SZENT ISTVÁN UNIVERSITY

THE EXAMINATION OF CALCIUM DEFICIENCY DEVELOPMENT AND DEFICIENCY SYMPTOMS IN PEPPER PRODUCTION

Doctoral (PhD) theses

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Doctoral School approval	Supervisor's approval

1. SCIENTIFIC BACKGROUND, OBJECTIVES

Today in Hungary pepper is grown under intensive conditions, which takes place in pepper forcing facilities equipped with the most modern technologies. Among the vegetables the intensive cultivation of sweet pepper (Capsicum annuum L.) means about 50% of the Hungarian vegetable production on approximately 2000 ha. Annually 150 to 175 thousand tons of sweet peppers are harvested on this area. Apart from this, Hungary cannot contribute considerably to the pepper production and sale in the EU.

Out of the member states, the Netherlands, Italy and Spain are the three biggest exporters. In Hungary 10-12 kg of peppers is consumed per person each year. This quantity is less than we produce, so the country can produce for export. Nearly all the major pepper-growing European countries produce peppers predominantly intensively, in a so-called “without soil” greenhouse. In the Netherlands an average of 25-28 kg/m2 pepper is harvested during 10-11 months as a result of a so called “long-cultured” pepper forcing. This allows for a continuous export all the year round.

Hungarian pepper production has been very unsettled since 2004; the country harvests much more sweet peppers than they sell on the EU markets. It is an encouraging phenomenon, however, that in recent years in several countries in Asia a very high level of interest in Hungarian peppers has been experienced. In Japan, forcing the Hungarian tomato-shaped paprika could be spread; several Asian companies would be willing to purchase the pepper seed as well as fresh pepper, and also to process them. Establishing a cooperation to breed peppers could be a breakout point for current Hungarian pepper production.

Hungarian sweet peppers should stand out from those in the European market in several respects so that they will be able to be present on Asian markets on the long run. In addition to the Ca-utilisation properties of the Californian pepper created during my hybrid breeding work, I also considered the earliness, the100 g bell-weight, the high fructose content and the sweet taste as important aspects. I wanted to improve the marketability of this type, the bright colour of the pepper bells, as well as the easy pickability and the good stand of the bells.

1.1. Objectives

- To explore the plant physiological role and importance of Ca^{2+} in pepper production;

- To define precisely and examine the tissue harm on pepper bells evolving as a result of calcium deficiency;

- To reveal and analyse the complex of the ecological and production technology factors leading to Blossom-end rot;

- To explore the endogenous plant factors responsible for the Ca^{2+} uptake and translocation ability of peppers and the inheritance of these properties in new pepper generations;
- To improve the Ca^{2+} uptake and transport through the production of hybrids;

- To examine the safe growth of the new pepper generation in different soil lime content ($CaCO_3$);

- To examine the effect of root-stock use with regard to the Ca^{2+} absorption and translocation abilities as well as seed production of peppers.

2. MATERIAL AND METHOD

2.1. The plants of the experiments and examinations

I examined the causes of calcium deficiency development with regard to production technology problems and different production media in pepper hybrids of Emese F_1 and Cecei fehér F_1 types, which are continuously growing, white, long funnel-shaped peppers used for stuffing.

The Tokyo hybrid was created by crossing two different types of peppers. The mother line was a tomato-shaped, open-pollinated pepper in Szentes (PAZ), while the pollen-giving was the Torkál F_1 Californian hybrid.

- The PAZ is a tomato-shaped pepper originating from free-range selection. The colour of the bell is changing from green to deep red. It has determinate growth and relatively large foliage. 83% of the flowers are pendulous, 13% stand aside, while 4% stand upwards. PAZ bells are susceptible to *Botrytis cinerea*. They are also sensitive to the appearance of the symptoms of calcium deficiency.
- The Torkál F_1 is a Californian type hybrid created by plant breeding and suggested for free-range production. The bell is pendulous, with thick wall, changing from green to deep red. The flowers are 100% pendulous. It is a hybrid with determinate growth, strong root system, and relatively large foliage. The bells are not susceptible to *Botrytis cinerea* or the appearance of the symptoms of calcium deficiency.
- Considering the root-stock effect I used Tm0; HR= PVY 0,1,2,; Pc rezisztens Snooker root-stock.

