Scientific Papers. Series B, Horticulture. Vol. LXV, No. 1, 2021
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

STUDY REGARDING THE EVOLUTION OF HIGH-PERFORMANCE CULTIVATION TECHNOLOGIES IN GREENHOUSES AND HIGHT TUNNELS IN ROMANIA

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Abstract

The present study on the evolution of high-performance technologies as well as the evolution of areas with greenhouses and solariums in Romania aimed, in particular, to identify farmers who have adopted high-performance technologies in order to increase tomato production. We identified the high-performance greenhouses in Romania, especially those that grow tomatoes in them. They also identified the areas occupied by greenhouses and high tunnels, cultivated in a soilless system, on substrates or on the ground in some areas of Romania.

Key words*: Romania, greenhouses, tomatoes, soilless, substrate.*

INTRODUCTION

Greenhouse vegetables are a viable alternative to the constant supply of fresh vegetables, demonstrating their effectiveness by using technologies that have proven to meet the challenges of the greenhouse effect and ensure the sustainability of the system.

Numerous studies argue that the protection of vegetable crops is not a new concept, it existed since the Roman Empire during the reign of Emperor Tiberius (14-37 BC) when he consumed cucumbers all year round using a greenhouse-like protection system (Leoni, 1994; Tognoni and Serra, 1994), The first information about heating greenhouses appeared during the Joseon dynasty in Korea in the 1450s, they arrived in America in the 1700s and then in the Netherlands around the 1800s.

After 1960, when polyethylene foil appeared, protected cultures (areas) began to develop and evolve. At present, significant performs have been ensured regarding UV resistance and service life.

Integrated control guarantees the best economic result, and provides a systematic way to design control systems for the innovative greenhouses of the future (Straten and Hente, 2010; Kolokotsa et al., 2010; Doltu et al., 2020; Sora et al., 2019; Sora and Doltu, 2018).

Romania, due to its geographical position has beneficial conditions for obtaining extra-early vegetable crops in greenhouses because during the winter, December - February, it has a light radiation superior to the countries of Western Europe.

Through the studies carried out within the project "Development of the administrative capacity of MCI to implement some actions established in the National Strategy for Research, Technological Development and Innovation 2014-2020", SIPOCA code 27, financed by the Operational Program Administrative Capacity (POCA) it is mentioned that In terms of market performance, the South Muntenia Region achieves 20% of national vegetable production (Tran et al., 2018).

In order to take advantage of this advantage, it is necessary to streamline the technology of protected vegetable crops in Romania, regardless of how they are heated.

If before 1989 the vegetable farms were merged and the properties belonged to the State after this period, the areas were taken over by their owners, thus leading to their fragmentation. Thus, due to the uncertainty of an association, the surfaces remained in fragmented ownership, and it was not possible to conceive the construction of large greenhouse complexes by associating the landowners.

However, recently land has been leased or purchased, which has made it possible to build high-performance greenhouse complexes.

Regarding the areas occupied by greenhouses before 1989, there were 2,460 ha of heated greenhouses, built in all areas of the country that ensured both the domestic market and the export of fresh vegetables (tomatoes, cucumbers, bell peppers, lettuce, greens). Many of them were located both in large, heavily populated urban areas (Bucharest) and near large cities (Codlea - Brașov, Ișalnița - Dolj), Scornicești - Olt, etc.).

Analyzing the territorial distribution of greenhouses, before 1990, they were found in each county, and their areas and number depended on the population of the area but also on the degree of suitability for climatic conditions. The largest areas of greenhouses but also the mode of distribution and specialization of production were found in Bucharest (Popești greenhouses 142 ha) followed by Arad, Timiș, Bihor and Dolj. Also, the favorable areas for the protected cultures (areas) covered with different types of plastics were found, in the largest area, in zone I, (Bihor, Arad and Timiș counties) as well as in the entire southern part of Romania. Thus, the largest areas were found in the counties of Dolj (Ișalnița 200 ha) (Popa et al., 2021), Olt, Teleorman, Giurgiu, Ilfov, Arad, Bihor, Timiș and Galați.

Regarding the production of seedlings intended for covered areas there were sectors in greenhouses, specialized for seedling production but also certain farms specialized in this regard. The ratio between the area of the for seedling greenhouses and that of the heated covered spaces was 1: 5.

