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THEORETICAL OVERALL ENERGY BALANCE IN A GREENHOUSE FOR FLOWERS

Bodolan Ciprian [1], Gh. Brătucu [2]

[1] Transilvania University of Brasov, Braşov, ROMANIA, bodolan.ciprian@gmail.com

[2] Transilvania University of Brasov, Braşov, ROMANIA, gh.bratucu@unitbv.ro

Abstract: The meteorological factors participate in the formation of the energetic balance influencing the exchange of heat and air circulation in greenhouses. Building type, orientation, size and location of the greenhouses are obviously conditioned by weather elements. Exists a close connection between the action of internal and external climatic factors in the construction of greenhouses, with many implications for economic, technological and biological, to be considered in drafting greenhouses and specialized studies. To calculate the overall balance should take into account the heating balance, the radiative balance and the energy required to sweat, evaporation, the sensible heat of air and soil as well as the stored energy in the process of formation of assimilates through photosynthesis.

Keywords: *greenhouse, energy, balance, flowers*

Introduction

In the design and operation of greenhouses, as well as dimensioning the heating installations of such, the energy balance occupies a central place. With this we can determine any changes in the greenhouse microclimate, with also the possibility of determining the size of heat loss.

In greenhouses, heat consumption is related to heat loss, which appears in the expression of equality:

$$Q_{cons.} = Q_{loss.} \quad (1)$$

The higher heat losses are, the greater the consumption of heat is, up to achieves equality between them, conditioned by optimum heat regime that cultivated plants grow up and develop. So, the energy balance can be simplified formula:

$$Q_{cons.} = Q_{rad.} + Q_{rad.} + Q_{cond.} - Q_{rad.s.} \quad (2)$$

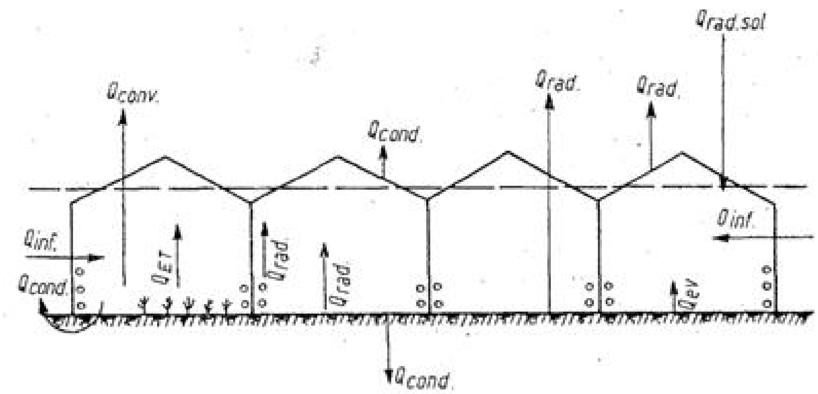

Figure 1: Simplified energy balance components

2. THE OVERALL BALANCE

To calculate the overall balance should take into account the heating balance, the radiative balance and energy required to sweat, evaporation, sensible heat of air and soil as well as the stored energy in the process of formation of assimilates through photosynthesis.

The heating balance

Inside the greenhouse, the amount of heat necessary for plant growth and development as for the normal biological processes is given by the heating system used, to which is added the heat ceded from the ground as a result of radiation emission with longer wavelengths retained by the roof of glass or plastic. In greenhouses coated with polyethylene there is a possibility in case of frost or during the night that temperatures will fall below values recorded in the atmosphere. This phenomenon of thermal inversion is explained by excessive transparency of polyethylene for long wavelength radiation is depending on the nature of the soil, wind action and building leaks.

For greenhouses, Kurtener (1969) believes that thermal balance is determined by the structural characteristics and thermal physical properties of construction by meteorological factors and thermal characteristics of the soil. Heat balance equation for a time interval $(0, \tau_m)$ is represented as follows:

$$Q_{inc} + Q_r - Q_s - Q_c = 0 \tag{3}$$

where:

Q_{inc} - the amount of heat transferred by the heating pipes;

Q_r - the average amount of heat for the period $(0, \tau_m)$ added to greenhouse by solar radiant energy;

Q_s - the average amount of heat taken from the ground;

Q_c - quantity of heat lost through building elements.

