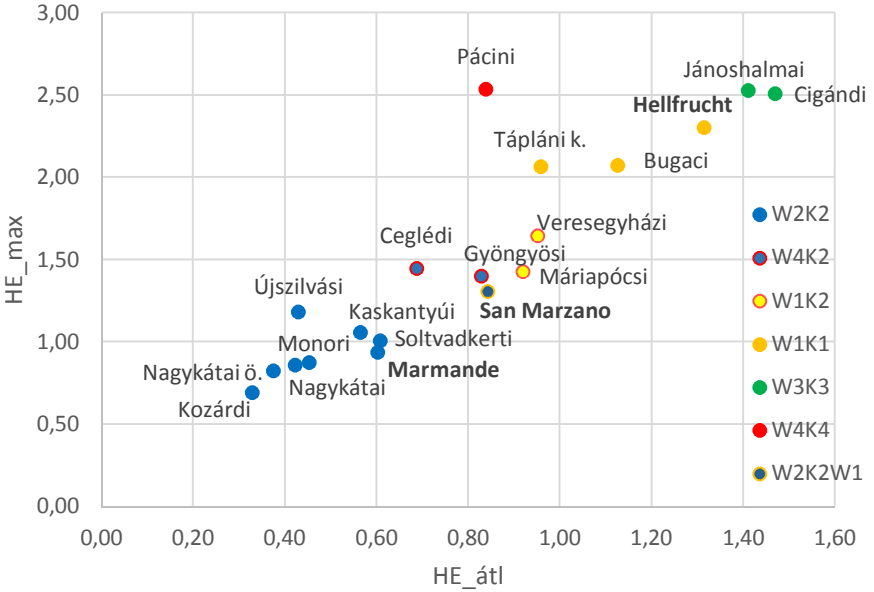

Figure 1. The mean value (HE_atl) and maximum (HE_max) of utility values of investigated accessions and varieties.

The middle color of the data points refers to the results of the K-means clustering (K), while the edge color refers to those of the Ward-clustering (W). In case of the same color within a data point, the results were consensual.

NEW SCIENTIFIC RESULTS

1. Based on a three-year open field trial, the yield quantity and quality, as well as nutritional parameters of 16 Hungarian tomato accessions were identified.

2. Based on scientific literature, the definitions of the term landrace were collected, the synonyms were characterized, and Hungarian translations were suggested for their use in scientific language.

3. The investigations justified, that with the parallel use of FRAP, TPC and DPPH methodologies the antioxidant status of tomato landraces can be identified.

4. With the use of statistical analysis it was demonstrated, that the salad type tomatoes are promising nutritional raw materials from the point o lycopene content.

5. It was justified by statistical analysis, that the general statements with regards to landraces are not applicable, and the investigation of each accession is reasonable.

6. The results justified, that in case of uniform production technology, the yield and nutritional parameters of the investigated accessions do not divide significantly from those of the varieties.

7. Correlations of yield, weather, and nutritional parameters were explored with data reduction methodology.

8. With the use of two statistical methodologies the accessions were divided into the following groups, based on their yield and nutritional results: suggested for organic farming, suggested with reservations, and not suggested for organic farming.

9. The greatest barrier of the applicability of tomato landraces is the strong susceptibility to cracking; the type and severity of them is influenced by the shape and size of the fruit.

RELATED PUBLICATIONS OF THE AUTHOR

Journal article with IF

Csambalik L, Divéky-Ertsey A, Pap Z, Orbán Cs, Stégerné Máté M, Gere A, Stefanovits-Bányai É, Sipos L (2014) Coherences of Instrumental and Sensory Characteristics: Case Study on Cherry Tomatoes. JOURNAL OF FOOD SCIENCE 79:(11) pp. C2192-C2202. (2014) (IF=1,791, SJR: Food science, 41/242 (Q1))

Journal article without IF

Csambalik László, Pusztai Péter, Szalai Zita, Divéky-Ertsey Anna (2014) Közép-magyarországi tájjellegű paradicsomfajták érzékszervi szempontú összehasonlítása. KERTGAZDASÁG 46: (4) pp. 45-54.

