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ENERGY SUPPLY FOR THE PROCESSES OF GREENHOUSE BUSINESS WITH APPLICATION OF RENEWABLE SOURCES OF ENERGY

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Syrotiuk V., Syrotiuk S., Ptashnyk V. Energy supply for the processes of greenhouse business with application of renewable sources of energy
The article stresses that photosynthesis is a basis for the technological process of covered soil constructions used for growing of vegetables and flowers. The process is revealed in transformation of carbon dioxide into a marketable organic substance with oxygen release under the impact of light. Main factors of the production environment were analysed. To perform tasks of the technological process effectively, it is necessary to secure the best-possible levels of such principal parameters as air temperature in the greenhouse; temperature of the air outside (control); temperature of soil in the greenhouse; air humidity in the greenhouse; soil humidity in the greenhouse; concentration of carbon dioxide CO_2 in the greenhouse; concentration of carbon monoxide CO in the greenhouse; level of lighting in the greenhouse; air velocity in the greenhouse. In addition, one has to ensure the continuous monitoring of following aspects: type and the total level of radiation; airspeed outside the greenhouse (control). The work notes that in the structure of production costs of a covered soil construction, a considerable share is taken by costs for energy sources. Hence, the system of energy supply for greenhouse business should be developed with application of renewable sources of energy referring to the approved structural scheme. In particular, it has been shown that the main renewable energy sources suitable for use in a greenhouse are wind and solar. An obligatory element of such energy system includes an automatic system of control for the parameters of greenhouse microclimate. Such solution will reduce costs for energy sources and improve ecological compatibility of production. It is also proved that the optimization of the structural scheme of the system of control and management of the microclimate parameters increases the level of reliability of the developed system, allows reducing the costs of its development and maintenance.
Key words: greenhouse, renewable energy sources, energy saving, automation, microclimate control system.

Сиротюк В., Сиротюк С., Пташник В. Енергозабезпечення процесів тепличного виробництва з використанням відновлюваних джерел енергії
У роботі відзначено, що основою технологічного процесу при вирощуванні овочів та квітів у закритому ґрунті є фотосинтез, який передбачає перетворення вуглекислого газу під впливом світла у товарну органічну речовину з вивільненням кисню.
Проаналізовано основні фактори виробничого середовища та показано, що для ефективної реалізації технологічних процесів у теплиці необхідно забезпечити оптимальний рівень таких основних параметрів: температура повітря у теплиці; температура ґрунту у теплиці; вологість повітря у теплиці; вологість ґрунту у теплиці; концентрація вуглекислого газу CO_2 у теплиці; концентрація чадного газу CO у теплиці; рівень освітленості у телиці; швидкість руху повітря у теплиці. Крім того, необхідно забезпечити неперервний контроль за: видом та сумарним рівнем опромінення; швидкістю руху повітряного потоку за межами теплиці, температурою зовнішнього повітря.
Зазначено, що значну частку в структурі собівартості продукції, отриманої в спорудах закритого ґрунту, становлять витрати на енергоносії. Тому систему енергозабезпечення тепличного господарства доцільно будувати з використанням відновлюваних джерел енергії, у роботі розроблено та обґрунтовано відповідну структурну схему. Зокрема, показано, що основними відновлюваними джерелами енергії, придатними для використання в тепличному господарстві, є енергія вітру та сонця. Невід'ємною частиною такої енергетичної системи повинна бути автоматична система підтримання параметрів мікроклімату теплиці. Це забезпечить зниження витрат на енергоносії та підвищить екологічність виробництва. Також доведено, що оптимізація структурної схеми системи контролю та управління параметрами мікроклімату підвищує рівень надійності розроблюваної системи, дозволяє скоротити витрати на її розгортання та обслуговування.
Ключові слова: теплиці, джерела відновлюваної енергії, енергозбереження, автоматизація, системи управління мікрокліматом.

Problem setting. Climatic characteristics of Ukraine do not allow producing of vegetables a year round. The problem of extension of the period of employment of land resources during a year is solved by applying the technologies of greenhouse production with use of covered soil constructions.