2.2. The date and venue of the experiments and examinations

During the analysis of the development of calcium deficiency I examined the hybrid peppers on rock wool, soil as well as perlite; I carried out my examinations at the vegetable production site of DABIC Ltd in Szentes and Kirshe Ltd in Kiskunmajsa during the summer production periods between 2007 and 2009. The selection before the hybrid breeding was carried out at the pilot production site of Agrohobby Ltd in Nagymegyer, Slovakia and also at the vegetable production site of DABIC Ltd in Szentes. The production (breeding) of hybrids took place under isolated circumstances in a tent made of Rashel-net at the vegetable production site of DABIC Ltd in Szentes in the summer of 2007.

The Tokyo hybrids were taken into the experiments in private gardens with different soil types and $CaCO_3$ content in Szentes, Ópusztaszer, Magyarbánhegyes and Mórahalom in the summer forcing period of 2008. I made test production on two sites abroad in the summer of 2009: on the horticultural pilot farm of the Nihonnouken Center Agricultural Research Institute in Hitachinaka and on the Horticultural Pilot Farm of the University of Osh, Kyrgyzstan.

The microscopic examination of the Ca2+-deficiency of the bells as well as the tissue damage resulted from sunburn were examined in the laboratory of the Cereal Research Institute, in Szeged with the help of the staff of the Institute.

The determination of the calcium content of the examined, biologically mature bells was performed in the laboratory of the University of Szeged, Faculty of Agriculture continuously, from 2006 onwards. The nutritive value (vitamin C, carotene, fructose, glucose) of the bells of Tokyo hybrid and the parent components were examined in the laboratory of the Hungarian Food and Nutrition Sciences Institute (OÉTI) in co-operation with the staff of the Institute.
The carbohydrate (sugar) – was determined after a short hydrolysis, measuring reducing sugars titrimetrically (Schoorl method). Vitamin C was measured by HPLC method. A rapid spectrophotometric procedure was performed to determine carotenoids.

The root-stock change of peppers was carried out in the greenhouse of the Grow-Group Plantgrowing Ltd in Felgyő..

I examined the properties of the Tokyo hybrid and the parental lines with regard to bell-weight (g), the thousand seed weight (g), the thickness of the bell walls (mm), growing time (day), and their susceptibility to grey mould *(Botrytis cinerea)*.

To examine the root stock effect of the peppers concerning the Ca^{2+} absorption and translocation ability the simple matching method was applied to graft the rootstock and the breed.

To determine the factors having a role in Blossom end rot development a Pearson's correlation model has been set up. For further statistical analyses a linear model examination and a multi-factor analysis of variance was used with the help of the staff of the Horticultural Technology Institute of Szent István University.

3. RESULTS AND EVALUATIONS

3.1. Blossom end rot tissue examination

The examination of the Blossom-end-rot-damaged bells was set up mostly on the basis of visual plant diagnosis. During the summer forcing period, however, the Blossom-end-rot symptoms often appear as different-colour patches. Most of the white Blossom-end-rot bells appeared at the lower parts of, where high air temperature and relatively low humidity (70%) was measured. The brown Blossom-end-rot bells, by contrast, appeared in plastic tunnels where the internal temperature was 35-40 ° C and a humidity often exceeding 90% was registered. The analysis of the anatomical damage, however, could be accurately located and determined by microscopic examination.

On the basis of the comparison of 20-fold magnification of 0.5 mm thick cross-section slices of the intact and damaged bells under light microscope we can conclude that the Ca^{2+} deficiency causes irreversible tissue damage in the pepper resulting in deep, crater-like brownish necrosis of the pericarp. Inside such pepper bells grey mould appears very often, which is caused by Botrytis cinerea fungus penetrating the necrotic tissue then developing flaky, greyish-coloured growths conidia. The white spots cause the irreversible damage to the epidermis; they are epidermis caused by the sudden change in weather and strong sunshine. Under the damaged tissues the cells remain intact; they do not lose their turgor status.

