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DEVELOPMENT OF A PRACTICAL MECHANISM FOR THE ENVIRONMENTAL DIRECTION OF THE "GREEN OFFICE" PROGRAMME WHEN WATERING INDOOR PLANTS IN ACCORDANCE WITH SUSTAINABLE DEVELOPMENT

The object of research is a continuous action device with an alarm for rationalizing the irrigation system, which will help support the sustainable development program and improve the environmental situation in the country.

The problem solved in this study is related to the need to optimize the consumption of resources during plant care at enterprises of various forms of ownership that have begun to introduce environmental management. This is also one of the problematic aspects associated with the landscaping of industrial centers, offices and premises where a significant number of people work and live. The development of mechanisms for solving the problem should contribute to increasing the decorative properties of plants and optimizing work related to care, watering and maintaining a given soil moisture.

In order to solve the problem, a simple-to-use device for maintaining optimal soil moisture in pots (containers) with indoor plants has been developed, which occurs by visual registration (when the LED lights up).

This is due to the fact that the order of mounting and arrangement of needle electrodes in the design of the plant container with the placement of the LED on the soil surface has been changed. The proposed design features have made it possible to constantly monitor soil moisture – if the humidity reaches a value less than the required value, the LED turns on and records the need for watering.

Thanks to the conducted research, an increase in the qualitative component of moisture intake is ensured, the decorativeness of plants increases and the risk of their death is reduced, which will allow enterprises to actively move towards supporting the "green" economy. Compared with known analogues, the device gives confidence in the reliability of soil moisture control in containers with plants, and in case of its deviation from the optimal indicator, the sensor gives an instant light signal.

The proposed development also allows to improve the qualitative composition of the moisture supply, optimize the use of water resources, reduce death and increase the efficiency of plant care while ensuring their healthy growth.

Keywords: *soil moisture monitoring, irrigation control, automatic soil moisture recording device, LED indicator.*

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1. Introduction

Since the end of the 20th century, a period of intellectual and technical development has begun, so the world community had to activate its potential for a balanced combination of the innovation and technical boom in the economy with social issues and rational conservation of the planet's resources and the environment. In this regard, in 1992, at the UN Conference on Environment and Development in Rio de Janeiro, the "Concept of Sustainable Development" was proclaimed. At the UN Summit in 2015, a program was formed and sustainable development goals were approved, which in subsequent years became a priority area of international cooperation and acquired a leading status for the development of most countries in the world, including Ukraine [1–3]. Considering the European integration directions of Ukraine's development, it should be said that those where science is connected with sectors of the national economy that protect the environment and contribute to the development of the "green fund of the planet" are becoming relevant. This is primarily research related to the scientific foundations of the organization of ornamental gardening and floriculture, where all determinants (soil looseness, irrigation frequency, fertilizer application, oxygen supply to roots, etc.) are taken into account [4]. These determinants ensure the production of healthy plants for home gardening, landscaping of enterprises, parks, recreation centers, tourist complexes, hotels, etc.

More and more companies are implementing environmental management, principles of social responsibility, actively reducing their impact on the environment. The implementation of environmental initiatives is becoming more active and developing in the world. Enterprises are beginning to involve employees in resource conservation and are actively joining the movement under the Green Office program, the concept of which is based on three principles: reducing resource consumption, reusing materials, and introducing environmentally friendly alternatives. By joining the program, both industrial enterprises and every office-type organization have the opportunity to contribute to green modernization and ecological balance. Companies that implement this concept not only reduce costs and optimize work processes, but also become more active in the direction of greening the external and internal space of premises, thereby improving their image among partners and clients.

In Ukraine, despite minimal state support, the implementation of such initiatives is becoming increasingly widespread; companies are already implementing measures to comply with environmental standards and design plant landscapes outside and inside the buildings of enterprises during the construction of offices. After all, adhering to the principles of "Green Office" allows businesses not only to reduce costs, but also to improve their reputation among clients and partners. Along with the development of the desire to green enterprises, the problem of hiring employees with appropriate qualifications and optimizing plant care arises [5, 6].

