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ENERGY BALANCE OF AMPELOCOENOSIS AT DIFFERENT STRUCTURES OF PLANTATION AND ARCHITECTURE OF PLANTS

The purpose. To study energy balance ampelocoenosis and to tap their efficiency. **Methods.** Field, laboratory and energy-balance. Probes were carried out in 2013 – 2015 on technical cultivars of grape Rubin Tairovskiy, Suholimanskiy belyi and Odesskiy chornyi. **Results.** On the basis of credit and debit part of energy balance effectiveness ratio of absorbed and general physiologically active radiation of ampelocoenosis with different structure of plantation and architecture of plants is determined. **Conclusions.** The method of energy balance enables to study experimentally magnitude of entering solar radiation, its absorbtion by leaves and sowings in separate spectral ranges, real photosynthesis and other processes. In the long term this method can be used in probes of production process of plants of grape and development of modern agrotechniques.

Key words: grape, ampelocoenosis, energy balance, structure of plantations, architecture of plants.

Introduction. The quantity of plant biomass and crop yield in agrocenoses is related to photosynthetic activity, with is the process of transformation the absorbed energy of solar radiation into the chemical energy of organic substances. In plants about 90% of dry biomass accumulates as a result of photosynthesis activity and 10% - of mineral nutrition. One of the most important problems of crops is the research of technologies for evaluating the maximum productivity and yield. Increase of agrocenoses efficiency is the scientific problem of food security and economic efficiency.

In the study of the effectiveness of agrocenoses, the method of energy buget, which consists of input and output components, is used. The values allow to estimate maximum possible productivity and yield of crops under optimum conditions [6].

The grapevine training system includes two principal parameters: vine spacing and vine forming. These factors measure the canopy architectures which plays a key role in light energy capture, water use as regulated by transpiration, and microclimate of ripening grapes. Canopy management system is an important aspect of viticulture due to its effect on vine productivity and fruit composition [4, 5, 7, 8]. However, the method of energy budget is not sufficiently studied in vineyards establishing in various climate conditions.

The aim – study of the possibility of using the method of energy budget to evaluate the efficiency of use natural resources on vineyards with different canopy management systems in climate condition of Northern Black sea region.

Materials and methods. The experiment was carried out during 2013-2015 years, on 12-15-year old vineyards of technical cultivars Rubin tairovskii, Suholimanskii belii and Odesskii ciornii; grafted on Riparia x Rupestris 101-14. The vineyards differ by training system (tabl. 1).

Table 1.

Scion-rootstock combination	Training system	Vine spacing (m x m)	Vine forming
Rubin tairovskii on R x R 101-14	Vertical shoot positioned	3 x 1.5	Horizontal bilateral cordon with low trunk (70 cm)
	Cordon	3 x 1.5	Horizontal bilateral cordon with high trunk (120 cm)
Suholimanskii belii on R x R 101-14	Vertical shoot positioned	3 x 1.25	Horizontal bilateral cordon with low trunk (70 cm)
	Cordon	3 x 1.5	Horizontal bilateral cordon with high trunk (150 cm)
Odesskii ciornii on	Guyot	3 x 1.25	Guyot bilateral with low trunk (70

			cm)
R x R 101-14	Vertical shoot	3 x 1.5	cordon with low trunk (70 cm)
	positione d		

The soil is represented by chernozem clay loam; maintenance under black fallow; fertilizers not used. The vineyard is not irrigated. The experimental plot is establishing on the plain location; geographical latitude 46.36° and longitude 30.65°. The rows are in the north-south orientation.

The energy budget of experimental vineyards per unit biological time for photosynthetically active radiation (PAR) was determined according to the equation:

$$Q_{Af} = Q_M + Q_T + Q_t + Q_{ir}$$

Input components of plant energy budget: Q_{Af} – solar radiation absorbed by plants; $Q_{Af} = Q \cdot k_f \cdot A_f$, where Q – insolation incident on a horizontal surface during the plant growing season. This dates is calculated on the coordinates of the experimental lot at average values for 1983-2005, presented by NASA's Meteorological Data Center [9]; k_f – the coefficient of transition Q to PAR (Q_f), equal to the coefficient of 0.48 [6]; A_f – performance the absorption coefficient of the Q_f, calculated on the basis of decade measuring parameters of canopy structure during vegetation and average relative radiation fluxes on the upper (0.9), eastern and western parts of the rows (0.38-0.48) [2]. *Output components of plant energy budget:* Q_M – the energy Q_f accumulated in biomass; $Q_M = M \cdot q$, where M – weight of dry biomass; q - energy of 1 g of dry biomass, equal 16.8 kJ [2]; Q_T – transpiration energy (Q_T); Q_t – energy of heating of leaves. It is equal to the energy Q_T in the period of water deficiency and closing leaf stomatas; Q_{ir} – the energy of regulatory information processes, on average, is 1-2% from Q_{Af} [1].

