Hungarian University of Agriculture and Life Sciences

The effect of grafting on the quantitative and qualitative parameters of forced sweet pepper (*Capsicum annuum* L.)

Thesis of doctoral (Ph.D.) dissertation

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1. INTRODUCTION, AIM OF THE STUDY

Sweet pepper (Capsicum annuum L.) is classified as less important vegetable crop in various countries of the world, in contrast to Hungary and the areas inhabited by Hungarians in Central Europe. It is considered an important food item in these regions, it has a number of content values that have a positive effect on the human body. For example vitamin C, vitamin P, carotene, vitamins B1 and B2 and capsaicin. In recent years, the average consumption of sweet pepper has been close to 10 kg / capita, which, in addition to tradition, has been helped by the fact that sweet pepper can be consumed fresh and processed throughout the year. China ranks first among the world's pepper-producing countries; In Europe, Turkey, Spain, the Netherlands and Italy boast the highest production standards. In Hungary, sweet pepper is the largest surface-grown vegetable crop, the production area has stabilized at about 1500-1600 hectares in the last years, its field cultivation has decreased to 600 hectares (Fruitveb, 2019).

The production area of sweet pepper has not changed significantly in the last 5 years, however, there have been significant rearrangements between the types of varieties produced. While the production area of kapia type peppers increased significantly due to the need for less labor and higher producer prices, the production area of white conical varieties decreased further and the production of strong varieties showed a slight increase. At the same time, the area of soilless cultivation has increased, as well as the proportion of users of integrated biological plant protection. Integrated cultivation requires a higher technical and technological level, thereby reducing the proportion of small-air plastic tunnels, improving the quality of production, positively affecting the quantity and quality of goods produced. The amount of peppers produced in the country reached 185 thousand tons in 2019, while in 2013 the pepper production of Hungary was only 155 thousand tons. The export market for sweet pepper has shrunk further in the past year, driven by significantly increased domestic demand (Fruitveb, 2019).

During monoculture cultivation, our soils became infected to such an extent that growers has two alternatives to switch to soilless cultivation or to use grafted plants. In practice, today in Hungary we can propagate six vegetable species (watermelon and melon, cucumber, tomato, pepper, eggplant) by grafting. While in the case of tomatoes the proportion of grafted seedlings in long term forcing exceeds 90%, in the case of peppers and eggplants this figure barely reaches 1-2 %.

Like in Hungary, the technology of grafting in pepper cultivation has not spread significantly in other countries of the world. Of the Asian countries, 10 % of the amount of seedlings produced in South Korea is grafted, while in Japan it is half, 5 %. In China, the proportion of grafted plants compared to their nongrafted is just over 1 %, yet it is still the world leader with its 1.450 thousand pepper grafts produced.

In Spain, 70 % of all grafted vegetable seedlings produced are planted in the provinces of Almeria and Murcia. Similar to Hungary, the use of grafted pepper plants in Spain is close to 3 %, while Greece is only slightly behind, using 1-3 % of this technology.

Grafting not only provides resistance to pathogens and pests infectious from the soil, but also increases the cold and heat tolerance of the graft, which can result in earlier planting and even earlier picking. Additional benefits of grafting, that it regulates the growth of the scion, can increase the fruit size, thereby increasing the average yield, and can even affect the inner content of the crop.

The main goal of my experiments was to:

- in both cultivation year (2016, 2017) to evaluate one conical cultivar and one kapia cultivar as nongrafted and grafted in unheated plastic tunnel using biological pest control,
- to evaluate the grafted and nongrafted plants not only in soil culture but also in soilless production,
- to evaluate the habitat and yield of grafted and nongrafted plants,
- of both cultivars to determine the refraction value, the dry matter content, the titratable acidity, the antioxidant capacity, the total polyphenol and NPK content of fruits of grafted and nongrafted plants in laboratory conditions, furthermure to examine the lycopene content of kapia type,
- to carry out sensory evaluations to determine whether consumers feel a difference between nongrafted and grafted pepper fruits from soil and soilless cultivation,
- to make various calculations about the economics of grafted and nongrafted sweet pepper cultivation.

2. MATERIALS AND METHODS

2.1. The materials of the experiment

In 2016 and 2017 I set my experiment at the Experimental and Research Farm of Szent István University at the Vegetable Growing Division in a 350 m^2 unheated plastic tunnel. The plants were tested in soil and soilless culture (coconut fiber) using biological pest control.

For the evaluations one conical type (*SV 9702* PP F1) and one kapia type (*Karpex* F1) cultivar, which are commonly produced varieties, furthermore two rootstocks (*Snooker* F1, *Capsifort* F1) was chosen.

For propagation transplants were used. **Table 1.** shows the dates of propagation. For grafting the tube method was chosen, which means, that the scion and the rootstock was cut in 45 angle and then with the help of silicon tube the two plant part were fixed together.

Table 1. Dates of propagation, Szentes, 2016, 2017

<table>
<tr><th rowspan="2">2016</th><th colspan="2">Date of sowing</th><th colspan="2">Date of grafting</th></tr>
<tr><th>Soil block</th><th>Rockwool</th><th>Soil block</th><th>Rockwool</th></tr>
<tr><td>SV9702 and Karpex</td><td rowspan="3">4th March.</td><td rowspan="3">11th March</td><td rowspan="3">25th March.</td><td rowspan="3">29th March</td></tr>
<tr><td>Snooker</td></tr>
<tr><td>Capsifort</td></tr>
<tr><td>SV9702 and Karpex (nongrafted)</td><td>7th March</td><td>18th March</td><td></td><td></td></tr>
<tr><td>2017</td><td colspan="4"></td></tr>
<tr><td>SV9702 and Karpex</td><td rowspan="3">1st March</td><td rowspan="3">1st March</td><td rowspan="3">23rd March</td><td rowspan="3">23rd March.</td></tr>
<tr><td>Snooker</td></tr>
<tr><td>Capsifort</td></tr>
<tr><td>SV9702 and Karpex (nongrafted)</td><td>8th March</td><td>8th March</td><td></td><td></td></tr>
</table>

For the white conical treatments, a 100 + 40x33 cm spacing was used, while for the kapia type, a 100 + 40x25 cm. Thus, the number of plants per square meter was 4.33 and 5.71. Plants were planted in 4 replicates, each replicate containing 12 plants. The nutrient solution was adapted to the habits of the plants and to the environmental conditions. The plants were cut into 2 stems.