That is, plant biodiversity and care for their decorativeness are of crucial importance for entrepreneurs and ordinary residents in all countries, and in a number of sectors of the economy, production and development of enterprises depend on the implementation of ecosystem services and measures. For example, the trade in potted flowers, park and homestead landscapes, and wood forest products are related to biodiversity and are important sources of income in some areas [7]. In tourism, hotel and restaurant management, there is a development of a separate direction that activates the eco-component of its activities. This is manifested in the development of rural green tourism, where hotels create natural oases with a variety of indoor and outdoor plants, with their own farms, apiaries, vegetable gardens, etc. [8]. Therefore, scientific research is advisable to direct to projects related to the preservation of biodiversity and the development of the concept of Sustainable Development, with technologies for improving the cultivation of plants in both open and closed soil for landscaping the landscape of cities, enterprises, offices and homes of ordinary citizens.

Currently, preferences for plant biodiversity vary according to national preferences, but green and flowering plants adorn the homes and gardens of consumers around the world [7]. Floriculture farms and ordinary consumers (the former to expand the sales market and increase profits, the latter to improve the aesthetic appearance of the premises) specialize in growing indoor plants collected from different parts of the world and belonging to different families, genera and species.

Accordingly, their requirements for soil structure and moisture are different, and for normal growth, representatives of different families need different ratios of water quantity and frequency of irrigation. However, water, as a source of life, must be in a balanced ratio with other physicochemical characteristics of the soil [9].

One of the most important negative factors in irrigation is the different sensitivity of plants to excess or lack of moisture. This is due to the fact that the main harm is caused not by the lack or excess of water itself, but by its effect on the soil: with an excess, its acidity increases, and with a deficiency, its alkalinity [10, 11].

The main threat to plants from systematic waterlogging is a violation of the oxygen regime of the root system. Limited access of oxygen to the roots leads to hypoxia, and in the case of complete cessation of access – to anoxia. That is, the content of a sufficient amount of moisture in the soil is one of the necessary conditions for normal plant growth and affects their absorption of vital elements [7, 12–17]. This is especially true for flowers grown in pots, the roots of which are located in an isolated closed soil system.

However, today this issue is mainly studied by agronomists and florists and less by scientists specializing in the technical solution of the process of improving the quality assurance system for such a specific and profitable product for the country's economy as flowers. At the moment, a number of methods have been developed to maintain optimal soil moisture in flower pots, using various devices that allow measuring soil moisture. These devices are based on the strain gauge method of determining soil moisture, the reflectometric method, or measuring the change in direct current electromotive force [18–21]. But all of them require similar repeated measurements every day, which increases the laboriousness of the growing process and does not contribute to the automation of watering. In addition, such devices determine soil moisture at those points where the device is placed. And it is desirable that the device shows the integral value of moisture at different points, which may differ in this indicator when watering plants. To do this, it is necessary to perform several measurements and determine their average value. At the same time, if they are moved to another place, it is necessary to wait a certain time for the indicators to stabilize, which complicates the process of obtaining its average value. Also, the disadvantage of devices based on measuring soil moisture by the strain gauge method is the close location of metal electrodes that are inserted into the soil when measuring its moisture. And this leads to the fact that with uneven watering, the readings of the moisture meter will be different at different points, that is, they will not correspond to reality. In addition, these devices are high cost.

However, modern farms, in order to reduce water consumption and labor resources for growing flower products in closed ground, prefer to implement simple and cheap automated processes for controlling plant growth. This, in turn, actualizes the development of devices that reduce the use of manual labor, which makes it advisable to continue conducting research to improve existing soil moisture meters.

The aim of research is to develop a continuous-action device for visual automatic registration of changes in the specified soil moisture when watering plants in closed ground, which is a practical mechanism for implementing the environmental direction of the Green Office program in accordance with sustainable development. To achieve the aim, the following objectives were solved: to invent a simple method for automatically registering changes in soil moisture; to develop a reliable device for measuring soil moisture, which has a low cost and relatively high accuracy; to investigate the effectiveness of the device.