If in 1971 in Romania there were only 2 ha of seedling greenhouses and 10 ha of heated solariums in 1976 the surface of seelding greenhouses reached 90 ha and that of heated solariums reached 270 ha (Ceaușescu, 1979).

The evolution of the surfaces occupied by greenhouses or heated solariums according to the recorded statistical data varied from one year to another. Thus, if in 2007 the total area of greenhouses in Romania was 418 ha in 2008 it increased to 668 ha and it will fluctuate year by year in 2015 the area of greenhouses in Romania was 323 ha. In 2016, there was an increase to 431 ha and then to decrease continuously to 250 ha in 2017 to 233 ha in 2018 reaching that in 2019 only 206 ha of greenhouses will be registered (Statistical Yearbook 2020). The motivation for the continuous decrease of heated surfaces is due to both the high costs of heating and their lack of technology. The vegetables obtained in greenhouses were grown in a conventional system, on the ground, being destined for foreign markets.

According to data from the National Institute of Statistics, areas built with greenhouses decreased after 1990 due to both high heating costs.

If we follow the distribution of greenhouses on large cultivating units, according to data recorded in 2012 Hortifruct Association owned an area of 180 ha with greenhouses of which 137 ha located around Bucharest through three production points: Popesti - Leordeni with 90 ha, Berceni with 30 ha and Pipera with 13.5 ha. Another 3.5 ha in Ișalnita are currently fully compromised due to the fact that during the winter they were no longer heated.

An area of about 2000 ha of modern greenhouses would be needed to provide the necessary with vegetables during the year. In present, according to statistical data, 80% of vegetables come from imports.

From 1951-1956 there were conventions for the export of fresh vegetables with some states such as Austria, Czechoslovakia, R.D. Germany also with R.F. Germany (1955-1956) USSR (1956), Hungary (1952), Switzerland (1953-1956) (Stefan et al., 2008).

If in Romania, in 1989, the value of global production was 196,920 million lei, of which 54.4% owned vegetable production (Statistical Yearbook of Romania, 1990, p. 398-399).

According to data centralized by the National Institute of Statistics, in 2019, over 740,000

tons of vegetables were imported, worth 516 million euros. In 2018, imports were 678,000 tons, 62,000 tons lower compared to 2019 with an average price per ton of product of 697.3 euros/ton compared to 625.81 euros/ton in 2018.

The studies regarding the zoning of the vegetable culture started since 1954 and in the period 1956-1961 the Zoning Commission within the Ministry of Agriculture established on the basis of the competent studies the favorable areas for the vegetable cultivation. Currently, Law no. 312/2003 establishes three areas for vegetable production.

There is also the concern for obtaining and marketing quality vegetables, so by Law no. 312/2003, Article 14 prohibits the marketing of both fresh and processed vegetables for human consumption, which contain pesticide residues and heavy metals, nitrates, nitrites or other products, which exceed the maximum permitted levels established by the legislation in force.

If before 1989 the greenhouses were built according to a standard technology, with a height of 4-6 m at the ridge, now in Romania there are companies specialized in the construction of greenhouses or solariums with high-performance professional structures, with or without endowments, heating equipment and installations, drip irrigation, hydroponic systems, fertigation. The constructive variants of the tunnel greenhouses are varied, with vertical side walls and side vents, with vertical side walls, with large volumes and with side vents, with single or double foil, 2.5-3.0 m or 4 m high, with opening of more than 5 m.

As there is also a global demand for vegetables throughout the year, new technologies are being identified to increase the efficiency of vegetable production in greenhouses or solariums.

Worldwide, the area occupied by greenhouses and solariums in 2017 was 489214 ha, of which 173561 ha in Europe, 224974 in Asia, 19790 in America, 36993 ha in Africa (Cuesta Roble Consulting, 2017).

In 2019, the vegetable area in the greenhouse worldwide was 496,800 ha Cuesta Roble World Greenhouse Vegetable Statistics - 2019 https://www.producegrower.com/article/cuesta-roble-2019-global-greenhouse-statistics/

A solution for the efficient use of space is also the construction of vertical greenhouses in all areas of the world, mainly in arid areas and where the requirements for vegetables are high. Although the initial investment and energy costs are high, it is still a challenge to create a viable business based on a vertical farm, where LEDs are used for lighting (Publication date: Fri 26 Feb 2021 Source: freshPlaza.com)

In Turkey, the area occupied by greenhouses in an unconventional system, on substrates was 700 ha (Gruda, 2017).