In Ukraine, the structure of greenhouse production is developed with preference to vegetable growing, which constitutes 79 % of the total output of gross products. Cultivation of flowers and other plants occupies 19 and 2 % respectively. Greenhouses are mainly used for cultivation of such crops as tomatoes (their area occupies 1 thousand ha), cucumbers (1.4 thousand ha) and roses (above 60 ha) [9].

Cropping areas of covered soil vegetables have been lately increased from 5.7 to 6.36 thousand ha, while gross production has increased from 546.7 to 555.7 thousand tons. Among the total territory intended for vegetable growing, in 2018, the occupied area took 439.06 thousand ha of field, which supplied the yield of 9440.2 thousand tons of products. In the structure of cropping areas in 2018, open-ground vegetable growing occupied 98.56 % comparing to 1.44 % of the vegetable growing on covered soil. Moreover, yield on the open ground constituted 94.11% of products, while on the covered soil, it made 5.89 % [8].

Analysis of recent research and publications. The promising plans of greenhouse business development expect twice expansion of the area under constructions of covered soil until 2020 [6].

Constructions of covered soil are divided into heat-insulated soil, hotbeds and greenhouses [5]. The first is used for growing of seedlings and early vegetables, the second – for growing of seedlings for open-ground cultivation and early vegetables, while greenhouses, as the best technologically equipped kind of covered soil constructions – for industrial year-round growing of seedlings, vegetables and flowers.

A greenhouse is a construction of covered soil. Its principal task is to support the best-possible conditions for controlled photosynthesis (Fig. 1), i.e. transformation of carbon dioxide into a marketable organic substance with oxygen release under the impact of light.

Greenhouses are classified according to the following characteristics [2]:

- according to the functional use – into the greenhouses for vegetables and seedlings (production of seedlings for open ground), flowers (glass houses), selection greenhouses;

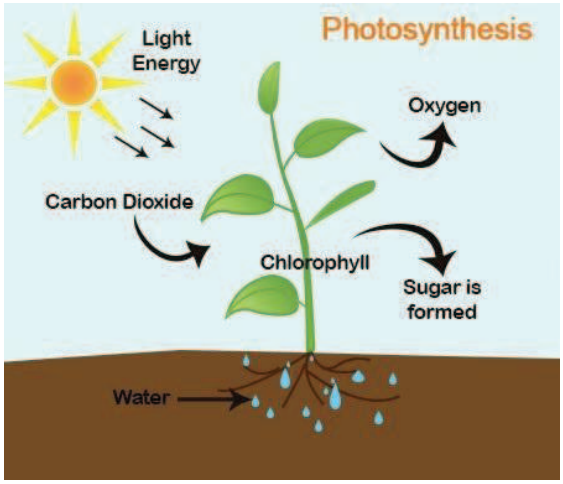

Fig. 1. The process of photosynthesis [7]

Рис. 1. Процес фотосинтезу [7]

- according to the technology of plant growing – into soil greenhouses (growing of agricultural crops on soil mixtures) and hydroponic greenhouses (growing of agricultural crops on artificial substrates in ponds and shelves);

- according to exploitation period – into year-round greenhouses (with artificial heating), spring-summer-autumn greenhouses (with heating by solar radiation and additional artificial heating in case of emergency);

- according to the planned and constructive decision – into shed greenhouses (one-run) and blocked greenhouses (multi-run);

- according to the type of construction envelope – into glass greenhouses, membrane greenhouses, and greenhouses of light-transparent synthetic materials.

A considerable share of exploitation costs is taken by an extremely high level of energy consumption of the technological processes in the covered soil constructions, particularly in winter greenhouses. On average, production of 1 kg of a vegetable product consumes almost 160–180 MJ of thermal and 1.2–2.3 kW·h of electric energy. According to different sources, in the structure of the costs of production of the covered soil products, energy sources take above 50 % [1; 3; 4; 8; 16].

Energy costs can be reduced by 20–30 % by complete automation and upgrading of the quality of regulation of the operating parameters of acting constructions of covered soil [8].

In case operating parameters exceed the limits of standard operating procedure, a crucial effect is observed in yield capacity and marketable quality of products. Hence, it is necessary to secure a reliable and fail-safe operation of the technological and energy

equipment in order to keep operating parameters within the technological tolerance.