Results and discussion. The duration of plant growing season of

cultivars Rubin tairovskii and Suholimanskii belii is an average 130 days, and cultivar Odesskii ciornii
– 140 days. During this biological time, the insolation incident Q on a horizontal surface of 1 ha plantation in the spectrum of 0.29-4 μm is 25.4-26.3 x 10^{12} joule (tabl. 2). However, the importance for most of the physiological processes of plants has solar radiation, absorbed in the spectrum of 380-750 nm (Qf), or PAR. High-energy light-dependent processes (net photosynthesis, photosynthesis, photorespiration, transpiration, heat exchange between leaf and air) occur in the spectrum 380-710 nm [6].

Table 2. Comparative dates of components of the energy budget of vineyards with different canopy structure, on average for 2013-2015. The calculations were carried out for the period from third decade of May to the first* and second** decade of September.

Components of the energy budget	Name of cultivar / Training system					
	* Rubin tairovskii / Vertical shoot positioned	* Rubin tairovskii / Cordon	* Suholi-manskii belii / Vertical shoot positioned	* Suholi-manskii belii / Cordon	** Odesskii ciornii / Guyot	** Odesskii ciornii / Vertical shoot positioned
Insolation incident on a horizontal surface (Q) of 1 ha plantation, 10^9 J	26354	26354	25394	25394	25394	25394
including PAR (Q_f), 10^9 J	12650	12650	12189	12189	12189	12189
Q_f absorbed by plants (Q_{Af}) of 1 ha plantation, 10^9 J	5821	6063	6248	6184	6064	5445

Q_{Af} accumulated by plant biomass (Q_M) of 1 ha plantation, 10^9 J	95	105	162	128	126	88
Q_{Af} output to transpiration and heating of leaves (Q_T + Q_t) of 1 ha plantation, 10^9 J	5638	5867	5993	5963	5847	5276

Agrocenoses of annual crops absorb about 80% of PAR under optimum leaf area per unit ground area (leaf area index) with interval from 4 to 5 m^2/m^2 [6]. Perennial crops', including grapevines, cultivated in row plantings, is characterized by incomplete coverage. As a result, the part of PAR in values of 40-60% incident on the soil surface [3]. In this regard, the value of PAR performance coefficient on vineyards is lower compared to agrocentoses of annual crops.

Determination of the PAR performance coefficient on vineyards is possible with the help of indicators of the relative fluxes of solar radiation on the horizontal and lateral parts of the simple geometric model parameters of the leaf cover. In vineyards, with training system of vertical shoot positioned and guyot, the canopy architecture is modeled as a prism, and the row - a rectangular parallelepiped; using of cordon training system with high trunk vine forming the canopy structure is modeled as an elliptic (with trunk 120 cm) or circular cylinder (with trunk 150 cm). In conditions of experiment during plant growing season values of Q_{Af} varies from 5.4 to 6.2 x 10^{12} joule depending on the parameters of the canopy management systems.

Values of Q_M is informative indicator of agrocenosis efficiency. Determination of the total annual biomass of perennial crops related with methodological and technical problems. In researches with grape plants for the size of annual biomass accepted weight of shoots, leaves and bunches [2]. It is established, that the values of Q_M is depending of vineyard training system vary in large intervals from 95 to 162 x 10^9 J. With increasing density of vines per unit area up to 2666 vines per 1 hectare, compared to 2222 vines per 1 hectare, energy accumulated in biomass increases by 26% on plantation of Suholimanskii belii cultivar and by 43% – Odesskii ciornii cultivar. With the identical vine spacing, but different types of vine forming on plantation of Rubin tairovskii cultivar the values of Q_M change only by 5%.

Approximately 90% of Q_{Af} is used for transpiration providing transport of substances in plants and the constant temperature of the photosynthetic apparatus. The energy expenses for the evaporation of water are about 2.5 x 10^6 J per gram of water, independently of the mechanism of water transformation from solid to gaseous state. The obtained dates are possible follow to calculate the required amount of water for the maximum possible transpiration. The efficiency of light energy capture in agrocenoses is estimated by the value of the absorbed and uses of PAR on the process of net photosynthesis (η_{Af}). Figure 1 shows that the values η_{Af} change insignificantly under the influence of the vine forming (Rubin tairovskii cultivar), but varies in a considerable interval (from 1.61 to 2.59%) under the influence of the vine spacing. High values of η_{Af} is characterized of vineyards with a vine spacing 3 x 1.25 m on the Suholimanskii belii cultivar for an average of 3 years is 2.59%, on the Odesskii ciornii cultivar – 2.06%.