3.2. The results of evaluating the ecological factors causing Blossom end rot

In the pepper forcing period in the summer of 2007 the Blossom-end-rot-symptoms on the bells were determined on the basis of visual plant diagnosis at the time of selection. The examinations were carried out in two plastic tunnels, each 9 m wide and 100 m. On the growing area the temperature and humidity were measured every hour during the critical period. The changes of the air temperatures inside the tunnels as well as the temperatures of the rock wool cubes and rock wool blanket at the harvest period are shown in Figure 1. The measurement results show that at the end of March and in April the air temperature was below 25 º C, while the wool blanket and the soil temperature was between 15-20 º C.

This temperature is close to optimal conditions provided for the development of sweet pepper. Subsequently, at the end of April an intense warming period followed, which determined the temperatures of the active root zone and that of the greenhouses.

With the linear regression analysis concerning the appearance of Blossom end rot pepper bells due to the rising temperature of the production media justified the fact that the temperature rise is in rock wool cubes and rock wool blanket had a greater effect on the development of Blossom end rot than the air temperature in the plastic tunnels.

The 35-40 ºC in the first and second decade of May significantly hindered the development of the crop, and the Ca^{2+} absorption and translocation ability of the root system. After the fourth harvest (from May 25th onwards) the growing places were covered with a Rashel-net in order to reduce the excessive warming, which improved the heat balance of the soil, but not the rock wool blanket. The lowest temperature of rock wool blanket was 25 ºC, while the highest was 30 ºC. Both values showed significant differences (4-5 ºC difference) compared to that of the soil.

A positive correlation was found between the temperature rise of the growing place and the quantity of Blossom end rot bells after the warming up in June. The above 20 ºC daytime temperature warmed up the rock wool blanket, which inhibited the Ca^{2+} absorption ability of the root. It also played a role in the growth of the volume of Blossom end rot bells. When assessing the effect of temperature, the number of Blossom end rot bells was compared to the average temperature of the period before harvest, which meant 12.5 bells % in case of soil, while 36.3 bells % in case of rock wool.

This value was obtained on the basis of the production data in the months of May and June (Figures. 2-3.). When selecting pepper bells following the harvest it was found that the number of Blossom end rot pepper bells compared to all the harvested crop remained averagely between 5-10% in case of soil, but in case of rock wool it was 31-34%, which means very serious economic loss.