2. Materials and Methods

The object of research was a continuous-action device with an alarm for rationalizing the irrigation system.

The research was conducted using electrophysical methods. For this purpose, an electrical circuit was used, consisting of a KT1102 transistor, which acted as a relay, an AL107 LED, and a variable resistor $R_1 = 150$ kOhm. The following potted plants were used as experimental flower samples: *Begonia semperflorens* in pots Ø20 cm and Ø40 cm; *Crassula ovata* in pots Ø15 cm and Ø30 cm. Soil moisture was determined using the standard method according to DSTU 11465-2001 (ISO 11465:1993) [22].

3. Results and Discussion

The tasks of the first stage of research included inventing a simple method for automatic registration of changes in soil moisture. For this purpose, it was proposed to use a relay that opens the electrical circuit if the soil moisture is higher than the minimum required and turns on the electrical circuit associated with the LED, which signals the need for watering [23]. Further, based on the action of the tensiometer, an electrical circuit was developed that serves to signal the need for watering the soil, which is presented in Fig. 1 [24]. The electrical circuit of the device includes:

– variable resistance $R_1 = 150$ kΩ, which is used to adjust the device to the appropriate soil moisture; load resistance $R_2 = 20$ kΩ (electrical load);
– LED AL107 – used as a visual indicator that notifies the need for watering the soil;
– transistor KT1102 – acts as a relay that turns on the LED when the soil moisture decreases to a minimum value, signaling the need for watering.

The device is set to the appropriate soil moisture using a regulator. To do this, two needle-shaped metal electrodes (length 15 cm) are inserted into the soil of the pot with minimum moisture, which are current conductors (the device operates from a DC source – 3 V). Rotate the resistance knob R1 until the LED AL107 goes out if it was on after installing the device, or until it lights up if it was not turned on before. After that, the necessary maximum watering is carried out, that is, the maximum possible soil moisture is created. The need for the next watering will be signaled by the LED turning on.

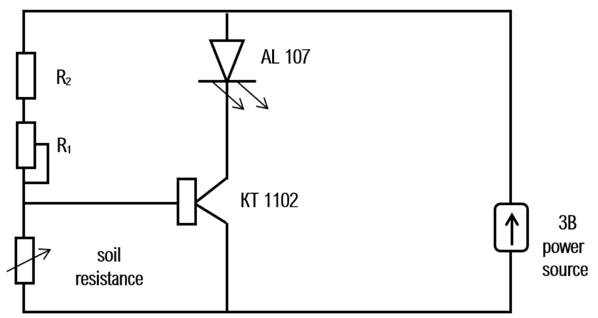

Fig. 1. Electrical diagram of the alarm

Unlike analogues, the developed device had a simple design and allowed to maintain soil moisture in flower pots within optimal limits by providing a light signal.

Further studies of the action of the developed alarm showed the existence of certain shortcomings in registering the moment of soil drying in sufficiently large containers for growing flowers, which consisted in the close location (3 cm) of needle electrodes immersed in the soil. This is due to the fact that the moisture content was measured in a limited volume of soil and the LED sensor showed point values of humidity, instead of the average value. And in the case of uneven watering, the device gave different readings at different points, which did not correspond to reality.

In the course of further work, the method of automatic registration of irrigation was improved by mounting the device in the structure of the flower pot, which allowed to place needle electrodes of shorter length (5 cm) at the maximum distance from each other. In this case, the electrical circuit is one with the flower pot, and its parts are hidden in the handles of the pot, which are intended for its transfer, and the LED has an outlet to the surface of the pot. Thus, the device continuously monitors soil moisture – if the humidity reaches less than the required value, the LED turns on and records the need for watering. The device diagram is shown in Fig. 2.