Main results. Microclimate parameters in the construction of covered soil are regulated by the State Building Standards of Ukraine "Buildings and constructions. Greenhouses and hotbeds" DBN B.2.2-2-95. They are primarily focused on support of safe conditions for permanently working personnel of the constructions. Moreover, correction of the microclimate parameters is performed according to the intended use, kind and type of commodities, level of intensity of the process of their growing and other factors. Such parameters include temperature of air and soil; share of carbon dioxide in the air; relative humidity of the air and soil; and air velocity.

Hence, automatic control and management is done referring to such parameters of microclimate, as [14; 15]:

– air temperature in the greenhouse;
– air temperature outside (control);
– soil temperature in the greenhouse;
– air humidity in the greenhouse;
– soil humidity in the greenhouse;
– concentration of carbon dioxide CO_2 in the greenhouse;
– concentration of carbon monoxide CO in the greenhouse;
– level of lighting in the greenhouse;
– air velocity in the greenhouse;
– type and the total level of radiation;
– airspeed outside the greenhouse (control).

The mentioned parameters should be supported by the automatic system referring to the regulatory documents [10–13].

Thermal conditions of cultivation constructions are maintained by automatic systems of heating and ventilation. The conditions are determined by capacity of the source of heat, as well as constructive particularities of the constructions. Accuracy of maintenance of the set temperature should be secured within ± 1 °C. Besides, the set temperature should agree with the level of lighting referring to physiological peculiarities of plants' living. Systems of greenhouse heating expect heating of soil and air.

Water regime is maintained by keeping of the required humidity of air and soil by means of different irrigation systems (irrigation above the surface, under the soil, drip system). Irrigation should not violate thermal conditions in the construction, and thus, the water used for irrigation should be kept at the level of the temperature of air and soil (within 20–25 °C).

Gas conditions within the volume of a covered soil construction expect control and maintenance of the concentration of carbon dioxide at the level of 0.1–0.35 %. Regulation of the concentration is performed at the level of lighting above 5 klx. The share of carbon dioxide in the greenhouse can be increased by burning of natural gas in specialized combustion installations or by exhausted gas of boiler installations. Initiation of the scheme of CO_2 supply is automatically blocked under reduction of the level of lighting, in case of opened fanlights and increased relative humidity in the greenhouse.

Intensification of the processes of plants' living requires air velocity at the level of 0.15 m/s. Natural and technical ventilation is used in greenhouses to dispose the excess of heat from solar radiation, as well as to season seedlings.

Regulated artificial lighting is used for growing of seedlings and in selection constrictions.

One of the ways to maintain the necessary parameters of microclimate in a greenhouse expects use of an internal combustion engine in the system of energy supply. The engine runs on natural gas or biogas in a cogeneration mode. In such system, operation of the engine, which is loaded on an electric generator, will produce water vapour, carbon dioxide, heat and electric energy.

The electric energy can be used for lighting, heating of soil and air, as well as serve as activator of mechanisms. The carbon dioxide can be used for nutrition of plants.

Considering the fact that in case of a fault situation the engine can generate carbon monoxide, it is necessary to plan an appropriate primary transformer of CO in the system of control.

As it has been mentioned above, in the structure of prime costs of crop production on covered soil, expenditures for energy sources take from 20 to 60 %, depending on the technology of growing, technical equipment, and level of production automation. Hence, to reduce the costs of crop growing on covered soil and improve the level of ecological qualities of production, it is reasonable to use renewable sources of energy, particularly energy of the Sun and wind, heat of the environment and subsoil, etc.

In particular, to support thermal processes of warming of the water for irrigation, heating of soil and air, it is possible to use solar thermal installations, thermal pumps, etc. Supply of the processes of greenhouse production with electric energy can be secured by application of wind electric and photoelectric installations.

Under such conditions, structural scheme of the system of energy supply is presented at the following picture (Fig. 2).