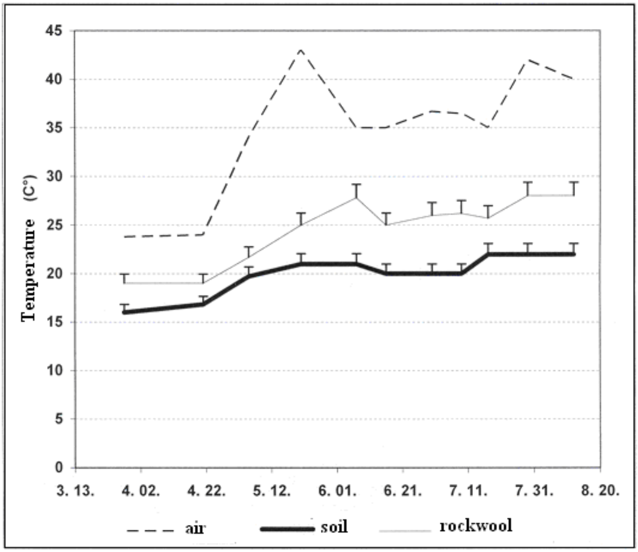

Figure 1 The temperature of the air and the root zones during harvests in 2007

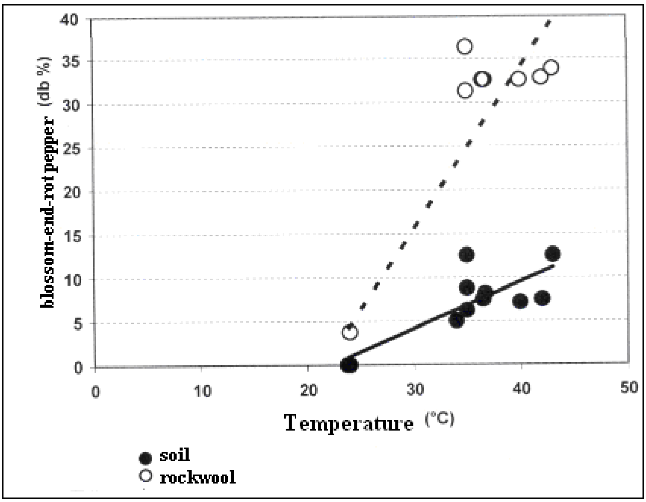

Figure 2. The effect of air temperature on the quantity of Blossom-end-rot pepper bells Szentes, 2007

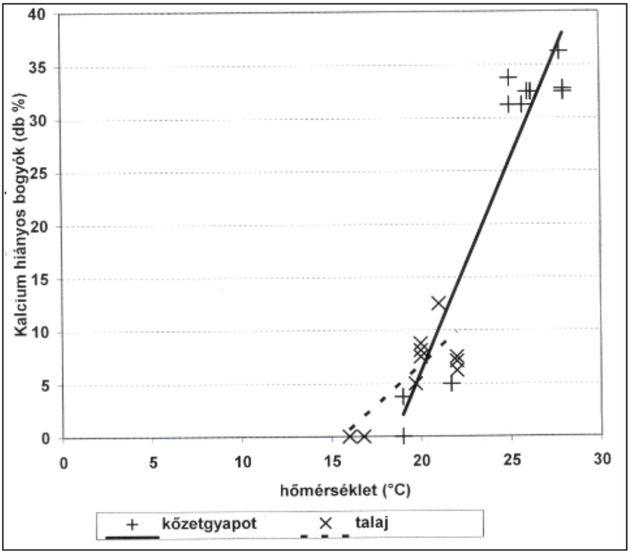

Figure 3. The effect of root-zone temperature on the quantity of Blossom-end-rot pepper bells in the two examined production media
Szentes, 2007

The research results of the forcing a period, however, did not contain sufficient measurement data appropriate in every respect, therefore I thought it wise to continue investigating the problem considering other production technology factors during the summer pepper forcing periods in further years.

The results the summer forcing period of 2007 and also that of 2008 and 2009, together with the observations made during 69 harvests were modelled with Pearson's correlation analysis (Table 1). The three-year test results showed that the quantity of Blossom end rot bells in the summer forcing period was mostly affected by the root zone temperature and air humidity. The internal temperature of the production site, which was warmed up by external radiation, had an impact on the calcium absorption and translocation, but only to a lesser extent.

Table 1. The results of the Pearson correlation analysis based on the data of three years

(n=69)

	Bells with calcium deficiency (%)	**Root zone temperature (°C)**	**Internal temperature (°C)**	**External temperature (°C)**	**Humidity (%)**
Bells with calcium deficiency %	1	,675(**)	,504(**)	,451(**)	,608(**)
Root zone temperature	,675(**)	1	,849(**)	,789(**)	,432(**)
Internal temperature	,504(**)	,849(**)	1	,892(**)	,484(**)
External temperature	,451(**)	,789(**)	,892(**)	1	,282(*)
Humidity	,608(**)	,432(**)	,484(**)	,282(*)	1

**** Correlation on level 0.01**
*** Correlation on level 0.05**

3.3. The results of hybrid breeding

As the results summarized in the autumn of 2009 show no Blossom end rot symptoms appeared on Tokyo hybrid bells in any production area. So on the 12 investigated plants I could not identify the symptoms of Blossom end rot. Based on the diagnostic results of the mother plant PAZ bells harvested in six different production areas we could observe that Blossom end rot was not characteristically present in the bells during the first and second harvest.