The prospect of implementing new technologies as well as advanced artificial intelligence and machine learning are the future of maintaining the climate in the greenhouse. Greenhouse automation leads to better economic efficiency and reduced product cost.

In China, a high-tech greenhouse was recently built (Shanghai in eastern China), covering an area of about 56 hectares, using additional artificial LED lighting but also intelligent technologies to control the plant growth environment. it is possible for the huge plant factory to operate non-stop in all seasons (www.news.cgtn.com.).

In the Netherlands, over 90% of the area cultivated with vegetables is represented by substrate crops.

Taking into account that in Romania the areas occupied by solariums in crops in conventional system, on soil, are currently registered 1600 ha, with a view to increasing their areas, in this study we will make an analysis and identification of areas occupied by protected areas in some areas southern Romania as well as the identification of high-performance greenhouses in unconventional system, on different types of substrate or in NFT system.

MATERIALS AND METHODS

The study aimed to identify the areas occupied by greenhouses and solariums in some zones of Romania, especially in the south but also in the center of the country. Some data were taken from the County Agricultural Directorates, APIA, but also from the field analysis. We aimed to:

- identify the areas and the size of the surfaces with heated and unheated protected spaces, by counties;

- identification of the type of construction;
- degree of technologicalization;
- the cultivation system practiced conventionnally or unconventional;
- type of substrate used;
- culture structure and culture cycle;
- the productions obtained.

RESULTS AND DISCUSSIONS

According to data recorded by the Research Institute for Agricultural Economics and Rural Development in 2018, the average annual consumption of tomatoes per capita was 41.4 kg. Starting from the reality that in 2019, 1420 ha of protected surface (areas) were declared in Romania, in order to ensure the Romanian market with fresh vegetables, it is necessary to increase the protected surfaces areas so that according to its program it will reach in 827 to about 8-10 thousand hectares.
In Romania most greenhouses were between 4 and 7 m high (Figure 1).

Figure 1. Appearance of low greenhouses 4 m high and 7 m high in România (original)

Data on the situation of areas declared with protected, by farmers, and beneficiaries of payments managed by APIA (Agency for Payments and Intervention in Agriculture) show that in 2020 there were a total surfaces 2889.2 ha of which 160.76 ha in greenhouse, 1750.28 ha in high tunnels, and 978.08 ha represented other types of protected cultures. By counties the situation is presented in the Figures 2, 3 and 4).

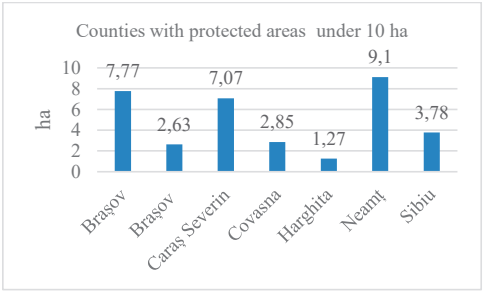

Figure 2. Counties with protected areas under 10 ha from Romania

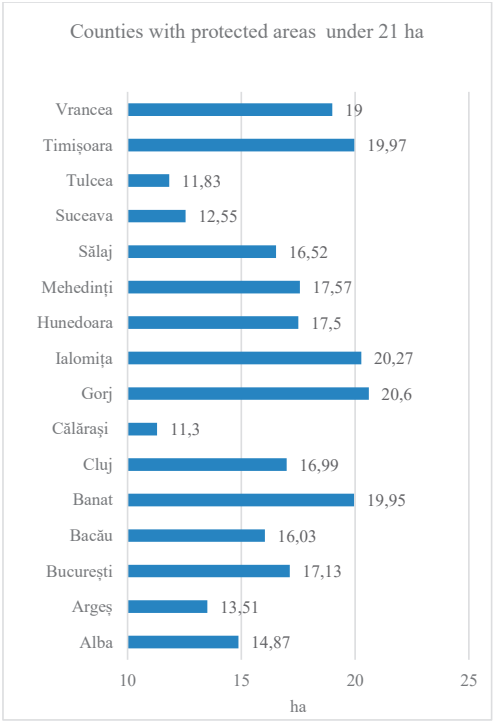

Figure 3. Counties with protected areas over 10 ha up to 21 ha in Romania

In the study we identified a total of 29,548 ha occupied by modern greenhouses that use unconventional technology, on nutrient substrates and 11.4 ha modern greenhouses that use conventional technology, some on the ground being ecologically accredited (Figure 5).