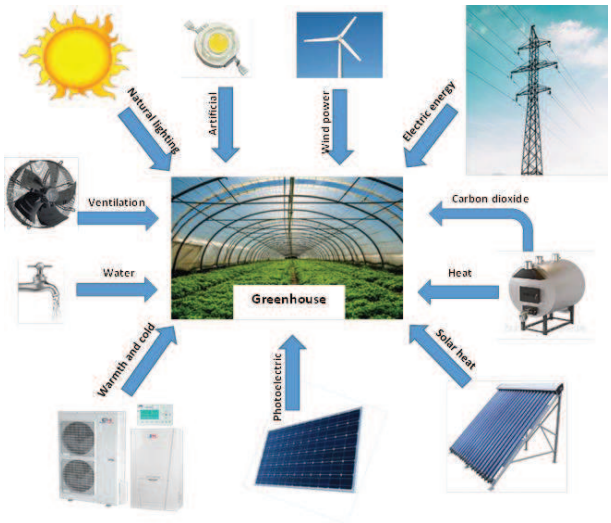

Fig. 2. Structural scheme of the system of energy supply for the processes of greenhouse production

Рис. 2. Структурна схема системи енергопостачання тепличного господарства

Conclusions. Intensity of plant photosynthesis, and thus, efficiency of the covered soil constructions, considerably depends on an optimal level of microclimate parameters, which can be secured by application of automatic systems of control for the processes. A peculiarity of such system of control is not only to support a regulated microclimate in a covered soil construction, but also to manage energy flows from different sources, including renewable ones, contributing to improvement of economic and energy efficiency of the system.

Considering the tendencies of farming development in Ukraine and its limited financial resources, the developed system of control for the microclimate and energy flows in the constructions of covered soil is capable to secure profitability, primarily under conditions of small-scale production.

References

1. Avdzhyan, N., Kirichenko, A., Skorohod, A. (2016). Sozdanie neobhodimogo mikroklimata v teplitsah za schet ispolzovaniya vozobnovlyaemyih istochnikov energii. *Aktualnyie problemyi energetiki APK*: materialy VII mezhdunar. nauch.-prakt. konf. Saratov: TseSAin.

2. Bolotskih, N. (2015). Zarubezhnyie tehnologii infrakrasnogo obogreva teplits. *Naukovyi visnyk budivnytstva*, 1(79), 150–158.

3. Nadirov, N., Nekrasov, V., Shevchenko, S., Solodova, E., Suhanberdieva, D. (2016). Vozobnovlyaemaya energetika v teplichnyih tehnologiyah. *Dokladyi Natsionalnoy akademii nauk Respubliki Kazahstan*, 2, 137–144.

4. Ivanenko, V. (2011). Osoblyvosti formuvannia enerhovytrat na vyrobnytstvo produktsii ovochivnytstva zakrytoho gruntu. *Naukovyi visnyk LNUVMBT im. Gzhytskoho*, 2(48), 71–78.

5. Martynenko, I. (1995). *Avtomatyzatsiia tekhnolohichnykh protsesiv silskohospodarskoho vyrobnytstva.* Kyiv: Urozhai.

6. Nadirov, N., Nekrasov, V., Tanirbergenova, A., Yusupova, M. (2015). Teplitsyi – novyie resheniya v proizvodstve produktov pitaniya. *Agrarnyiy sektor*, 4, 89–93.

7. Nekrasov, V. G., Shevchenko, S. A., Yusupova, M. (2015). *Energetika teplits (teplichnyie tehnologii).* Berlin: LAMBERT Academuc Publishing.

8. State Statistics Service of Ukraine. (2018). Agrarian sector: statistical notes. Retrieved from www.ukrstat.gov.ua.

9. Tiravskiy, V. (2011). Parnikovyiy effekt. *Status*, 22(192). Retrieved from http://statuspress.com.ua/nisha/parnikovyj-effekt-2.html.

10. Anushree, M. K., Krishna, R. (2018). A smart farming system using Arduino based technology. *International Journal of Advance Research, Ideas and Innovations in Technology,* 4(4), 850–856.

11. Shankaraiah, D., Prajwal, G., Hemanth Kumar, B. S., Shweta B., Nayana, R. (2019). Automated green house. *International Journal of Advance Research, Ideas and Innovations in Technology*, 5(3), 1831–1834.

12. Eddahhak, A., Lachhab, A., Ezzine, L., Bouchikhi, B. (2007). Performance evaluation of a developing greenhouse climate control with a computer system. *AMSE Journal Modelling*, 68(1), 53–64.