In both experimental years (2016, 2017), the fruits of the white conical treatments were harvested economically, while the fruits of the kapia treatments were harvested at biological ripeness.

2.2. Measurments, observation methods

2.2.1. Plant height, tyield and morphological evaluations

The growth vigor of sweet peppers was measured by height measurement every other week using a bamboo wand.

The fruits were measured one by one after the pickings. Using a ruler and a digital scale, I determined the shoulder diameter, length, and weight of the fruits, and recorded the deviations from the deformed, calcium-deficient and infected fruits. Thus, I determined the average yield per m^2, the number of fruits per m^2, the number of fruits per stem, the average fruit weight, and I also classified the fruits.

For grouping the fruits by size, I followed the following classification **(Table 2.)**:

Table 2. Classification of sweet pepper fruits

	White conical		Kapia	
	min. diameter (mm)	**min. length (mm)**	**min. diameter (mm)**	**min. length (mm)**
extra	70	140	67	150
I.	60	100	57	140
II.	50	80	47	130
III.	40	70	44	90

Furthermore, I distinguished a fifth category, which I referred to as waste. I classified calcium-deficient, sunburned and out of size fruits into this category.

2.2.2. Laboratory measurments

For laboratory tests, I used 6 healthy fruits per plot. After sampling, the samples were processed in three ways:

- blended for the measurment of refraction value, titratable acidity, dry matter and lycopene content,
- dried for the determination of macroelement (N, P, K) content,
- freeze-dried for the determination of antioxidant capacity and total polyphenol content.

The measurment of refraction value

The refraction value of the fruits was measured with a digital refractometer (PAL-1, ATAGO). Three parallel measurements were made per sample. The results are granted in Brix̊.

The measurment of dry matter content

To determine the total dry matter content of the fruits, two parallel tests were performed in accordance with the MSZ 2429-1980 standard.

The measurment of titratable acidity

To determine the titratable acid content of sweet pepper fruits, I used the standard MSZ 3619-1983 in both experimental years.

The measurment of lycopene content

To determine the lycopene content of the samples, I used the hexane extraction spectrophotometric method developed by Sadler et al. (1990). Measurements were performed at 502 nm. A molar extension coefficient was used to calculate the results (Merck & Co., 1989). Values were given in mg / 100g fresh weight and normalized in 6 Brix̊ dimensions (Barrett and Anthon, 2001).

Macro nutrient content of the fruits

The macroelement content of the fruits was examined during both years. To determine the nitrogen content of the samples, I used the Kjeldahl method (Erdey-Georg, 1965). The phosphorus content was performed spectrophotometrically, while potassium measurements were performed with a flame photometer.

The measurment of antioxidant capacity

For evaluating the antioxidant capacity of the samples I used the modified method of Benzie and Strain (1966). The method was originally developed to determine the antioxidant capacity of plasma (FRAP, Ferric Reducing Ability of Plasma). The essence of the process is that ferric (Fe^{3+}) ions are reduced by antioxidant compounds to ferro- (Fe^{2+}) - ions, which at low pH form a complex with tripyridyltriazine (TPTZ, 2,4,6 tripyridyl-S-triazine) form colored compounds (ferrotripyridyl triazine). From the value of this compound measured spectrophotometrically at λ = 593 nm, the total antioxidant capacity of the measured sample can be determined in μM ascorbic acid / dry weight (μMAS / dry weight) by means of a calibration curve with ascorbic acid.

The measurment of total poliphenols

Total polyphenol content (μMGS / dry weight) relative to gallic acid was measured in both experimental years with Folin-Ciocalteu reagent at λ = 760 nm (Singleton and Rossi, 1965) by spectrophotometric method.

In the two examined years I represent the results of the white conical and kapia types in 3-3 picking times **(Table 3)**.

Table 3. Date of sampling for laboratory measurments, Budapest, 2016, 2017

White conical		Kapia	
2016	**2017**	**2016**	**2017**
28th June	5th July	1st august	27th July.
20th July	18th August	24th August	17th August
5th September	11th September	21st September	18th September

2.2.3. Sensory evaluation

I performed my tests according to the ISO 13229 standard. Samples were judged by 10 trained staff during each study. This means that the judges received training before the test, where they were selected according to the ISO 8586: 2012 standard.

For each of the 11 sensory characteristics, the reviewers rated the samples on a scale of 0 to 100, for both cultivars the nongrafted control was the reference from the soil cultivation (ISO 11035: 1994).

2.2.4. The method of the economical evaluations

In my economic analyzes, there were costs that I did not include in my calculations because in the division these were given: foil frame, training system, humidification system, tanks for nutrient solution, pumps and hand tools. There were also material / service costs that I did not project over a year, as they can be used for several years. I divided these into two groups:

- which can be used for 7 years: vector net, raschel net, dripping tube,
- which can be used for 2 years: plastic foil, drip tape, test of irrigation water, nutrient solution recipe.

To determine the profit, I used the daily average prices of the Wholesale Market. Finally, I was able to determine the profit differences between each treatment, taking into account the expenditures and revenues per unit area.

2.2.5. The method of statistical analysis

Statistical evaluation of my results was performed with IBM SPSS Statistics 25 software package at 95% significance level.

The results of the sensory examinations were analyzed by one-way ANOVA with the calculation of the smallest significant differences. This step of data analysis is built into ProfiSense, which runs as a macro in Microsoft Excel.

3. RESULTS AND DISCUSSION

3.1. Plant height

In soil cultivation of white conical (*SV9702*) cultivars, I observed that during both experimental years, the use of *Snooker* rootstock increased plant height, while *Capsifort* rootstock had no effect on plant growth. In soilless production none of the rootstocks had positive effect on the height of the plants, which results are similar to Saporta és Gisbert (2013).

Regarding the height of the **kapia** (*Karpex*) plants on soil, both rootstocks had a positive effect on the *Karpex* cultivar, in the case of soilless cultivation I came to the conclusion that grafting has only a small effect on the height of the plants.

3.2. Yield

Examining the yield results of **white conical type** on soil, I noticed that the application of the two rootstocks resulted in a higher yield average in soil culture than in nongrafted plants, which results are similar to Leal-Fernandez an co-workers (2013), Ergun and Aktas (2018) and Sarswat and co-authors (2020). In the case of soilless cultivation, I came to the conclusion that grafting does not affect the average yield **(Figure 1. and Figure 2.)**.

