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Researches the efficiency of evaporation systems for decreasing the air's temperature in the greenhouses during summer period

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ABSTRACT: The article deals with the issues of modern technical solutions for maintaining the microclimate in flower farms. Modern methods of growing and cutting rose flowers include, on the one hand, effective regulation of the microclimate in greenhouses throughout the year, and, on the other hand, the technical re-equipment of greenhouses for low-energy technology. Temperature and relative humidity in greenhouses can be controlled using "wet mat" type evaporative coolers with an exhaust ventilation system. The calculation of the technical parameters of evaporative air cooling systems in the greenhouse in a summer period was performed. Experimental studies were carried out in the economy of the Tashkent region, revealed temperature and humidity modes and factors affecting the efficiency of evaporative cooling systems with exhaust ventilation

KEY WORDS: system of air conditioning, evaporative cooling, greenhouses, temperature and humidity conditions

I.INTRODUCTION

In climatic zones where the maximum summer temperature is consistently above 35^{0}C, and the internal temperature of the greenhouse exceeds 300C for a long period, it is advisable to combine an exhaust ventilation system with evaporative air cooling systems [1].
For the rose culture, the air temperature in greenhouses in summer up to 27^{0}C allows you to get high-quality cut flowers [2]. Under conditions of high summer temperatures over 40^{0}C and low air humidity, a system of additional air humidification is used on the rose culture [3]. Evaporative cooling systems atomize water to particles with a diameter of less than 100 microns, which does not lead to the formation of moisture droplets on the leaves and, as a result, the leaf surface of plants [4]. The use of such systems allows not only to effectively reduce the temperature of the leaves due to the evaporation of moisture from their surface, but also saves the energy spent by plants on the evaporation of water to cool the leaves. The temperature of leaves and flowers in summer is usually 2÷7^{0}C more than the air temperature in greenhouse [5].
Modern methods of growing and cutting rose flowers include, on the one hand, effective regulation of the microclimate in greenhouses throughout the year, and, on the other hand, the technical re-equipment of greenhouses for low-energy technology. At the same time, during the blooming of the buds, the temperature needs to be slightly lowered, during the flowering period - to be increased. The humidity level should be at around 70 percent [6]. In winter, additional lighting is required. In summer, on the contrary, it is necessary to slightly shade the bushes with curtains. Among other things, regular ventilation is required. The problem of cooling greenhouses lies in the fact that at high summer air temperatures in greenhouses, the length of the shoots and the diameter of rose flowers are sharply reduced [7]. Temperature control in greenhouses during the summer period is a necessary element for high yields [8]. High temperature can have a negative effect on the growth of plants in greenhouses, as it affects the processes that take place in the plants [9].

II. DESCRIPTION OF SCHEME

Fans work to exhaust air from the greenhouse. Moisture is sprayed onto the mats, and cooled air is supplied to the greenhouse by lowering the temperature of the air passing through the wet mats. Despite certain energy costs, such a

system effectively reduces the air temperature in greenhouses. In this process, the greenhouse vents are in the closed position [10].
Temperature and relative humidity in greenhouses can be controlled using evaporative coolers (Figure 1).