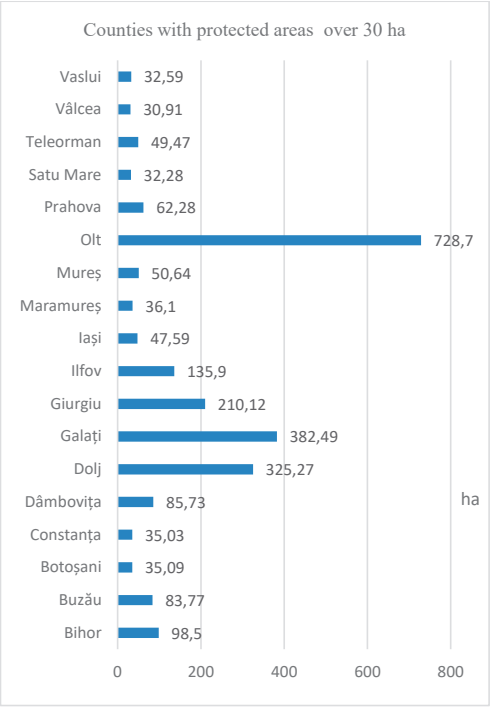

Figure 4. Counties with protected areas over 30 ha

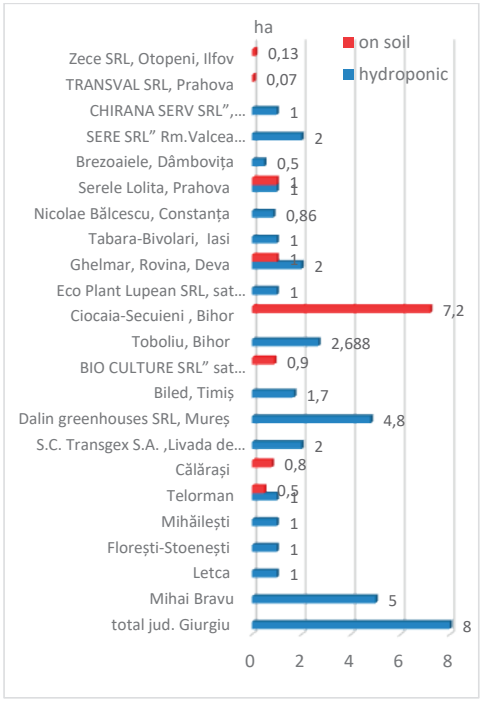

Figure 5. Situation of areas occupied by greenhouses and high tunnels, cultivated in a system without soil, on substrates, or on the ground in some areas of Romania

From the data registered in the documents of the Agricultural Directorates we found that in Giurgiu county the area occupied with unheated and heated solariums was in 2020 of 513 ha of which only 15 ha have a heating system. Of the heated greenhouses, only one has the largest surface of 5 ha, in Mihai Bravu. This is a modern greenhouse that has all the specialized equipment for a greenhouse on nutritive substrates. They grow tomatoes using coconut mattresses as the growing medium.

In three other localities in Giurgiu county, Letca, Mihăilești and Floresti-Stoenești, we had indentify modern greenhouses are built on an area of one ha each. Of these, only the greenhouses built in Floresti-Stoenești are intended for flower crops on substrates.

In the greenhouse from Letca Nouă commune, S.C. Gradina Letca SRL is grown in an unconventional system, on the ground, tomatoes but also other vegetable species, all of which are certified GlobalGAP. These were built through a Project financed with non-reimbursable European funds through the National Rural Development Program (PNDR). (https://letca.ro/produse/).

The greenhouses from Mihăilești distict - *Oxigen Agro Product Company* - from Giurgiu county are modern greenhouses, in cultivation system on coconut substrate. The obtained products have GlobalGAP certification (Figure 6). As for the type of construction, they are tall greenhouses, covered with polyethylene foil.

Figure 6. Greenhouses Oxigen Agro Product Company, Mihăilești, Giurgiu county (original)

The applied technologies at this greenhouses are of the latest generation this being endowed with specific equipment for crops on nutritive

substrates. Coconut mattresses are used as culture substrates. The constructive system is closed, the nutrient solution being recovered and reused. Tomatoes, cucumbers and peppers are mainly grown in the greenhouse. Using modern technologies, the productions exceed the level of the conventional ones on the ground, eeaching over 500 t/ha.