In the further stages of production, however, especially in the months of June and August, different size patches of calcium deficiency could be seen on the PAZ pepper bells in each of the production sites. As for the frequency of the Blossom end rot symptoms of the harvested PAZ pepper bells, with regard to the soil lime content of the various production sites, significant differences of $p = 0.1\%$ level were observed. The highest percentage of occurrence of Blossom end rot bells (68.8% ± 18.8) was in Japan. This was followed by Szentes (54.2% ± 17.9), Bánhegyes (46.4% ± 17:3), Ópusztaszer (31.3% ± 11.3), Mórahalom (27.1% ±12.9), and finally, Kyrgyz (14.6% ± 16.7) sampling results.

The frequency of calcium deficiency of pepper bells grown in sites with the lowest $CaCO_3$ content was significantly higher on $p = 0.1\%$ level in Japan than Mórahalom, Szentes and Kyrgyzstan, which was on $p = 1\%$ level different from the results of Bánhegyes. In cases of pepper bells grown in Szentes and in Japan there was no significant difference. In PAZ pepper bells grown in sites with the highest $CaCO_3$ content in Kyrgyzstan, calcium deficiency appeared on $p = 0.1\%$ level significantly less frequently than in case of peppers grown in

Japan, Szentes and Bánhegyes. The peppers tested in Kyrgyz and Mórahalom production sites did not differ significantly from each other.

Among Hungarian observations, in case of PAZ pepper bells grown in Szentes calcium deficiency was extremely high. The gathered results based on a visual survey showed that the incidence of Blossom end rot in Szentes was significantly higher p = 0.1% level than in Kyrgyzstan and Mórahalom. However, there was no critical difference compared to the bells tested in Bánhegyes and in Japan.

Table 2. The percentage of Blossom End Rot appearance on PAZ bells regarding the$CaCO_3$ levels of the production sites in 2008 and 2009

	Average values	Deviations	Significance levels		
			Production site	**t-value**	**Significance level (P %)**
JAPAN	**68,75**	**12,9**	**Szentes**	**1,96**	**ns**
			Bánhegyes	**3,01**	**1 %**
			Ópusztaszer	**5,05**	**0,1 %**
			Mórahalom	**5,61**	**0,1 %**
			Kyrgyzstan	**7,30**	**0,1 %**
SZENTES	**54,17**	**17,9**	**Bánhegyes**	**1,04**	**ns**
			Ópusztaszer	**2,53**	**5 %**
			Mórahalom	**3,65**	**0,1 %**
			Kyrgyzstan	**5,33**	**0,1 %**
BÁNHEGYES	**46,43**	**17,3**	**Ópusztaszer**	**2,04**	**5 %**
			Mórahalom	**2,61**	**5 %**
			Kyrgyzstan	**4,29**	**0,1 %**
ÓPUSZTASZER	**31,25**	**11,3**	**Mórahalom**	**0,56**	**ns**
			Kyrgyzstan	**2,25**	**5 %**
MÓRAHALOM	**27,8**	**12,9**	**Kyrgyzstan**	**1,68**	**ns**
KYRGYZSTAN	**14,58**	**16,7**			

ns = not significant

critical value: p 0,1% = 3,43; p1% = 2,65; p5% = 1,99

3.4. The results of root stock use on the total calcium content of the mother plant PAZ and on the Tokyo hybrid

Following root stock use, the calcium content of the Tokyo hybrid pepper bells harvested at four different times in a state of full biological maturity improved. On comparing the total calcium content of the bells of the two types a significant difference was found. The total calcium value of the two plant crops measured in 48-48 bells differed from each other by almost 60% (Table 3), namely the Tokyo hybrid with that much less calcium developed healthy, intact bells. However, no symptoms of Blossom end rot appeared on the harvested bells of either type, however, in case of neither type was not seen for a variety of formation.

The quality parameters of the PAZ bells did not exceed the values of the Tokyo hybrid bells even when a root stock was used, but better results were reached than in case of PAZ bells grown on their own roots. The root stock did not influence the length of the growing season. Probably due to the better calcium absorption ability the seed growing of bells has improved. During the test production in the period preceding the root stock use an average of 70 healthy seeds grew in a PAZ bell, while after using the root stock it increased to 90. I found 5% dead seeds during both seed tests.