The electrical circuit of the alarm consists of electrical resistances R1 and R2, LED AL107, transistor KT1102, current source with a voltage of 3 V and needle electrodes. The device is set to the appropriate minimum soil moisture using variable resistance R1. When it is adjusted, relay KT1102 opens the electrical circuit if the soil moisture is higher than the minimum required, and turns on the electrical circuit if the soil moisture is lower than the minimum required, signaling the need for watering [25].

As can be seen from Fig. 2, *b*, the electrical circuit is placed partly in the left handle of the pot (R1; R2 and AL107) and partly in the right – KT1102 and current source. Needle electrodes are inserted into the soil from each handle for carrying the pot. The electrical circuit of the device works as follows: if the entire soil between the handles of the pot is evenly watered, the electrical circuit closes and the LED goes out. In the case of partial or very uneven watering, the circuit does not work, that is, the electrical circuit does not close through the soil. In this form, the device is not a separate device for measuring soil moisture, but is one with the flower pot.

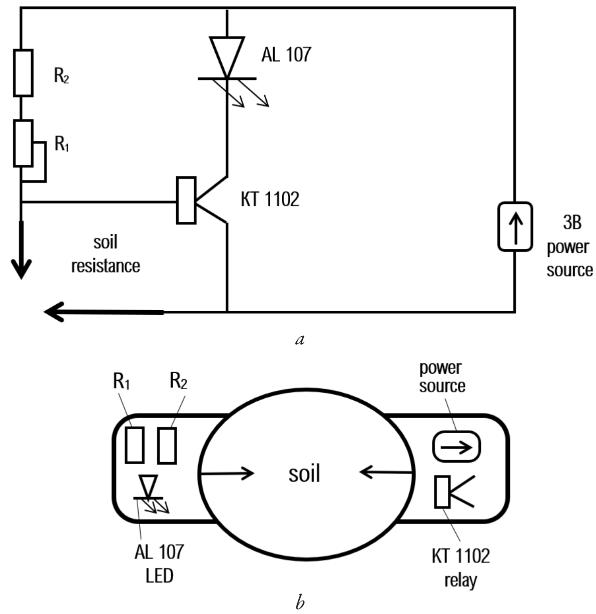

Fig. 2. Device system:
a – electrical circuit of the alarm; *b* – pot with an alarm

A number of studies were then conducted that show the effectiveness of the device for automatically recording and maintaining soil moisture over time. According to literature, for each type of plant there is an optimal lower threshold of soil moisture, when it is reached, it is advisable to water: for Begonia semperflorens – 50 %, for Crassula ovata – 30 %. Therefore, the device sensors in pots with these plants were set to operate when the specified indicators are reached. Each time the LED was lit (the watering device was activated), soil was sampled to study its moisture content. The number of LED lights, and accordingly the number of soil samples for all experimental plant samples, was 20. The measurement results are shown in Fig. 3.

The results of the study showed that the deviation of soil moisture from the average value (30.94 %) for Crassula ovata in a Ø15 cm pot is ±2.46–3.04 %, the deviation of soil moisture from the average value (30.50 %) for Crassula ovata in a Ø30 pot is ±2.6 %. For Begonia semperflorens in a Ø20 cm pot, the deviation of soil moisture from the average value (50.83 %) is ±2.9–3.1 %, for Begonia semperflorens in a Ø40 cm pot, the deviation of soil moisture from the average value (50.78 %) is ±1.72–2.58 %.

Thus, the fluctuation of soil moisture at the moment of lighting the LED is within the standard error for this type of device (5–7 %) and is up to 4 %.

It should be said that the conditions of martial law in Ukraine have significantly affected the country's ecosystem. This is due to the neutralization of flora and fauna both in cities and in villages and suburban areas where hostilities were fought. Therefore, maximum efforts should be made to develop and implement effective mechanisms for restoring the ecosystem in the direction of implementing the concept of sustainable development.