In Teleorman county, we identified as protected surfaces areas on the surface of 57.9 ha, of which only 0.5 ha are heated greenhouses. In these, the classic soil cultivation system is used. According of data from agriculture department (2020) in Călărași county 10.5 ha with solariums are registered, of which only 0.8 ha are heated. And in their case, the technology of unconventional cultivation is practiced, on the soil.

The belief of some private entrepreneurs that, by adopting modern greenhouse cultivation technologies both their production and their quality is much higher compared to the unconventional system led to their adoption on the ground. In the unconventional system, the quality of the products can vary from one week to another, due to the variations of the environmental factors in the culture space. Starting from the fact that in the unconventional system, in Romania, the obtained tomato productions reach only 120-250 t/ha, in extended cycle, but, using the unconventional cultivation system, on nutritive substrates (mineral wool, coconut or perlite), some farmers also obtained yields of 500-650 t/ha.

In Romania, in all areas of the country, there are constantly new surfaces built with modern, heated greenhouses or solariums, which have high-performance equipment. Although some farmers start with constructions on small areas, of about 2500 m^2 or 5000 m^2 but convinced of the efficiency of modern technologies they have expanded their areas from 10,000 m^2 to about 50,000 m^2. According to economic analyzes, modern greenhouse areas under 1 ha are considered family businesses for small farmers. The maximum economic efficiency is felt in the case of greenhouses over 2 ha.

In Ialomița county, in 2020, the company "Green Houses Andrei", built in Sinești commune, a modern greenhouse on an area of 1.2 ha, specific for tomato cultivation, in an unconventional system, without soil, using grodan as a substrate. The seedlings were purchased from Greece (Figure 7).

Figure 7. Greenhouses "Green Houses Andrei", from Sinești, Ialomița county (original)

The greenhouses of the "AnnaBella Group" of Companies "SERE SRL" Râmnicu Valcea, Gradinari have a surface of protected space, covered with polyethylene foil, in an area of 2 ha. In particular, it cultivates cucumbers in an unconventional system, on Grodan substrates (Figure 8).

Figure 8. Appearance from the Greenhouses of the AnnaBella Group of Companies "SERE SRL" Râmnicu Valcea (original)

The greenhouse complex "CHIRANA SERV SRL", from Mihail Kogălniceanu commune, Ialomita county, has an area of 1 ha, fully automated block greenhouse. It specializes in growing tomatoes on nutritive grodan substrates (Figure 9).

Figure 9. Aspect from "CHIRANA SERV SRL" greenhouse, Ialomita county (original)

One of the first modern greenhouses with the largest area in the Bucharest area was built during 2007-2008, in Pipera, on an area of 13.2 ha, and the establishment of the tomato crop, was made in January 2019 on substrate of grodan, This greenhouses construction was made by "Sere com Ro SRL" (Figure 10).

Figure 10. Appearance inside Pipera greenhouses (original)

The Greenhouse Complex of S.C. Transgex S.A. Oradea, from Livada de Bihor, with an area of 2 ha of crops on mineral wool grodan substrates, has been producing tomatoes since 2006 with very good results using geothermal energy, this being unique in Romania.

The yields obtained are over 400 tons of tomatoes per hectare, per production cycle, which meansa harvest three times higher compared to the yield of the classic greenhouse system.

In Reghin, Breaza commune, Mureș country, Dalin greenhouses, initially the built surface was 2 ha but now it has expanded to 4.8 ha. The greenhouse complex was built using Dutch technology. Greenhouses are specific for growing tomatoes on a nutritious grodan substrate. In 2012, yields of 500 t/ha were obtained, but currently they are over 610 t/ha. The greenhouse is equipped with specific technological equipment and the quality of the products is high because they use cultivars with resistance to diseases but also pollination with the help of bumblebees.

For a short time in the Dalin complex was grown lettuce in NFT system on an area of only 2200 m^2 but the farmer thought it better to specialize in one or two species grown on larger areas, as control and efficiency were higher. In the case of salad, the nitrite / nitrate concentration was below the standard maximum limits.