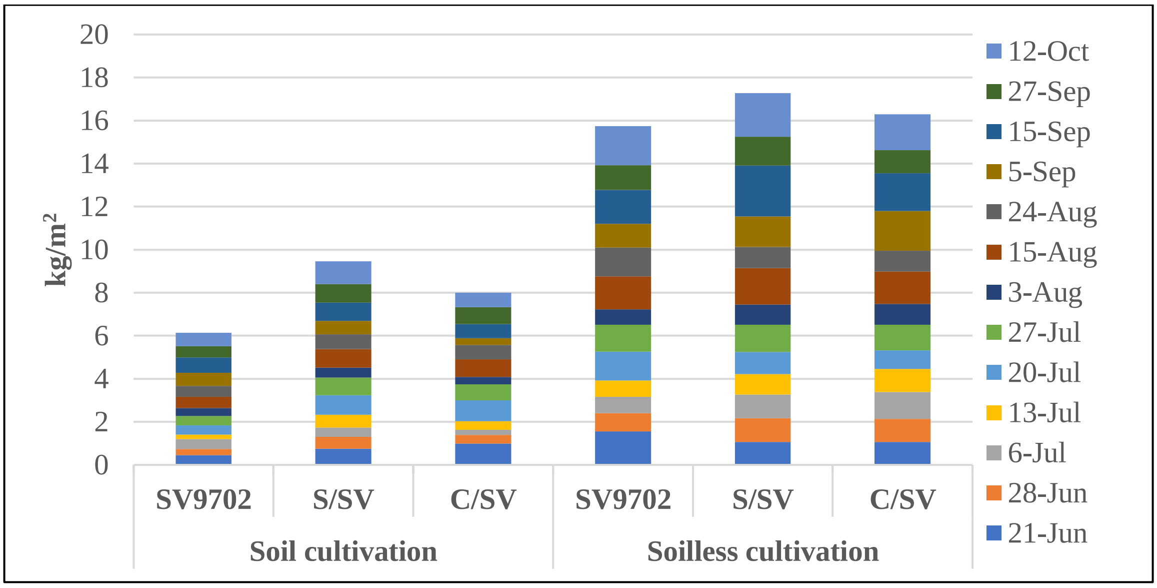

Figure 1. Yield of *SV9702* cultivar and its grafted combinations in soil and soilless cultivation 2016

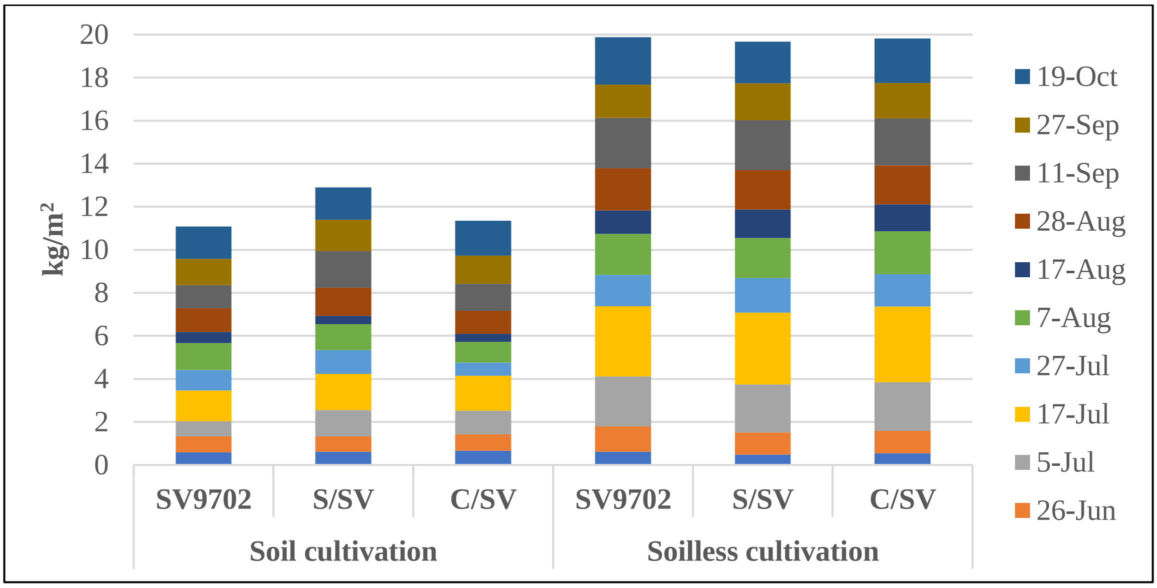

Figure 2. Yield of *SV9702* cultivar and its grafted combinations in soil and soilless cultivation 2017

In the course of the examination of the yield results of **kapia type (Figure 3. and Figure 4.)**, after my two-year experiments, I found that in soil cultivation under unfavourable soil conditions, a higher average yield can be achieved, which can be attributed to the better root system of the plants. In soilless cultivation I observed the same as in case of the white conical type, that grafting has no positive effect on yiled.