The heat balance components Q_{inc} and Q_r can be calculated with the following relations:

$$Q_{inc} = q_{inc} * S \tag{4}$$

$$Q_r = \phi\,(1 - r)\, q_{rs} * S \tag{5}$$

where:

S - greenhouse area in m2;

φ - the transparency of glass in the visible range of the solar spectrum;

r - surface albedo of building elements;

q_{rs} - the amount of solar radiation, the average for the time τ_m.

The radiative balance

To calculate the net amount of radiation is appropriate to compile a thorough radiative balance. In this respect, often is used the calculation scheme of Poliak's that total radiative flux density ϕ'' issued by a surface must be equal to the sum of densities of radiative fluxes from the surface own emission $e\phi_p''$ (,,) and that of the radiation falling on the surface regarded as foreign and is reflected $(1-a)\phi_s''$.

Generally this means:

total radiation = own emission + reflected radiation.

The mathematical expression of this radiative balance is:

$$\phi_r'' = e\phi_p'' + (1-a)\phi_s'' \tag{6}$$

where:

ϕ_r''- total radiative flux density emitted by a surface;

e - emission coefficient;

ψ_p'' - radiative flux density due to their emissions of the area concerned;

a - absorption coefficient;

ϕ_s''- foreign radiation radiative flux density.

In addition, it can be seen that the density of the net radiative flux emitted by a surface can be written:

net radiation = own emission own - radiation absorption,

which mathematically comes down to:

$$\phi_n'' = c\phi_p'' \quad a\phi_s'' \tag{7}$$

Poliak's system can be written more simply using Kirchoff's law:

$$\phi_n'' = \phi'' - \phi_s'' \tag{8}$$

$$\Phi'' - \Phi''_p - \frac{1-a}{a}\Phi''_n \qquad (9)$$

When doing calculations proceed as follows: ϕ''- total radiation depending on the surface temperature, expresses that knowing: $\phi''_p = \sigma T^4$ and unknown function ϕ''_n .

Therewith can be calculated immediately the foreign radiation ϕ''_s so that, finally, shall be found, in fact, the value of ϕ''_n which seeks expressed based on the surface temperature.

This simplified radiative balance is applied to each element of the greenhouse in part: soil and for clear cover. Its disadvantage is that the calculation ignores some important factors of radiative balance that can be found detailed in the scheme detailed by Bouchet and Damagnez (1967).

For the calculation of the radiation balance they take into account both the balance at the surface of the ground as the surface of the roof (the inner and outside side), in this case polyethylene (figure 2).

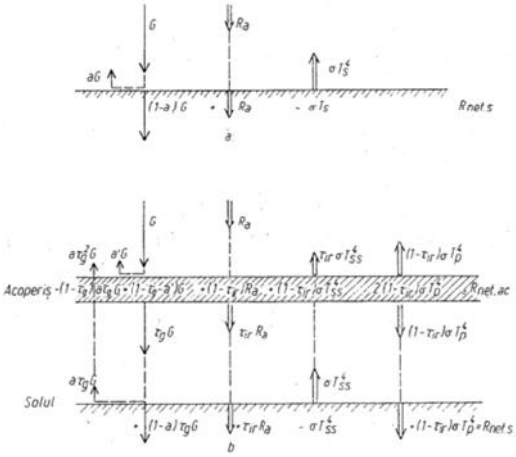

Figure 2: Main radiative balance scheme for greenhouse plastic; a - in the atmosphere; b - in the greenhouse (after Bouchet and Damagnez**)**

Soil surface radiative balance has the following expression:

$$R_s - (1-a)\tau_g G + \tau_{r,ir} R_{at} - \sigma\left[T_s^4 + T_p^4(1-\tau_{r,ir})\right] \qquad (10)$$