Table 3. The total calcium content (mg/100g) in PAZ and Tokyo hybrid peppers produced on Snooker-root-stock

Total calcium content in peppers	
Tokyo	**PAZ**
67,8	91
68,9	128,9
63,8	108,9
62,8	120,7
Average: 65,8	**Average: 112,3**
Deviation:2,9	**Deviation: 16,4**

4. CONCLUSIONS AND SUGGESTIONS

A complex examination was necessary to find the exact factors leading to the development of calcium deficiency in pepper bells. During the experiments to observe, define and mathematically evaluate the causes leading to Blossom end rot development on plants I examined:

- the extent and impact of environmental factors,
- the physical properties of production media and also the $CaCO_3$ content level,
- the status, maturity and development of roots in the production media and their significance in the development of Blossom end rot,
- the existing and inherited genetic properties of plants with regard to Ca2+ absorption and translocation ability,
- the extent of water balance in the plant and its role Ca2+-ion translocation and absorption.

During the histological analysis of the microscopic cross-section test results of the calcium deficiency in peppers showed that Blossom end rot at the apical part of pepper bells is caused by the absence of Ca^{2+}. Blossom end rot caused by calcium deficiency is an irreversible process, in which the regeneration of damaged cells can not be achieved even by the immediate calcium-containing nutrient refills. However, the increase of $CaCO_3$ content in the soil or in the alimentary medium could not prevent the emergence of the deficiency either, provided the optimal temperature conditions for the peppers are ensured (both air and root zone temperature).

We had different experiences in calcium supplementation during pepper forcing in soil and in rock wool. I found that during soilless pepper forcing on rock wool we had to apply automatically adjusted 100% water-soluble calcium-containing fertilizers otherwise the system may become inoperative due to the blockage. To maintain the $CaCO_3$ concentration in the medium the dolomite powder in the CAN fertilizers proved to be unsuitable. Thus, the ammonium nitrate fertilizer is much more in line with expectations.

In the case of pepper forcing in soil the dolomite powder resolved more easily due to the CO_2 content of the soil, so the CAN fertilizer proved to be perfectly suitable for pepper fertilization and $CaCO_3$ supply but it did not influence the incidence of Blossom end rot in pepper bells.

However, in case of pepper forcing in rock wool, the water used to dilute the medium in the tank C, despite of the resolving effect of the nitric acid, slowed down the dissolution of $CaCO_3$ therefore the use of CAN fertilizer to adjust the calcium concentration in the medium proved to be unsuitable for intensive pepper forcing. In tanks A and B the large, unresolved granules resulted in the blockages of the pipes.

During the summer vegetable forcing period the temperature in the plastic tunnels was often above the optimal level required for organic pepper growing. Due to the internal air temperature increases, the temperature of the growing medium was also easily heated to the temperature, which made it difficult for the roots to absorb Ca^{2+}, or even blocked them. Air temperatures higher than 32 ° C and root zone temperatures higher than 22 ° C were significant factors in the development of Blossom end rot in pepper bells, apart from the growing media.

We found in plastic tunnels in particular that during the summer forcing period (June-August), the humidity rose above 90% due to the outside temperatures of 30-32 ° C, as well as the internal temperatures of 40-42 ° C, which increased the level of the foliage- temperature-radiation of peppers, thereby reducing the ecological conditions in relation to the water balance, and aggravated the nutrient flow. The inhibited nutrient flow, however, could not meet the various degree Ca^{2+}requirement of the cells of pepper bells. The results the tests of peppers grown in different production media that the calcium deficiency in the bells are not exclusively caused by the ecological factors affecting them but also they have a close correlation with the spatial location of the roots and their underdeveloped condition

Ca^{2+} is the most difficult nutrient to carry to plants, therefore if any of the driving forces of transpiration is inhibited, in the nutrient flow, in the plants or crops deficiency will be diagnosed. To achieve a smooth supply of calcium-supply for the bells the highest humidity may not exceed 80-85% in the production area in the critical period. Higher relative humidity than that will hamper the Ca^{2+} absorption and translocation ability of the plant regardless of its location in the production site.

