The influence pattern of the transpiration process on plant productivity

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Abstract. Scientific background of the energy-informational approach in the development of irrigation technologies, which is based on the principle of energy extremality of self-organization, and the law of survival is given. The paper notes that it is necessary to promote self-organizing processes in the system “plant – environment,” when a significant solar irradiance (SI) mechanism of transpiration, due to the limited opportunities of disclosure of the stomata, does not perform fully its function of evaporative cooling, which leads to a decrease in the rate of photosynthesis and therefore plant productivity. The paper shows the relationship of the modes of transpiration irrigation with the advent of the energy of SI, and discusses some of the theoretical principles on which one could base modes of transpiration irrigation. In particular, we focus on the regularity of the influence of the process of transpiration on plant productivity, providing a speed increase photosynthesis and, consequently, its productivity.

1. Introduction

With all its diversity, the climate of our planet has remained relatively stable for hundreds of millions of years, providing life on Earth with the necessary conditions. The reasons for such stability we, first of all, see in the constancy of solar radiation reaching the surface of the Earth. Second, it is a powerful air insulation of the atmosphere. Third, a huge amount of water resources, which is a natural heat accumulator with the most common heat-generating substance on Earth. And life itself on Earth, with its elementary ecological cells — ecosystems, in the form of a natural complex, biocenoses and their habitat, interconnected by metabolism and energy and differing thermodynamic disequilibrium, — is an effective tool for preserving Earth’s climatic and biogeochemical characteristics.

The main source of energy that ensures the formation of all biomass, including the crop of plants, is solar energy.

The ability to adapt to changes in the external environment, evolve, and survive determines the adaptability of all living organisms and plants, in particular. This ability directly depends on how effectively they perceive and assimilate the free available energy of the main energy source (the sun) that underlies photosynthesis.

The main process studied by agrarian and environmental science is the transformation of energy by living self-organizing evolving organisms and their communities. In this regard, the basic law of energy conversion — the second law of thermodynamics (SLT), and from biology — the theory of biological evolution, could be used to build the theoretical foundations of agroecology from the important principles of physics [1].
However, the relationship between these provisions was one of the fundamental problems of thermodynamics and the evolution of the living nature. I. Prigogine called this problem a “blatant contradiction” between the evolution of nature according to SLT, according to which structures are destroyed, energy degrades, and entropy everywhere and continuously increases, and the theory of biological evolution, according to which structures and functions of organisms are improved, and free (efficient) energy in living systems spontaneously increases.

The problem of this contradiction was successfully and simply resolved in [2] on the basis of substantiation and consideration of the law of survival (PS), as well as the principle of energy extremality of self-organization and progressive evolution (PEER and PE) that underlie the energy-informational approach in the considered studies.

The essence of the law of survival is the following: every element of the self-organizing nature of its development (ontogeny, phylogeny) spontaneously aspires to the condition of the most complete, efficient use of the existing conditions of available free energy trophic level system to which it belongs.

This is also confirmed by the dissipative transpiration process discussed above, as a physiological process in plants, providing a temperature optimum for the maximum rate of photosynthesis, i.e. the temperature at which the plant most fully uses the part of solar radiation free for photosynthesis – photosynthesis exergy [3].

Thermoregulation in a plant occurs due to transpiration – evaporative cooling from the surface of the plant, which consumes almost 95% of all water consumed by the plant.

The rate of photosynthesis, and, consequently, productivity, depends on the temperature of the leaf surface and has a maximum value at a certain temperature value, which is provided by the self-organizing transpiration process.

The transpiration $q_T$ is a process that most fully determines the need of plants for water. As already noted, the main purpose of transpiration is to reduce the temperature of a leaf of a plant – $t_l$, which perceives the total, including thermal, exergy of solar irradiance (SI) – $\Delta e_x$, and approximation of $t_l$ to the temperature optimum of photosynthesis – $t_o$ due to evaporative cooling, which in its the queue is aimed at achieving maximum crop production.

The purpose of this work is to confirm this position with the help of an experimental study of the productivity of plants depending on the transpiration of seedlings of beet, cauliflower, and potato seedlings.

2. Research Method and Tools

Studies on the transpiration of seedlings of beet, cauliflower, and potato shoots were carried out according to the method [4]. During the experiment, the caps with the plant and the container with the nutrient solution were weighed once a day with fixing time. The weight of the lid and container was subtracted from the weighted values, the net weight of the green mass of the plant and the weight of the solution were obtained. Further, by calculating the growth of green mass and the flow rate of the solution through the upper part of the plant (by transpiration). Mass measurement was performed using an ML-A01 electronic digital scale with a measurement limit of 100 g and an accuracy of 10 mg. Number of measurements (days) was not less than 15.

3. Experimental part, results and discussion

To determine the degree of influence of water flow through the plants on its productivity, the correlation coefficients between the flow and increase arrays for each plant were determined. The results are presented in Table 1.
Table 1. Correlation coefficients between consumption and growth arrays for each plant.

| №  | Samples                  | Correlation coefficients |
|----|--------------------------|--------------------------|
| 1  | Beet seedlings           | 0.38                     |
| 2  | Cauliflower seedlings    | 0.18                     |
| 3  | Potato seedlings         | 0.31                     |

We will conduct an additional regression analysis of the time series of consumption and growth, for which we construct the correlation fields of the series and define the analytical expression of the regression equations. Namely, the dependence of the resultant attribute (Y, plant growth) on the factor sign (X, water consumption) for each sample is analyzed, the results are summarized in Table 2.

Table 2. Analytical expressions of regression equations.

| №  | Samples       | Regression equations |
|----|---------------|----------------------|
| 1  | Beet seedlings| y = 1.1741x – 0.0359  |
| 2  | Cauliflower seedings | y = 0.1716x – 0.0101 |
| 3  | Potato seedlings | y = 1.9407x – 0.0057  |

It is known, that the coefficient in the regression equation before the factor sign shows how much the resultant sign changes when the factor sign changes by one. The resultant sign of a potato sample changes most strongly, which is consistent with a large correlation coefficient.

4. Conclusions
The pattern of the influence of the transpiration process on the productivity of a plant, which provides for an increase in the rate of photosynthesis, and, consequently, its productivity has been experimentally confirmed. The correlation coefficients between the arrays of the values of transpiration consumption (water consumption of water regime q) and the increase in green mass for seedlings of beets, cauliflower, and potato seedlings (0.38, 0.18, and 0.31) characterize a sufficient degree of connection between these processes.

Regression analysis of these processes showed that with a change in the factor sign (transpiration flow rate) per unit for potatoes, the resultant sign (increase in green mass) changes by almost 100%, and it is by almost 20% for beets.

References
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