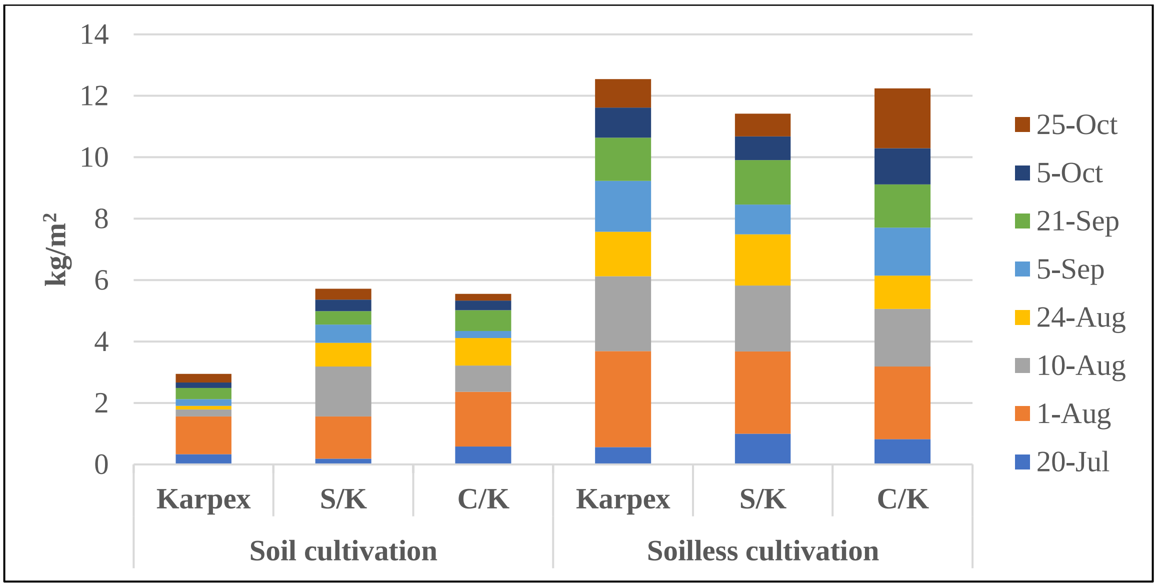

Figure 3. Yield of *Karpex* cultivar and its grafted combinations in soil and soilless cultivation 2016

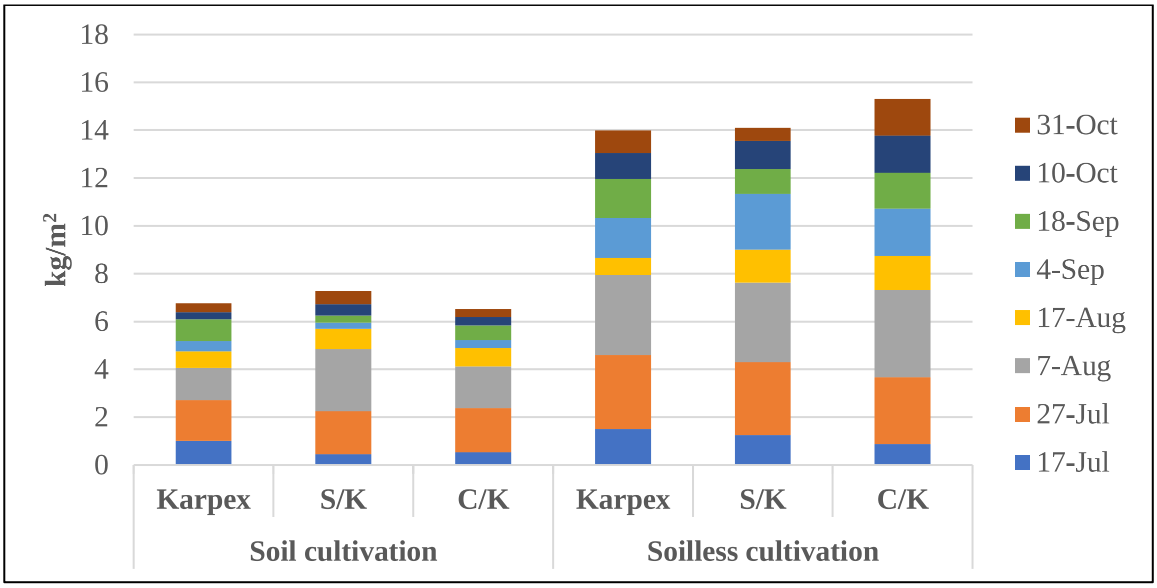

Figure 4. Yield of *Karpex* cultivar and its grafted combinations in soil and soilless cultivation 2017

3.3. The average weight of fruits

During the measurement of fruit weight, I came to the conclusion that in soil cultivation grafting can only have a positive effect on the average weights under unfavourable environmental conditions (results measured in 2016). In soilless cultivation of **kapia type**, I observed that the *Capsifort* rootstock increased the average weight of the fruits during most of the picking, which results are similar to other researchers (Donas-Ucles et al., 2014; Campesco-Montejo et al. 2018; Sarswat et al., 2020).

3.4. The size distribution of fruits

Regarding the size distribution of **white conical type** fruits, grafting had a positive effect on the proportion of first class fruits in both growing media in the studied years, and the use of both rootstocks in soilless cultivation reduced the proportion of calcium-deficient and sunburned fruits **(Figures 5. and Figure 6.)**. Thus I came to the conclusion, that plants were better able to utilize calcium in the medium, thereby increasing the proportion of marketable fruits, similar to the results of Leal-Fernandez et al. (2013).

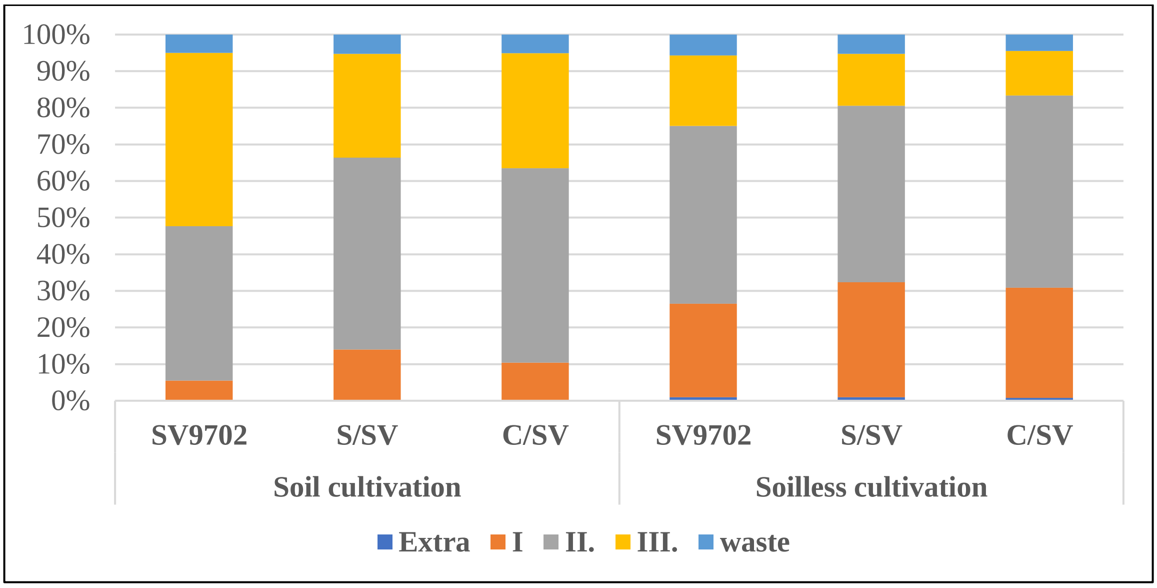

Figure 5. Size distribution of *SV9702* cultivar and its grafted combinations in soil and soilless cultivation - 2016