Where:

R_s - radiative balance at the soil surface;

$(1-a)\tau_g G$ - global radiation absorbed by the soil;

a - ground surface albedo;

τ_g- absorption coefficient of the roof in the visible range;

G - global radiation;

$\tau_{r.ir} R_{at}$ - atmospheric radiation transmitted by the roof and received by soil;

$\tau_{r.ir}$ - the roof absorption coefficient in the infrared;

R_{at} - atmospheric radiation;

σT_S^4 - radiation from the soil;

$\sigma T_S^4(1-\tau_{r.ir})$ - the radiation emitted by the roof and received by soil.

At the roof surface the radiative balance is expressed by the relation:

$$R_p = (1-\tau_g - a')G + (1+\tau_g)a\tau_g G + (1+\tau_{r,ir})R_{at} + (1-\tau_{r,ir})\sigma T_S^4 - 2(1-\tau_{r.ir})\sigma T_p^4 \qquad (11)$$

where: $(1-\tau_g - a')G$ - global radiation absorbed by the roof;

$(1+\tau_g)a\tau_g G$ - radiation reflected by soil in the visible and absorbed by the roof;

$(1+\tau_{r.ir})R_{at}$ - infrared radiation absorbed by the soil;

$(1 \text{ I } \tau_{r.ir})\sigma T_S^4$ - radiation from soil and absorbed by greenhouse cover;

$(1+\tau_{r.ir})\sigma T_p^4$ - the radiation emitted by the two surfaces of the roof;

a' - the roof albedo

After Spoelstra van der Post and Hopmans (1973) the energy balance for determining the crop transpiration has the following expression:

$$R_{abs} - E_p + E_a + E_s + V_p + V_s + F \qquad (12)$$

Where: R_{abs}. - Radiation absorbed by plant and soil;

E_p - plant transpiration;

E_a - intercepted water evaporation due to irrigation;

E_s - water evaporation from the soil;

V_p - air sensible heat taken from plants and soil;

V_s - sensible heat taken from the ground;

F - energy from photosynthesis.

All of these components of energy balance are expressed in kcal / m^2 / h.

To determine the radiation absorbed by plant and soil we used the following expression:

$$R_{abs} = \alpha_r(T_{sticlă} - T_{plană}) + C_2 - C_3 \qquad (13)$$

where:

α_r- coefficient of heat transfer due to the radiation; value used in the calculations is 5 kcal / m 2 h ° C;

C_2 – radiation measured with pyrometer located near top of plant

C_3 – radiation measured with pyrometer located at a greater height above the vegetation.

However in the greenhouse determine the penetration of light by using the following equation:

$$P_t = \frac{C_2}{C_1} * 100\% \qquad (14)$$

where:

P_t - penetration of light in the greenhouse;

C_1 – radiation measured with pyrometer above the greenhouse.

Total evaporation is given by:

$$E_t = E_p + E_a + E_s \qquad (15)$$

Total evaporation in greenhouses is determined by the expression:

$$E_r = N_a \frac{X_k - X_b}{1000} * \frac{C_e}{A} \qquad (16)$$

where:

E_t - in kcal / m2h

N_a - number of kilos of dry air;

X_b - the amount of moisture in the outside air, g / kg;

X_k - the amount of moisture in the air given by the fan, g / kg;

C_e - heat of evaporation, kcal / kg;

A - area of the ground covered in m2.

Determination of moisture content of the outside air or the one added by the fan is made with the Mollier diagram (figure 3). The other elements of the total evaporation balance are determined by the model below.