Csambalik L, Divéky-Ertsey A, Ladányi M, Orbán Cs (2014) Influence of abiotic disorders on nutritional values of tomato (Solanum lycopersicum) Review of Faculty of Engineering: Analecta Technica Szegediensiana (ONLINE) 2014:(1) p.

Divéky-Ertsey A, Csambalik L, Kókai Z, Stefanovits-Bányai É, Pap Z, Krisztiánné Kis M, Sipos L (2012) Antioxidant, polyphenol and sensory analysis of cherry tomato varieties and landraces. INTERNATIONAL JOURNAL OF HORTICULTURAL SCIENCE 18:(1) pp. 75-80.

Gilingerné Pankotai M, Csambalik L, Erdei G, Simon P (2013) Hagyományos paradicsomtípusok likopin- és C-vitamin-tartalmának változása az érés során. ÚJ DIÉTA 22:(1) pp. 17-19.

Informative articles

Csambalik L, Divéky-Ertsey A (2015) Minden tájfajta-termesztő nemesítő, vagy mi a jelentősége a saját magfogásnak? AGROFÓRUM 26:(1) pp. 142-145.

Csambalik L (2014) Változatos alak - változatos problémák?: A paradicsombogyó abiotikus elváltozásairól. AGROFÓRUM 25:(1) pp. 36-41.

Csambalik L (2013) Tájfajta, örökségfajta - ugyanaz a paradicsom? AGROFÓRUM 24:(6) pp. 93-95.

Papp O, Csambalik L (2012) Paradicsom tájfajták összehasonlító vizsgálata. ŐSTERMELŐ 16:(2) p. 100.

Csambalik L (2011) Tájfajták szerepe az ökológiai gazdálkodásban, paradicsom tesztnövényen vizsgálva. AGROINFORM 20:(10) pp. 26-28.

Hungarian conference abstracts

Csambalik L, Divéky-Ertsey A (2013) A paradicsom fajtaválaszték diverzifikációja tájfajták és környezettudatos teremsztéstechnológia bevezetésével, Gazdaság és Menedzsment Tudományos Konferencia, Kecskeméti Főiskola, 2013. szeptember 5., in press

Inernational conference abstracts

Csambalik László, Orbán Csaba, Stégerné Máté Mónika, Pusztai Péter, Divéky-Ertsey Anna (2016) Antioxidant profile of tomato landraces for fresh consumption. In: Gábor Keszthelyi-Szabó, Cecília Hodúr, Judit Krisch (szerk.) International Conference on Science and Technique Based on Applied and Fundamental Research (ICoSTAF'16): Book of Abstracts. 58 p.Szeged, Magyarország, 2016.06.02 Szeged: University of Szeged Faculty of Engineering, 2016. p. 19.

Csambalik L, Divéky-Ertsey A, Ladányi M, Orbán Cs (2014) Influence of abiotic disorders on nutritional values of tomato (Solanum lycopersicum). In: Gábor Keszthelyi-Szabó, Cecilia Hodúr, Judit Krisch (szerk.) ICoSTAF'14: International Conference on Science and Technique Based on Applied and Fundamental Research. 56 p. Szeged, Magyarország, 2014.04.25 Szegedi Tudományegyetem Mérnöki Kar, 2014. p. 16.

Csambalik L, Divéky-Ertsey A, Ladányi M (2013) Organic production of tomato landraces collected from the Central-Hungarian Region, 2. Transsilvanian Horticulture and Landscape Studies Conference, Sapientia Hongarian University of Transsylvania, 2013. április 12-13, Marosvásárhely, p 14.

Varga R, Radics L, Divéky-Ertsey A, Tóbiás A, Csambalik L, Pusztai P (2011) Research of Economical and Social Potential Within Organic Farming in the Central Hungarian Region In: Book of proceedings: 17th IFOAM OWC. p 188. Szöul, Dél-Korea, 2011.09.28-2011.10.01.