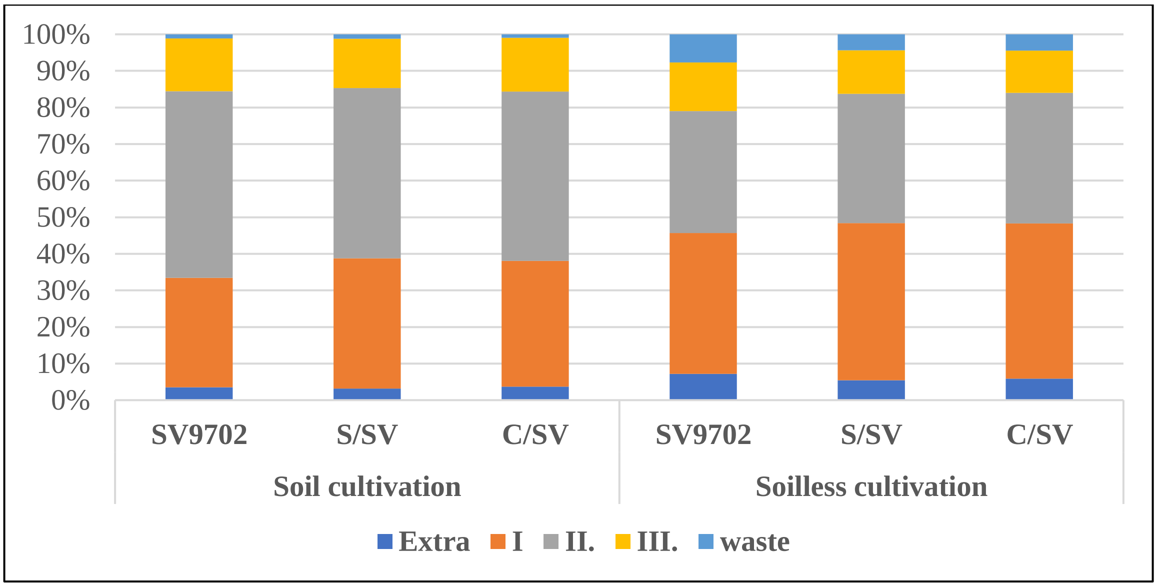

Figure 6. Size distribution of *SV9702* cultivar and its grafted combinations in soil and soilless cultivation - 2017

In the case of the **kapia type**, I found in the soil culture that the proportion of waste, calcium-deficient fruits decreased as a result of grafting, thus supporting the experience of Leal-Fernandez et al. (2013), that grafting has a positive effect on marketable yield. I came to the conclusion that the roots of the plants were able to utilize more calcium from the soil. Furthermore, I observed that the proportion of extra and first class fruits during the two years as a result of grafting was between 60-70%. Due to the appearance of too many sunburned and calcium-deficient fruits on coconut fiber, I suggest changing the nutrient solution formulation **(Figures 7. and Figure 8.)**.

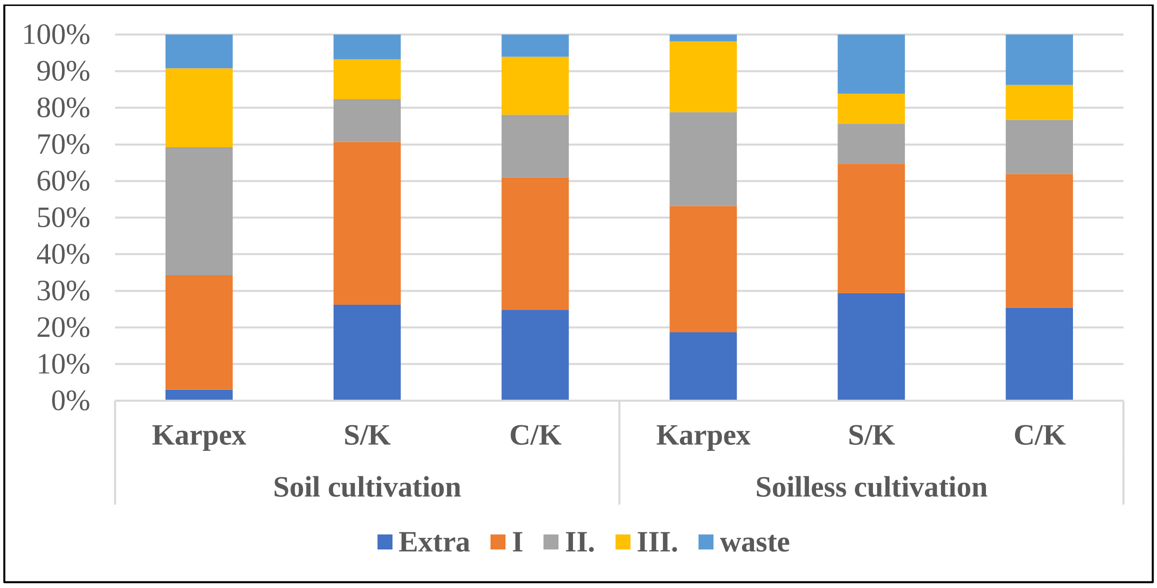

Figure 7. Size distribution of *Karpex* cultivar and its grafted combinations in soil and soilless cultivation - 2016