Figure 11. Aspects from Dalin greenhouses, Mureș county (original)

In 2015, a greenhouse was built in a soilless system, covered with plastic foil in Brezoaiele commune, Dambovița county. Initially he used the mineral wool substrate and then other perlite substrates, respectively coconut. The farmer found that the perlite substrate influenced the early growth of the tomato crop, obtaining yields two weeks earlier compared to the use of other types of substrate. The yields obtained were much higher than those of conventional culture, moreover the quality of the fruit was superior. It obtained productions from March to July of 280 t/ha and 372 t/ha, respectively, of which only about 7% was under STAS. Because in the summer the cost price was low, he set up successive crops of

cornichon cucumbers in an unconventional system (Figure 12).

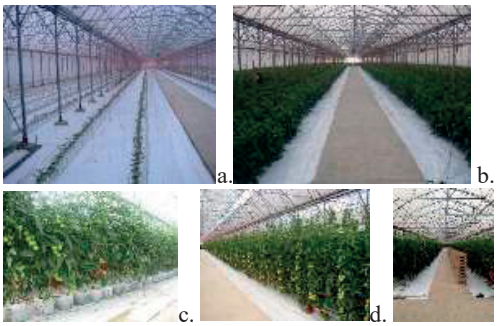

Figure 12. Greenhouse aspect - Brezoaiele, Dambovița county: a. the establishment of culture; b. after 40 days from planting; c. culture on perlite substrate at 70 days; d. culture on coconut substrate at 90 days (original)

In Biled, Timiș county, in 2017 the construction of a greenhouse on an area of 1.7 ha was completed, a greenhouse that has state-of-the-art technologies. In this, tomatoes will be grown on a coconut substrate. The average productions obtained in 2020 were about 550 tons.

In Bihor county, 7.2 ha of greenhouses are built in Ciocaia-Secuieni for tomatoes and cucumbers. The heat source is partially provided by the use of pellets (Figure 13).

Figure 13. Greenhouses Ciocaia-Secuieni, Bihor county (original)

Also, in 2018, in the Bihor commune Toboliu, through a project financed by the Agency for Financing Rural Investments, through the National Rural Development Program (PNDR) L, an investment of over 700,000 euros was built a hydroponic greenhouse for cherry tomatoes on an area of over 2,688 sqm.

The greenhouses "ECO PLANT LUPEAN SRL" located in Sanbenedic village from Alba county have an area of 1 ha, were built in 2010. Tomatoes are grown in a soilless system using nutritive substrates.

In Cluj county, Capusu Mare village, there are "BIO CULTURE SRL" greenhouses with an area of 0.9 ha. The greenhouses are covered with glass, and tomatoes are grown in a conventional system, the soil being organically certified crops (Figure 14).

Figure 14. Appearance inside the greenhouse, "BIO CULTURE SRL", Cluj county (original)

The Corvinia Producers Group has been producing vegetables since 2008 and the “big greenhouses” from Rovina, in an unconventional system, on coconut, perlite and grodan substrates with production over 500 t / ha tomatoes and about 260 t/ha cucumbers. The use as a substrate of mattresses filled with perlite from SC Perlit SA led to an earlier production compared to other types of substrate (Figure 15).

Figure 15. Rovina greenhouses, Deva (original)

Through the National Rural Development Program (PNDR) 2007-2013, Measure 121 - “Modernization of agricultural holdings”, SC SERRA-IVAS SRL implemented between December 2009-December 2013, a project through which a greenhouse was built with heating from sources renewable. Located in Constanța County in Nicolae Bălcescu locality, the greenhouse is built on an area of 0.86 ha,

using mineral wool Grodan as a culture substrate. The obtained production is capitalized in the area starting with March.
Another modern greenhouse on the surface of 1 ha, in system on nutritive substrates is located in Tabara-Bivolari commune, Iași county (Figure 16).

Figura 16. Tabara-Bivolari, Iasi (image from https://www.youtube.com/watch?v=fsIRdbBuRyc)

"Max Central Deposit SRL", is a firm from Brăila county, Village Muchea, county Braila, where is built high tunnel on an area of 0.4 ha, where are grown tomatoes, in a soilless system.
One of the largest hydroponic greenhouse areas, on cultivation tables in the Ebb and Flow system, in the area of 1 ha is found in Prahova County. Lolita Company greenhouses were built in 2011, in Poienarii Burchii commune, Prahova county, with own resources. In addition to the hydroponic greenhouse, cultivated throughout the year with lettuce, the farm has expanded with another 1 ha of solar high in which tomatoes, peppers and other successive vegetables are grown. The greenhouse, due to the specifics of construction and technology, can also be used for the production of seedlings for vegetable farms. The structure of the complex was made by a specialized Dutch company, it is equipped with the most modern heating, climate control, ventilation and shading systems, and the water management is ensured by an irrigation unit with perfect precision which helps to reduce water consumption necessary for irrigation (Figure 17).
And as technologies evolve, in favor of farmers, they invest in the permanent adaptation of the greenhouse.