Humidity can be reduced by continuous ventilation. Another important role of ventilation is to reduce the internal temperature in the production site. During the experiments I often observed that in case of forcing on rock wool in the summer period the temperatures were so high that plants were not able to give off enough heat and cool in the evening or at night either. The closed stomata of the plants in the evenings also contributed to it. When the internal temperature in the production site was about 40 ° C during the so-called critical midday period for several days, the root-zone temperature in the growing medium (rock wool cubes and

blankets) grew above the optimal 22 ° C, which hampered the nutrient absorption ability of the root.
Ventilation can only slightly reduce the increased temperature of the rock wool cube or rock wool blanket, mainly because of their plastic cover that would inhibit the air supply as well as the heat emission of the growing medium. Algae colonies are often formed top of the rock wool cubes during pepper forcing, which also hamper the air and CO_2 supply of the medium. In most production sites in Hungary the galvanized metal tanks for nutrients and water are placed inside, therefore the content of solved nutrients in them is also getting warmer together with the rising air temperature inside, because of the thermal conductivity of the material. In my experiments I found that the 20-22 °C nutrient solution was not able to cool the system, and its evaporation was even more intense. In the critical summer period, in rock wool blankets, the adjusted application rate of nutrient solutions reached a daily average of 10 l/m^2.

In case of soil pepper forcing it was observed that besides adequate ventilation the intensive soil-loosening, forking and possibly bed-ploughing as well as irrigation with 18 °C water could keep the root zone of the plant at proper temperature. Thus the roots of the plant developed as characteristic of the species, which supported the micorrhizal fungi as well as the root hair activity and also the absorption of Ca^{2+} and other nutrients.

Significantly better root development and nutrient availability is found in perlite, in case of peppers forced by container technology, where the nutrients were supplied in a similar system as in case of rock wool forcing, but the nutrient solution was dissolved in an insulated container just in the right temperature water. The size of the plastic container provided the space for the development of the root system. The water retention and nutrient-supplying capacity of the perlite, together with adequate climate control provided excellent conditions for pepper forcing. Certainly it does not mean that the security of pepper forcing in rock wool is underplayed by other technologies and it does not contradict the fact that the process of pepper forcing is well-manageable and controlled.

However, attention should be paid that humidity may not fall below 70% in production tunnels and opens sites either, or else sunburn injuries may appear on the pepper bells especially in those areas where there is less shade and the leaves do not provide enough protection against the excessive irradiation. To prevent the appearance of sunburn patches on pepper bells there is a procedure already applied abroad, the kaolin- powder spray treatment. With this treatment not only the intensity of solar radiation on plants can be reduced, but the yield and foliage temperature can also be decreased by 3-4 ° C.

In case of field pepper forcing my experiences confirmed that the furrow irrigation method, or applying soil cover film with drip irrigation system, the proper root zone temperature could be maintained even in the critical hot summer period, the significance of which was confirmed by is the results of the visual plant diagnosis. .

The activity of root-hairs and mycorrhizal fungi is not the only possible way for nutrient absorption. Several studies have demonstrated that calcium can also get into the tissue structures of roots by diffusion, where the Ca^{2+}ion concentration of the soil or the nutrient solution is increased. Its transportation to the bells, however, was influenced by several factors. During my experiments I observed that the smooth transport of nutrients was related to the development of the root system, the water utilisation as well as the level and continuity of transpiration, which feature is characteristic to the breed, so each pepper builds in a different amount of calcium in the tissues to create a healthy bell. This feature of the hybrid is inherited from the parents in all cases.

The biological mechanism process of nutrient translocation depends on the effects of various factors: ecological factors (air temperature, root zone temperature, relative humidity), chemical factors (nutrient solution or soil pH value), meteorological factors (radiation level, wind speed, rainfall) and production technology factors (growing-medium ventilation and shading, root-stock use). Therefore, during pepper forcing the development of Blossom end rot as a consequence of calcium deficiency can be determined by the complex examinations of factors affecting the plants.