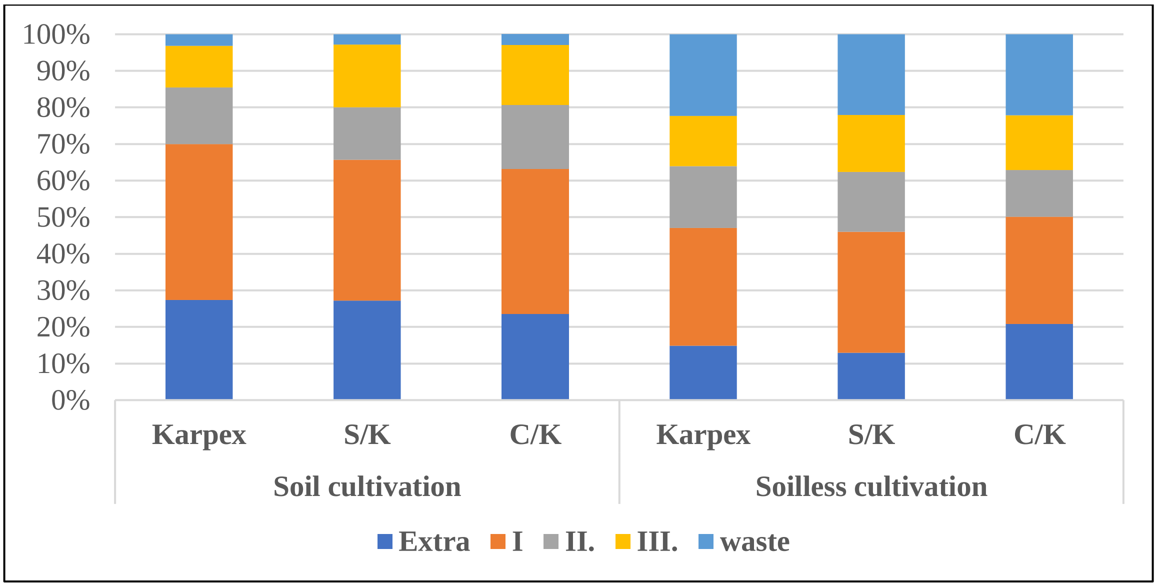

Figure 8. Size distribution of *Karpex* cultivar and its grafted combinations in soil and soilless cultivation - 2017

3.5. Refraction value, titratable acidity and dry matter content

After measurements of refraction value, titratable acid and dry matter content of **white conical type**, I concluded that grafting had no negative effect on these parameters. However, the results measured at different picking times show greater difference.

Regarding the results of refractive value and dry matter content of **kapia type**, I observed a similar tendency in both soil and soilless cultivation, based on which I concluded that there may be a correlation between the two parameters.

After the determination titratable acid content of fruits, I came to the conclusion, that the results measured at different picking times show greater difference, which results are similar to Colla and co-authors (2008).

3.6. Lycopene content

After determining the lycopene content of the **kapia type**, I came to the conclusion during both cultivation that the change of these parameters is more influenced by the different picking times than the treatments.

3.7. Antioxidant capacity

During the measurement of antioxidant capacity, which also plays an important role in maintaining health, I found that *Snooker* rootstock reduced while *Capsifort* rootstock increased the antioxidant capacity of the fruits of **white conical type** compared to the nongrafted control in both soil and soilless cultivation.

After determining the antioxidant capacity of **kapia type**, I came to the conclusion similarly to Chavez-Mendoza and co-authors (2013), that by averaging the data of the examined picking times on both, soil and coconut fiber, both rootstocks increased the measured values.

3.8. Total polyphenols

After determining the total polyphenol content of **white conical type**, which plays an important role in the protection of plants, I concluded that after averaging the values of the three pickings in the different cultivation methods, grafting either increased or decreased these values compared to nongrafted treatment.

During the two years, I got different results for the **kapia type**. In contrast to the results of Chavez-Mendoza et al. (2013) in the 2017 experimental year, both grafting combinations in soil and soilless cultivation increased these values.

3.9. Sensory evaluation

In **both cultivars** sensory examinations reveal, that the choice of appropriate rootstock/scion combination does not affect the quality of the fruits. Furthermore, I refuted the consumer's belief that the content of fruits in soilless cultivation is lower than that grown in soil.

3.10. Economical evaluations

My economic calculations have revealed that grafting technology, due to the increased seedling cultivation costs, does not pay off during cultivation. Similar to the white conical cultivar **(Figure 9.)**, despite the higher cost of cultivation of the soilless system the kapia cultivar **(Figure 10.)** has been also shown to produce higher returns.

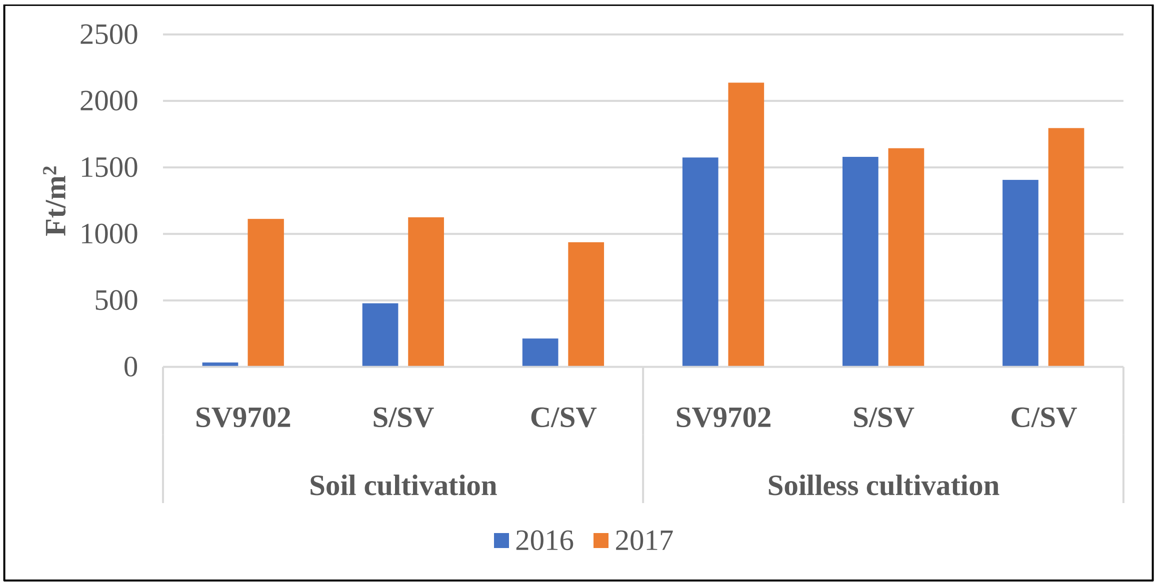

Figure 9. Results of profit calculation of *SV9702* cultivar and its grafted combinations 2016, 2017