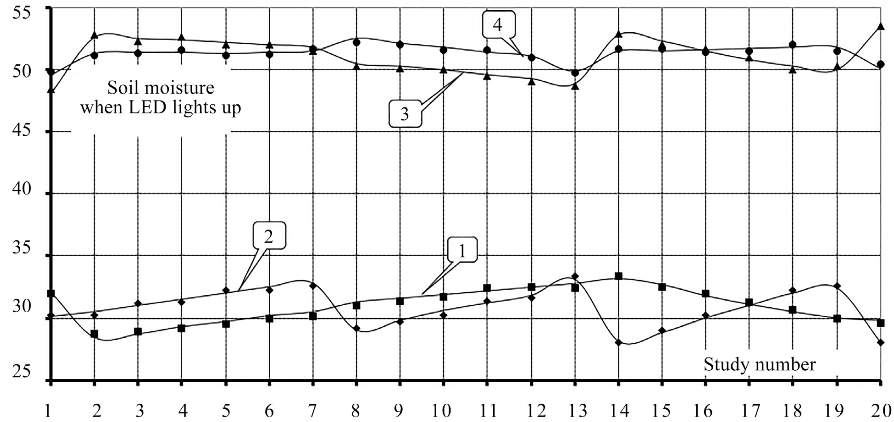

Fig. 3. Results of soil moisture testing in pots with plants: 1 – Crassula ovata in a pot Ø15 cm; 2 – Crassula ovata in a pot Ø30 cm; 3 – Begonia semperflorens in a pot Ø20 cm; 4 – Begonia semperflorens in a pot Ø40 cm

The use of the developed device allows optimizing watering of plants in the case of growing a large number of them in farm conditions, but the issue of the need to pay attention to controlling the moment of ignition of the LED remains at the stage of technical implementation, which is complicated by large areas of plants. Therefore, further research will be aimed at condensing all the signals of LEDs that light up within 2–3 hours into one sensor, which should be located at the entrance to the farm (greenhouse) on the signaling board. This will allow completing the development and achieving full automation of the signaling system.

In general, recording watering times will allow for more efficient plant care, maintaining their health and longevity, preserving the ecosystem functions of plants and improving air quality. That is, in the context of sustainable development, controlling plant watering is an important element of effective resource management, which contributes to saving water, preserving soil, increasing environmental awareness of citizens, improving the urban environment and reducing climate impact. This is one of the practical steps that both large companies and individual households can take to maintain ecological balance.

4. Conclusions

Thus, the research results of soil moisture in pots with plants allow to say that the developed device for maintaining optimal soil moisture is characterized by accuracy and reliability in operation, which is confirmed by studies on measuring soil moisture; it is simple in design and has a relatively low cost. The effectiveness and reliability of maintaining soil moisture within optimal limits is confirmed by the results of studies that showed that the fluctuation of soil moisture at the moment of lighting the LED is within the standard error for this type of devices (5–7 %) and is up to 4 %.

Thanks to the use of the device in greenhouse enterprises, in offices with a large number of green plants in closed soil, in the homes of ordinary citizens, there will be an opportunity for a rational approach to solving the problem of timely watering of plants, which in turn will contribute to:

– prevention of overmoistening and drying of the soil, and accordingly healthy growth, better flowering and increased resistance of plants to adverse conditions, the development of fungal diseases, wilting and death of the plant;
– an individual approach to each plant, because different types of plants have different needs for moisture;
– minimization of the human factor, which is especially important for large flower farms and busy owners of indoor plants;
– rational use of water, because timely watering helps to avoid unnecessary water consumption, which is an important aspect of environmental responsibility and saving resources;
– formation of environmental awareness and a responsible attitude to nature, because it helps to involve people in sustainable development programs and popularize environmentally friendly habits;
– reducing environmental pollution, as excess moisture promotes the development of pathogenic microorganisms, which can lead to the use of chemical plant protection products, which pollutes the environment;
– reducing the need to use mini-electric pumps that consume energy, which will help reduce greenhouse gas emissions, which is especially important for large enterprises and urban environmental projects.

Conflict of interest

The authors declare that they have no conflict of interest regarding this study, including financial, personal, authorship or other, that could influence the study and its results presented in this article.

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The study was conducted without financial support.

Data availability

The manuscript has no related data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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