13. Ganesan, K., Walele, U., Hambire, N., Choughule, P., Oommen, D. (2018). Raspberry-Pi Based Automated Greenhouse. *International Research Journal of Engineering and Technology (IRJET)*, 5(3), 2346–2350.

14. Shamshiri, R. (2007). *Principles of Greenhouse Control Engineering. Part 1: Theories & Concepts*. ITMA, UPM.

15. Somvanshi, S., Pandey, D., Asthana, P. (2017). Monitoring System of a Greenhouse. *International Journals of Advanced Research in Computer Science and Software Engineering,* 7(6), 847–851.

16. Woodenergy. (2019). Enerhetychnyi monitorynh ta ekonomichna otsinka teplychnykh hospodarstv. Retrieved from https://green-house.at.ua/publ/energetichnij_monitoring_ta_ekonomichna_ocinka_teplichnikh_gospodarstv/1-1-0-4.

Бібліографічний список

1. Авджан Н. С., Кириченко, А. С., Скороход, А. А. Создание необходимого микроклимата в теплицах за счет использования возобновляемых источников энергии. *Актуальные проблемы энергетики АПК*: материалы VII Междунар. науч.-практ. конф. Саратов: ЦеСАин, 2016. С. 90.

2. Болотских Н. Зарубежные технологии инфракрасного обогрева теплиц. *Науковий вісник будівництва*. 2011. № 1(79). С. 150–158.

3. Возобновляемая энергетика в тепличных технологиях / Н. Надиров и др. *Доклады Национальной академии наук Республики Казахстан*. 2016. № 2. С. 137–144.

4. Іваненко В. Ф. Особливості формування енерговитрат на виробництво продукції овочівництва закритого ґрунту. *Науковий вісник ЛНУВМБТ ім. Ґжицького*. 2011. № 2(48). С. 71–78.

5. Мартиненко І. І. Автоматизація технологічних процесів сільськогосподарського виробництва. Київ: Урожай, 1995. 224 с.

6. Надиров Н., Некрасов В., Танирбергенова А., Юсупова М. Теплицы – новые решения в производстве продуктов питания. *Аграрный сектор*. 2011. № 4. С. 89–93.

7. Некрасов В., Шевченко С., Юсупова М. *Энергетика теплиц (тепличные технологии)*. Берлин: LAMBERT Academuc Publishing, 2015. 138 с.

8. Статистичні нотатки. Аграрний сектор. *Державна служба статистики України*. 2018. URL: www.ukrstat.gov.ua (дата звернення: 25.09.2019).

9. Тиравский В. Парниковый эффект. *Статус*. 2011. № 22(192). URL: http://statuspress.com.ua/nisha/parnikovyj-effekt-2.html (дата обращения: 25.09.2019).

10. Anushree M. K., Krishna R. A smart farming system using Arduino based technology. *International Journal of Advance Research, Ideas and Innovations in Technology*. 2018. Vol. 4(4). P. 850–856.

11. Automated green house / D. Shankaraiah et al. *International Journal of Advance Research, Ideas and Innovations in Technology*. 2019. Vol. 5, issue. 3. P. 1831–1834.

12. Eddahhak A., Lachhab A., Ezzine L., Bouchikhi B. Performance evaluation of a developing greenhouse climate control with a computer system. *AMSE Journal Modelling*. 2007. Vol. 68(1). P. 53–64.

13. Raspberry-Pi Based Automated Greenhouse / K. Ganesan et al. *International Research Journal of Engineering and Technology (IRJET)*. 2018. Vol. 5(3). P. 2346–2350.

14. Shamshiri R. *Principles of Greenhouse Control Engineering. Part 1: Theories & Concepts*. ITMA, UPM, 2007. 86 p.

15. Somvanshi S., Pandey D., Asthana P. Monitoring System of a Greenhouse. *International Journals of Advanced Research in Computer Science and Software Engineering*. 2017. Vol. 7(6). P. 847–851.

16. Woodenergy. Економічний моніторинг та економічна оцінка тепличних господарств. 2011. URL: https://green-house.at.ua/publ/ energetichnij_monitoring_ta_ekonomichna_ocinka_teplichnikh_gospodarstv/1-1-0-4 (дата звернення: 25.09.2019).

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