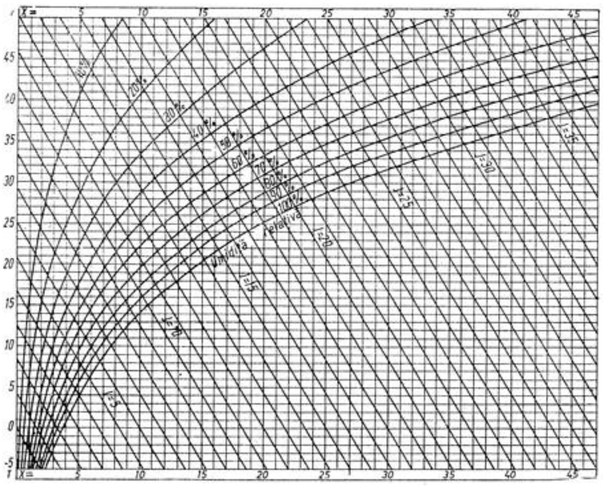

Figure 3: Mollier’s diagram for determining the relative humidity of the air.

Soil evaporation (E_s) is determined by gravimetric means; for example weigh in a cymbal with a 20cm diameter approx. 2cm home soil, considering that it is enlightening for short observation period of one day. Values of E_s are shown in the table below:

Table 1: Soil evaporation in mm (after Spoelstrav. d. Post and Hopmans)

Place of observation		Day period (hour)	
		from 9 to 13:30	from 13:30 to 15:30
section 1	alley	0,3	0,3
	layer	0,4	0,3
	average	0,35	0,3
section 2	alley	0,8	0,0
	layer	1,0	0,3
	average	0,9	0,15

Irrigation water evaporation (E_a) was determined experimentally by Spoelstrav and Hopmans by intercepting the water from a plant leaves in function of artificial rain intensity. Starting from to the maximum value of R_{abs} = 400 kcal / m^2 the artificial rain intensity given by sprinkler was set at 0.2 mm / h and time duration of watering was set at 1.5 minutes, with an interval of 6 minutes paused. Taking into account the water that drains from the leaves, it was estimated that 20% of intercepted water evaporates so, it is estimated at a value of 100 kcal / m^2h. Evaporation plant is calculated by subtracting the total evaporation E_s and E_a.

The total energy balance, in addition to the terms of evaporation, evapo-transpiration and the radiation other related terms appeared such as sensible heat balance:

$$V_t = V_c + V_p + V_s \tag{17}$$

Where:

V_t - total sensible heat;
V_c - heat sensitive cornice
V_p - air sensible heat taken from plant and soil;
V_s - sensible heat taken from the ground.

Compared to the other terms in equation (17) it is found that the term V_c is much smaller and therefore negligible. In this review, the sensible heat term Vp is central. Depending on how the greenhouse ventilation is made (horizontal or vertical) one can determine the heat taken from the ground and from other parts of the building. The sensible heat is given by the product of the total amount of ventilation, the difference of temperature between ventilated and outer air and the specific heat of air,

$$V_t = C_a * Q * \Delta T \tag{18}$$

where:

C_a - specific heat of air in kcal / m^3 °C;
Q - the greenhouse ventilation in m^3 / h;
ΔT - the difference of temperature between ventilated and outer air °C.

The formation heat of assimilates F is calculated after were measured the amounts of CO_2 taken up by plants from the greenhouse air. The total energy balance of a greenhouse make obviously, how radiation energy absorbed is used for transpiration, evaporation, sensible heat of the air and warming the soil as well as the stored energy in the process of formation of assimilates through photosynthesis.

3. CONCLUSION

1. In the design and operation of greenhouses, as well as dimensioning the heating installations of such, the energy balance occupies a central place. With this we can determine any changes in the greenhouse microclimate, with also the possibility of determining the size of heat loss.

2. In greenhouses coated with polyethylene there is a possibility in case of frost or during the night that temperatures will fall below values recorded in the atmosphere.
3. Determination of moisture content of the outside air or the one added by the fan is made with the Mollier diagram
4. The total energy balance of a greenhouse make obviously, how radiation energy absorbed is used for transpiration, evaporation, sensible heat of the air and warming the soil as well as the stored energy in the process of formation of assimilates through photosynthesis.

4. REFERENCES

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