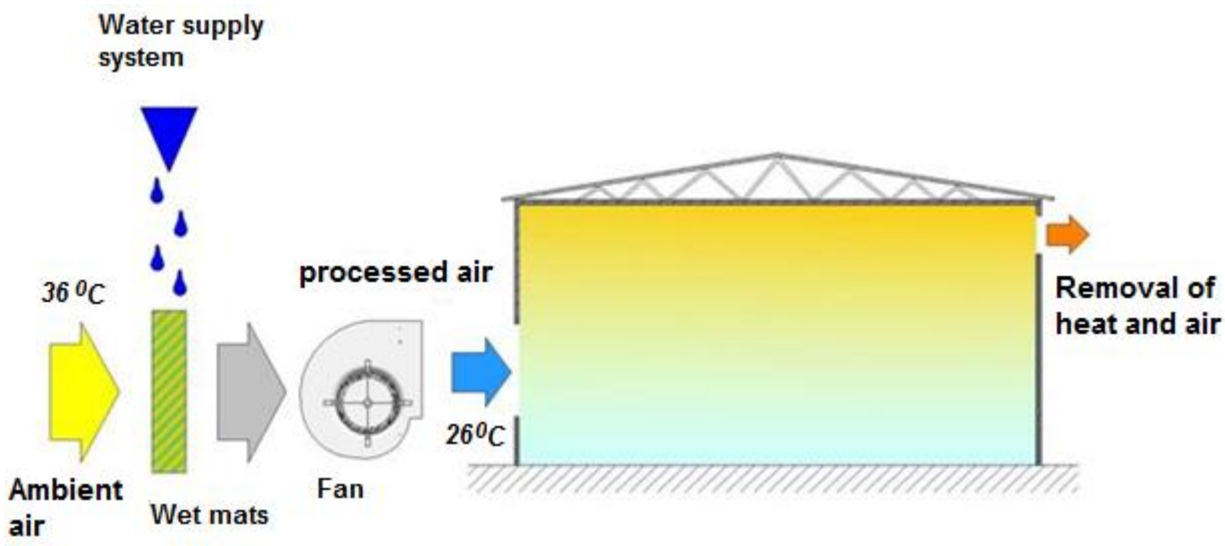

Figure 1. Air cooling evaporative system in greenhouses

The system is based on evaporative cooling cassettes "wet mats" [11]. The cassette consists of corrugated pulp and paper sheets with different corrugation angles. The sheets are impregnated with a special compound and joined together. The design of the cassette guarantees high evaporation efficiency and low pressure loss during operation [12]. Due to a special impregnation technology for highly absorbent cellulose paper, a strong self-supporting structure is created, protected from decay and destruction, with increased durability.
When using evaporative coolers in greenhouses, it is desirable that the supplied air has a range of no more than 15 meters in the greenhouse [13]. The heating of the cooled air during its run is limited by this distance. In some cases, it is desirable to reduce the air mileage to this limit. In some cases, this limit should be reduced to 9 meters [14]. Perhaps the use of flexible ducts for uniform air supply. The supply of cooled, humidified air to the greenhouse with the help of evaporative coolers creates, among other things, an additional greenhouse effect, which in many cases is useful for grown plants. The use of these coolers in greenhouses requires certain practical skills, since different plants require a different approach in creating an acceptable and most comfortable microclimate for them [15]. Air must enter the greenhouse at a relatively low speed so as not to damage the plants (which can be automatically controlled by coolers). In general, it should not exceed 0.5 m/s [16].
Experimental studies were carried out in one of the flower farm in the Tashkent region. The total volume of the greenhouse was 90m×32m×2m. Air was extracted by 16 fans with technical parameters: P=1.1 kW, n=1400 rpm. The construction of greenhouse with evaporative air cooling system is shown in Figure 2.
Mats are installed in special openings in the side glazing of greenhouses facing the direction of the prevailing winds in the summer. Slow-speed fans with a blade diameter of up to one meter and low power electric motors are installed in the middle of the greenhouse in the upper part.
Taking into account the heating of the exhaust air in the exhaust fans, we assume that at the inlet to the cooling towers, the air will have a dry temperature of 24.6 °C and t_m = 17.2 °C [17].
There are determined the final temperature of the water at the outlet of the "wet mats"

$$t_{w1} = 17{,}2 + 2 = 19{,}2\ °C.$$

There are taken the water temperature difference in the air cooler as 2.5 °C and calculate the water temperature at the inlet to the "wet mats" $t_{w2} = t_{w1} + 2.5 = 21.7$ °C.

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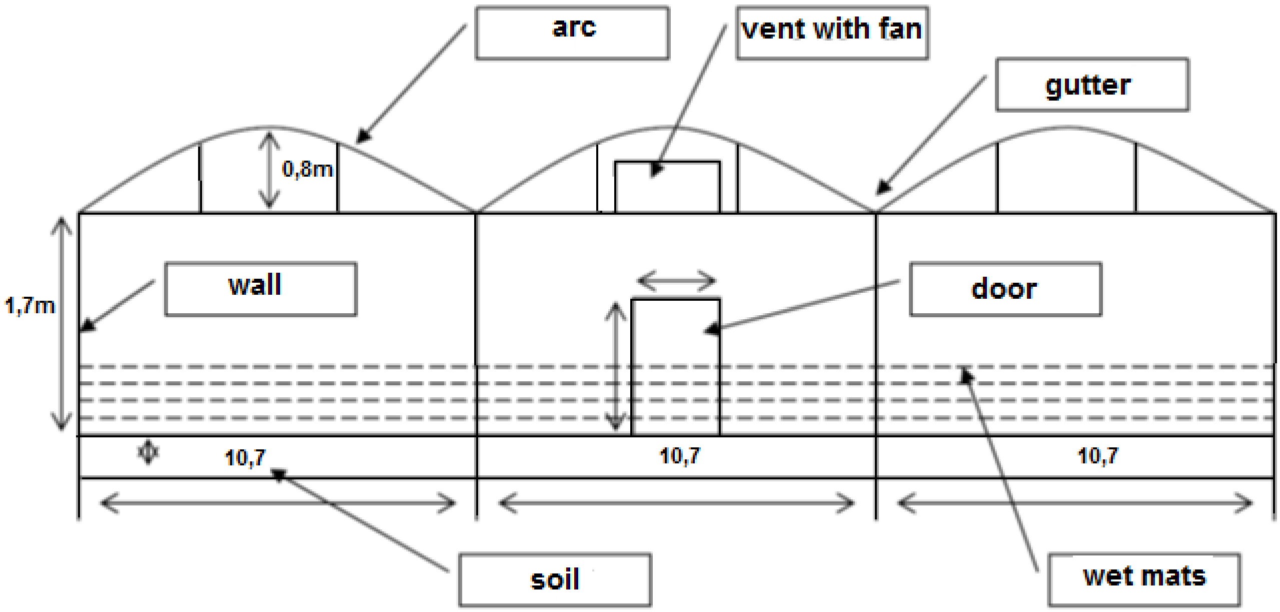