Figure 17. Appearance of greenhouses Lolita (original)

In Romania there are no farms specialized in producing specific seedlings for hydroponic crops. Grafted or non-grafted seedlings are purchased from Greece or Hungary. In Romania there is a seedling production complex at Fetești S.C. Cox Agricol Farms, S.R.L., which produces about 60 million seedlings, produced in 21 greenhouses.
The interest in securing the market with fresh fruit led to the intensive cultivation of cherries in a glass-covered greenhouse. The surface of the greenhouse is only 0.13 ha belongs to the company "ZECE SRL" and is located in Otopeni, Ilfov County.
The continuous expansion of the new high-performance greenhouses also involves the provision and continuous training of specialists who, by using high-performance technologies to ensure the market with fresh vegetables all year round but also safe in terms of product safety. That is why in the big university centres, high-performance greenhouses have been built through various research programs in which students acquire skills for the use and application of modern technologies. At the same time to ensure a high level research. Among the great university centers we mention:
Greenhouses within USAMV Bucharest, belonging to the Research Center for the Study of Agri-Food Quality with an area of 2752 m^2 (Figures 18 a and b).

Figure 18 a. Appearance from the research greenhouse - tomatoes, pepper, eggplants from USAMV Bucharest

Figure 18 b. Appearance from the research greenhouse - cucumbers, melons and gerbera on perlite substrates also lettuce in NFT from USAMV Bucharest

Research greenhouses within the University of Agricultural Sciences and Veterinary Medicine "Ion Ionescu de la Brad" of Iasi - Greenhouse 1 with an area: about 1200 m^2 for research. With the help of European funds and its own resources, the university has modernized its practice bases so that it is able to face the current challenges of contemporary society. (Figure 19).

Figure 19. The greenhouses from USAMV Iași (original)

University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca has 3 research greenhouses: Research greenhouse 1 with an area of 448 m^2; Research greenhouse 2 with surface of 1413.92 m^2; and Research greenhouse 3 with an area of 636.73 m^2 (Figure 20).

Figure 20. Research greenhouses from USAMV Cluj-Napoca (original)

Figure 21. Greenhouses from SCDL Buzău (original)

Research institutes in Romania also have heated greenhouses or tall solariums for carrying out improvement works. Thus, in Buzau there are research greenhouses on the surface of around 1 ha as well as a vertical greenhouse (Figure 21).

At SCDL Bacău, there are research greenhouses low, covered with glass, with a height of 3.4 m and a width of 3.2 m. There is also a research greenhouse of 3000 sqm and two greenhouses with a total area of 8000 square meter. They also have a multi-tunnel greenhouse, covered with double foil, with an area of 1050 sqm and 6.5 m high and tunnels with a height of 3.8 m. They also have a semi-buried greenhouse with an area of 100 sqm intended for organic farming research, 4.5 m high (Figure 22).

Figure 22. Research greenhouses from SCDL Buzău (original)

CONCLUSIONS

Modern shelters, greenhouses or high tunnels are an alternative to the constant supply of fresh vegetables. High-performance technologies demonstrate their efficiency in obtaining high yields per unit area but also by reducing the greenhouse effect.

In the study I made an analysis on the evolution of protected areas over time and after 1989. I came to the conclusion that in Romania the greenhouse areas covered the country's vegetable needs while also being exported.

After 1989 the areas have decreased from one year to another so that the need for vegetables, especially tomatoes, is covered by imports.
In present, a return to production is being attempted to cover consumption needs. Through the new constructions and high-performance technologies, although the areas with built greenhouses are smaller, the efficiency being much better with the productions high of over 700 t/ha.

ACKNOWLEDGEMENTS

This research work was carried out with the research leading to these results has funding from the Norway Grants 2014, under Project contract no. 40/2021

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