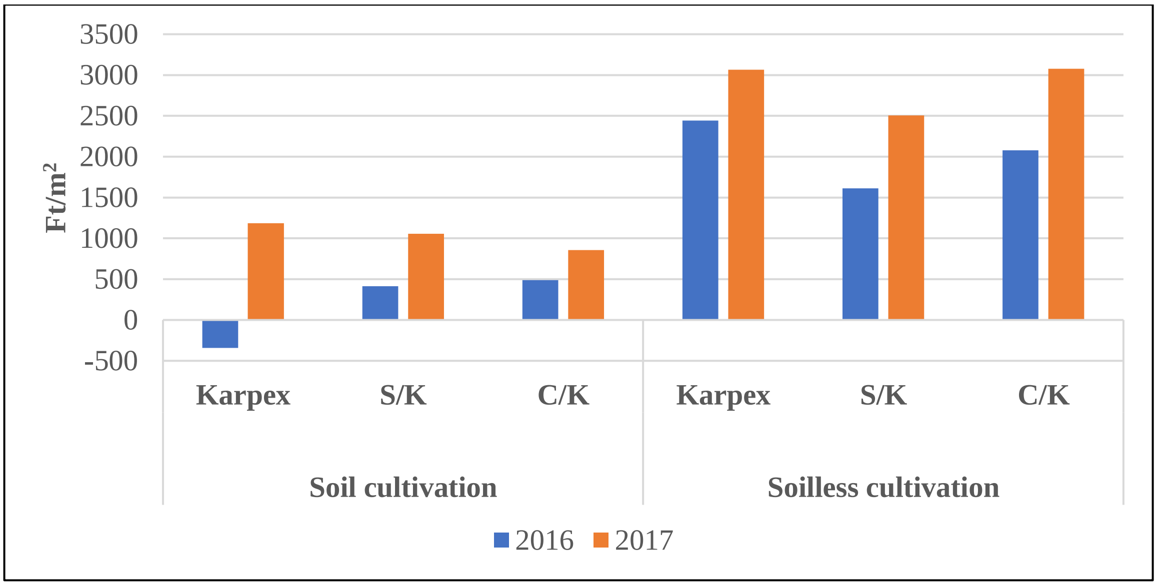

Figure 10. Results of profit calculation of Karpex cultivar and its grafted combinations 2016, 2017

4. NEW SCIENTIFIC RESULTS AND PROPOSALS FOR THE PRACTICE

In 2016 and 2017 based on the evaluation of my grafted sweet pepper experiment I formulate the following new scientific results:

1. In the case of white conical type *SV9702 PP* F1 cultivation in soil, I found that grafting increases the earliness (higher yield during the first harvest).
2. My two-year results showed that grafting did not increase the yields of the studied sweet pepper cultivars (*SV9702 PP* F1, *Karpex* F1) in all cases, as in the case of other vegetable species (field watermelon and melon, sprouted long-grown tomatoes), where it was scientifically proven that grafting can double the yield per square meter.
3. My laboratory tests confirmed that grafting does not decreases the inner content of the two tested cultivars of sweet peppers (*SV9702 PP* F1, *Karpex* F1).
4. Our sensory examinations confirmed that the judges could not distinguish between the texture and taste of the fruits of grafted and nongrafted and those grown on soil and coconut fiber. With this, I refuted the consumer misconception that fruits produced in soilless cultivation have a weaker inner content.
5. The economic calculations of nongrafted and grafted sweet pepper cultivation have shown that the increased costs of seed and seedling resulting from grafting cannot be recouped in unheated plastic tunnel cultivation in a way that is more economical than growing on own roots.
6. My experiments have shown that after several years of monoculture cultivation, switching to a simpler soilless system in unheated plastic tunnel can generate a higher income than growing grafted plants on soil.

Based on the sweet pepper grafting experiments carried out in 2016 and 2017, I formulated the following suggestions and conclusions for the practice:

1. In soil cultivation for both cultivars (*SV9702, Karpex*) I recommend the use of *Snooker* rootstock in order to increase crop safety.
2. In the case of white conical type *SV9702* both rootstocks (*Snooker, Capsifort*) had a positive effect on earliness in soil cultivation.
3. Based on my results, I came to the conclusion that grafting does not decreases the quality parameters of the studied cultivars.

4. Sensory evaluation has shown that grafting has no negative effect on the taste and texture of the fruits.
5. Consumers cannot distinguish between crops from the two cultivation methods, so it may be worthwhile to switch to a simpler soilless cultivation with higher incomes.

5. PUBLICATIONS FROM THE SUBJECT OF THE DISSERTATION

Journal articles with impact factor

Birkás Z., Balázs G., Kókai Z.: Effect of grafting and growing media on the choosen fruit quality compounds and sensory parameters of sweet pepper (Capsicum annuum L.) Acta Alimentaria (in press) (IF:0,570)

Ombódi A., Csorbainé Gogán A., Birkás Z., Kappel N., Morikawa C. K., Koczka N., Posta K. (2019) Effects of Mycorrhiza Inoculation and Grafting for Sweet Pepper (Capsicum annuum L.) Crop Under Low-Tech Greenhouse Conditions. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 47: 4 p. 1238-1245. Paper: 11641 (IF:1,168)

In reviewed article

Birkás Z., Terbe I., Mészáros M., Werner Á., Balázs G. (2017): Alanyhasználat hatása a fehér típusú étkezési paprika hajtatásban. Kertgazdaság 49 (1): 3-8.

Birkás Z., Balázs G., Füstös Zs., Ruszthi A., Kókai Z. (2017): The effect of growing system and growing media on the morphological, biological and sensory quality of sweet pepper (*Capsicum annum* L.). Journal of processing and energy in agriculture. (ISSN 1821-4487) p. 97-100.

Kerek M., Birkás Z. (2018): A szabadföldi paprika növényvédelmi technológiája. Növényvédelem 79(8): 341-352.

Kerek M., Birkás Z. (2018): A hajtatott paprika növényvédelmi technológiája. Növényvédelem 79(5): 204-214.

Conferences („full paper”)

Birkás Z., Terbe I., Mészáros M., Balázs G. (2016): Effect of rootstock on refraction of forced fresh pepper (Capsicum annum L.). Rewiew on agriculture and rural development. Hódmezővásárhely, 2016. május 18. (ISSN 2063-4803) p. 143-147.

Birkás Z., Terbe I., Mészáros M., Balázs G. (2016): The effect of grafting on the quantitative and qualitative parameters of fresh pepper. XVI. EUCARPIA Capsicum and Eggplant Meeting, Kecskemét 2016. szept. 12-14. (Proceedings) (ISBN 978-615- 5270-27- 7) p. 355-358.