Figure 2. Design of flower farm in the Tashkent region

With initial data: t_{m1} = 17.2 °C; t_{w2} = 21.7 °C; t_w = 19.2 °C are selected the evaporative cooling system with the following technical characteristics:
– design heat load 50.3 kW;
– maximum heat load at given temperatures 55.5 kW;
– water consumption 4.81 litr/seconds;
– pressure loss in the nozzles 30 kPa;
– loss of water for evaporation ~0.02 litr/second;
– water loss for drainage ~0.05 litr/second;
– air consumption 14400 m^3/h;
– number of fans 16;
– electric motor power 1 kW;
– weight, net 470 kg;
- working weight, with water 685 kg;
– dimensions one wet mat: length 1640 mm; width 128 mm; height 2300 mm.

As can be seen, the air flow rate in the cooling tower of 14400 m^3/h almost exactly coincides with the air flow rate removed from the greenhouse by exhaust systems: L_{sp} = 14500 m^3/h.

Perhaps the use of flexible ducts for uniform air supply. The supply of cooled, humidified air to the greenhouse with the help of evaporative coolers creates, among other things, an additional greenhouse effect, which in many cases is useful for grown plants [18]. The use of these coolers in greenhouses requires certain practical skills, since different plants require a different approach in creating an acceptable and most comfortable microclimate for its.

III. METHODOLOGY

A. Survey of publications

The mathematical model of the heat and mass transfer process consists of the following components (Figure 3):

energy equations in channels [19]:

$$\rho \cdot V_T(x,y) \cdot C \cdot \frac{\partial T}{\partial x} = \frac{\partial}{\partial y}\left(\lambda(T)\frac{\partial T}{\partial y}\right), x \in L, y \in (Hp, Hp + h) \quad (1)$$

$$\rho \cdot V_t(x,y) \cdot C \cdot \frac{\partial t}{\partial x} = \frac{\partial}{\partial y}\left(\lambda(t)\frac{\partial t}{\partial y}\right), x \in L, y \in (-h, 0) \quad (2)$$

mass transfer equations in a "wet" channel:

$$V_t(x,y) \cdot \frac{\partial W}{\partial x} = \frac{\partial}{\partial y}\left(D(t)\frac{\partial W}{\partial y}\right), x \in L, y \in (-h, 0) \quad (3)$$

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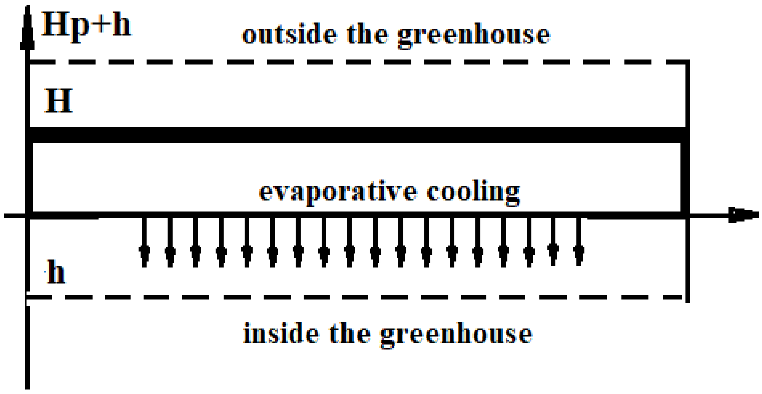