Using a function set by the results of the experiments a mathematical order of the plants can be determined considering the Ca^{2+} and translocation ability level. Based on the obtained value and with regard to the ecological factors correlation test can be made on the calcium demand and calcium utilization of peppers. The evaluation results can serve as a base to select the pollinator, which improves the genetic background of the pepper, changing the physical values as well. If you do not want the pepper bells to deviate from the starting (original) material in its form or habits, the function can also be used to breed and select types with improved Ca^{2+} absorption and translocation ability.

The root stock application can facilitate an enhanced Ca^{2+} and other nutrient absorption and utilisation of the hybrid. Similarly excellent results can be achieved by applying the method, as by plant breeding based on selection. In the final stage of trials, however, I experienced, that in the intensive pepper forcing as well as in pepper production on margin soil to achieve the best calcium utilisation the most effective way is to use both options together in practical gardening work.

5. NEW AND NOVEL SCIENTIFIC RESULTS

The following correlation has been detected based on the results of my research in the greenhouses during the summer pepper forcing period, and carried out on special pepper forcing soils under experimental conditions to examine the pepper Ca^{2+} absorption and translocation ability.

1. During pepper forcing, from among the ecological factors affecting the plants, when the root-zone temperature reach a critical value then, regardless of the production media, the Ca2+ absorption and translocation ability is inhibited.

2. The Ca^{2+} absorption and translocation ability is a complex feature depending also on the type, which can be transferred by cross-breeding and bells with good calcium absorption ability can be selected from the following generation, which can develop healthy bells.

3. The Ca^{2+} absorption, translocation and ecological adaptability of the hybrid is significantly better than that of the open pollinated type. The open pollinated type reacts more sensitively to the ecological, nutrient, water and meteorological changes of the land.

4. After crossing the *Capsicum annuum var. california* and the *Capsicum annuum var. lycopersiciforme* peppers the seed production ability of the hybrid generation improved, probably due to the improved calcium utilisation.

5. Based on the visual plant diagnosis we found that the symptoms of Blossom-end rot and sunburn can always be observed on the apical part of the pepper bell, which can be explained by the low level or the lack of calcium supply in the young cell. Such cells are easily destroyed by the intense solar radiation.

6. Regarding the Ca^{2+}-ion uptake and translocation, peppers with high EC-value-tolerant root properties can make significantly better use of the available calcium. It is not influenced by the actual $CaCO_3$ content of the production media.

7. The Ca^{2+}-uptake and translocation ability of the pepper, excluding ion-antagonism and with optimal EC-value, can be modelled with the following multi-factor linear function:

$$\mathbf{Y}_{\mathbf{Ca}^{2+}} = \mathbf{x_1} + \mathbf{x_2} + \mathbf{x_3} + \mathbf{x_4}$$

where:

$\mathbf{Y}_{\mathbf{Ca}^{2+}}$: the Ca^{2+} absorption and translocation ability of the pepper
$\mathbf{x_1}$: root zone temperature (°C)
$\mathbf{x_2}$: internal temperature (°C)
$\mathbf{x_3}$: external temperature (°C)
$\mathbf{x_4}$: relative humidity (%)

PUBLICATIONS IN THE TOPIC OF THE STUDY

Publications in international scientific journals

Lantos, F.- Wachi, Y.- Helyes, L.- Pék, Z.- Tajimamat, E.- Orozaliev, N. (2009): Effect of root zone on blossom-end rot of sweet pepper (*Capsicum annuum L.*) fruits. VESTNIK No. 5. Osh University Kyrgyzstan. pp. 272-277 ISBN 9967-03-030-5.
F. Lantos - K. Mike- T. Monostori- L. Helyes (2010): Evaluation of Calcium Deficiency Symptoms in Sweet Pepper (*Capsicum annuum* L.) Fruits via Visual Plant Diagnosis and Microscopic Examination. Acta Horticulturea **in PRESS.**

Publications in Hungarian scientific journals

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