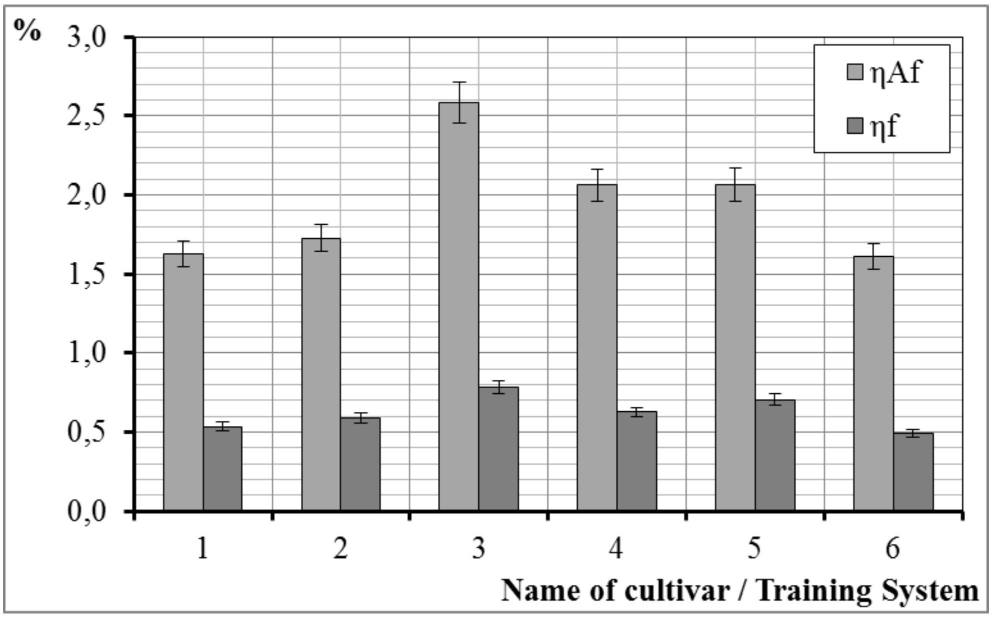

Figure 1. Performance coefficient of absorbed (ηAf) and incident (ηf) of PAR on vineyards with different canopy structure, on average for 2013-2015.

Name of cultivar / Training system: 1 – Rubin tairovskii / Vertical shoot positioned; 2 – Rubin tairovskii / Cordon;3 – Suholimanskii belii / Vertical shoot positioned; 4 – Suholimanskii belii / Cordon; 5 – Odesskii ciornii / Guyot; 6 – Odesskii ciornii / Vertical shoot positioned.

The values of η_f on vineyards of vertical shoot positioned training system with identical of vine spacing approximately correspond to plantations of cordon training system; the value of η_f is 0.53-0.59%. With increasing number of vines per unit area (vine spacing 3 x 1.25 m) independently of vine forming the values of η_f increased to 0.78% (on plantation of Suholimanskii belii cultivar) and 0.70% (on plantation of Odesskii ciornii cultivar), compared with vine spacing 3 x 1.5 m (0.63% and 0.49%, respectively). Evidently, in conditions of water and mineral deficiency the increase of plant productivity and vineyard yield is possibly by increasing the density of vines per unit area (vine spacing) to optimal values. The actual values of η_f (0.49-0.78%) is characterized of studied vineyards with low productivity. On the basis of calculations, the values of η_f on vineyards is possible to increase up to 4-5% in condition with optimal parameter of leaf area index, soil water available to plants and mineral nutrition during growing season; up to 1-2% only with optimized canopy management system, but in the natural environment conditions of moderately continental climate.

Conclusions

The method of energy budget is characterized by informativeness and can be used to evaluate the efficiency of vineyards with different training system and to establish the mechanism of influence of agrotechnical factor on biological productivity. Vineyards with the studied training system is characterized by a low level of biological productivity, is necessary to studying and developing bio-adaptive parameter of vine spacing and vine forming which in conditions of water deficit must be correspond to the optimal relationship between soil water availability for plants and insolation incident. Using the above described model set up, in researches of cultivation technologies of grapevines it is possible to estimate maximum possible productivity and yield under optimum conditions.

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