Birkás Z., Németh Dzs., Balázs G., Fekete K., Kókai Z. (2019): Sensory quality and chemical composition of different types of sweet pepper (*Capsicum annuum* L.) hybrids. In: Jakab, Gusztáv; Csengeri, Erzsébet (szerk.) XXI. Századi vízgazdálkodás a tudományok metszéspontjában: II. Víztudományi Nemzetközi Konferencia Szarvas, Magyarország : Szent István Egyetem Agrár- és Gazdaságtudományi Kar, (2019) p. 251-257. Paper: 978-963-269-808-3

Summaries from conferences („abstract")

Birkás Z., Balázs G., Ketata M. A., Slezák K. (2019): Effect of water stress on physiological parameters of sweet pepper In: Kende, Zoltán; Bálint, Csaba; Kunos, Viola (szerk.) 18th Alps-Adria Scientific Workshop : Alimentation and Agri-environment : Abstract book Gödöllő, Magyarország : Szent István Egyetem Egyetemi Kiadó, p. 28-29.,

Other scientific articles

Birkás Z. (2016): Az oltott paprika termesztésének sajátosságai egy kísérlet példáján. Agrofórum. 27 (6): 134-135..

Birkás Z., Balázs G., Nagy S., Kappel N. (2017): Paprika és tojásgyümölcs oltási kísérletek. Zöldség-Gyümölcs Piac és Technológia 21(1): 26-27 p.

Birkás Z., Kerek M. (2018): Az étkezési paprika növényvédelme. Agrofórum 29 (1): 34-36

Birkás Z. (2020): Alkalmazott oltásmódok a zöldségtermesztésben. Agrofórum 31 (2): 182-185.

6. LITERATURE

1. BARRETT, D.M, ANTHON, G. (2001): Lycopene content of California-grown tomato varieties. *Acta Horticulturae*, 542, 165-173. p.
2. BENZIE, V.F., STRAIN, J.J. (1966): The Ferric Reducing Ability of Plasma (FRAP) as a measure of „antioxidant power": The FRAP essay. *Analytical Biochemistry*, 239, 70-76. p.
3. CAMPESCO-MONTEJO, N., RoOBLEDO-TORRES, V., RAMIREZ-GODINA, F., MENDOZA-VILLARREAL, R., PEREZ-RODRIGUEZ, M.A., CABRERA-DE LA FUENTE, M. (2018): Response of bell pepper to rootstock and greenhouse cultivation in coconut fiber or soil. Agronomy, 8 (7): 111 p.
4. CHAVEZ-MENDOZA, C., SANCHEZ, E., CARVAJAL-MILLAN, E., MUNOZ-MARQUEZ, E., GUEVARA-AGUILLAR, A. (2013): Characterization of the nutraceutical quality and antioxidant activity in bell pepper in response to grafting. *Molecules*, 18, 15689-15703. p.
5. COLLA G., ROUPHAEL Y., CARDARELLI M., TEMPERINI O., REA E., SALERNO A., PIERANDREI F. (2008): Influence of grafting on yield and fruit quality of pepper (Capsicum annuum L.) grown under greenhouse conditions. In IV International Symposium on Seed, Transplant and Stand Establishment of Horticultural Crops. *Translating Seed and Seedling*, 782, 359-364. p.
6. DONAS-UCLES, F., DEL MAR JIMENEZ-LUNA, M., GONGORA-CORALL, J., PEREZ-MADRID, D., VERDE-FERNANDEZ, D., CAMACHO-FERRE, F. (2014): Influence of three rootstocks on yield and commercial quality of "Italian Sweet" pepper. *Ciência e Agrotecnologia*, 38 (6): 538-545. p.
7. ERDEY-GRÚZ, T. (1965): Fizikai kémiai praktikum. Tankönyvkiadó, Budapest
8. ERGUN, V., AKTAS, H. (2018): Effect of grafting on yield and fruit quality of pepper (Capsicum annum L.) grown under open field conditions. *Scientific Papers, Series B, Horticulture*, 62, 463-466. p.
9. FRUITVEB (2019): A zöldség és gyümölcs ágazat helyzete Magyarországon
10. ISO 11035:1994 Sensory analysis – Identification and selection of descriptors for establishing a sensory profile by a multidimensional approach.
11. ISO 13299:2003 Sensory analysis – Methodology – General guidance for establishing a sensory profile.

12. ISO 8586:2012 Sensory analysis – General guidelines for the selection, training and monitoring of selected assessors and expert sensory assessors.
13. KONG-SANG, L. (2008): Grafting of sweet pepper on hot pepper (Capsicum annuum L. var. annuum) and their effects in plant growth. National Digital Library of Thesis and Dissertations in Taiwan
14. LEAL-FERNÁNDEZ C., GODOY-HERNÁNDEZ H., NÚÑEZ-COLÍN C.A., ANAYA-LOPEZ J.A., VILLALOBOS-REYES S., CASTELLANOS J.Z. (2013): Morphological response and fruit yield of sweet pepper (Capsicum annuum L.) grafted onto different commercial rootstocks. *Biol. Agric. Hortic.*, 29, 1-11. p.
15. MERCK & CO. (1989): Merck index, 11th edition, Rahway, New Jersey, USA, 884. p.
16. MSZ ISO 2429:1980
17. MSZ ISO 3619:1983
18. SADLER, G., DAVIS, J., DEZMAN, D. (1990): Rapid extraction of lycopene and b-carotene from reconstituted tomato paste and pink grapefruit homogenates. *Journal of Food Science,* 55, 1460-1461. p.
19. SAPORTA, R., GISBERT, C. (2013): Grows and fruit production in pepper grafted on *Capsicum annuum, Capsicum baccatum* and *Capsicum pubescens* genotypes. Proceedings of the XV EUCARPIA Meeting on Genetics and Breeding of Capsicum and Eggplant 2-4 September 2013, Torino – Italy 641-644. p.
20. SARSWAT, S., KUMAR, P., SHARMA, P., THAKUR, V. (2020): Standardization of robotic grafting in bell-pepper (*Capsicum annuum* L. Var. *Grossum* Sendt.). *Int. J. Curr. Microbiol. App. Sci.*, 9 (3): 1410- 1418 p.
21. SINGLETON, V.L., ROSSI, J.A. (1965): Colorimetry of total phenolics with phosphomolibdic- phosphotungistic acid reagents. *American Journal of Enology and Viticulture,* 161, 144-158. p.