Figure 3. Mathematical model of the process of heat and mass transfer in a cassette based on "wet mats" of an evaporative cooling system

temperature distribution equations in the wet mat:

$$\frac{\partial Tp}{\partial x}+\frac{\partial Tp}{\partial y}=0, x\in(0,L), y\in(0,Hp) \quad (4)$$

input conditions:

$$t|_{x=0}=t_{in}, \qquad \varphi|_{x=0}=\varphi_{in}, \qquad y\in(-h,0)$$

$T|_{x=0}=T_{in},\ y\in(Hp,Hp+h)$- in the case of forward flow and

$T|_{x=L}=T_{in},\ y\in(Hp,Hp+h)$- in case of counter current,

parity conditions on the axes of symmetry of the channels

$$\frac{\partial T}{\partial y}\Big|_{y=Hp+h}=0, \qquad x\in(0,L), \qquad \frac{\partial t}{\partial y}\Big|_{y=-h}=0, \qquad x\in(0,L)$$

$$\frac{\partial W}{\partial y}\Big|_{y=-h}=0, \qquad x\in(0,L)$$

impermeability conditions at the ends of the wet mat

$$\frac{\partial Tp}{\partial y}\Big|_{x=0}=0, \qquad y\in(0,Hp), \qquad \frac{\partial Tp}{\partial y}\Big|_{x=L}=0, \qquad y\in(0,Hp)$$

pairing conditions [20]:

$$T|_{y=Hp}=Tp|_{y=Hp},\ x\in(0,L), \qquad t|_{y=0}=Tp|_{y=0},\ x\in(0,L)$$

$$\lambda(T)\frac{\partial T}{\partial y}=\lambda_{mat}(Tp)\frac{\partial Tp}{\partial y}, y=Hp,\ x\in(0,L) \quad (5)$$

$$\varepsilon\cdot R(t)\cdot D\cdot\frac{\partial W}{\partial y}=\lambda_{mat}(Tp)\frac{\partial Tp}{\partial y},\lambda(T)\frac{\partial t}{\partial y}y=0,\ x\in(0,L) \quad (6)$$

here W is the vapor density, kg/m^3, λ_{mat} is the thermal conductivity of the mat, W/m/deg, ρ is the air density, kg/m^3, C is the specific heat capacity, J/kg/deg, D is the diffusion coefficient, m^2/s.

B. Calculation of the characteristics

The coefficient of thermal conductivity of air was determined by the known linear relationship:

$$\lambda(t) = 0.023577 + 0.00007\cdot t. \quad (7)$$

Saturated vapor density and diffusion coefficient were determined by the formulas:

$$D(t)=10^{-5}\cdot e^{0.00616\cdot t+0.719}, \quad (8)$$

$$W_{saturated}=10^{-5}\cdot(3.5\cdot t^2+40.6\cdot t+1090.5), \quad (9)$$

obtained by approximating tabular data in the operating temperature ranges, by which it means the air temperatures at the inlet and outlet of the cooler, usually in the range 15÷45^{0}C.

$$R(t)= (2500.6 - 2.372\cdot t)\cdot 10^3 \quad (10)$$

here $R(t)$ is the specific heat of vaporization, J/kg, ε is a factor characterizing the difference between evaporation from the surface of a porous plate and evaporation from a free surface. It depends on porosity, pore shape, evaporation zone depth, etc. This coefficient can be determined from the balance equation:

$$\varepsilon\cdot R\cdot\left(\varphi_{out}\cdot W_{saturated}(t_{out})-\varphi_{in}\cdot W_{saturated}(t_{in})\right)=C\cdot\rho\cdot(t_{in}-t_{out})+k\cdot C\cdot\rho\cdot(T_{in}-T_{out}) \quad (11)$$

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k- the ratio of the costs of the main stream to the auxiliary one. The input and output characteristics for (11) are determined experimentally.
The velocity in the channels was determined by the formula for the laminar flow regime, taking into account the hydrodynamic initial section [17]:

$$V(x,y) = V_{in} \cdot \left[1{,}5 - \frac{1{,}5y^2}{h^2} - 2\left(\sum_{n=1}^{\infty}\left(1 - \frac{cos\left(\frac{g_n \cdot y}{h}\right)}{cos(g_n)}\right) \cdot e^{\left(-4\frac{g_n^2 \cdot \nu \cdot x}{v_{in} h^2}\right)} \Big/ g_n^2\right)\right] \quad (12)$$

here g_n are the positive roots of the equation *tgx* = *x*, ν is the kinematic viscosity of air, m^2/s, *h* is half the channel section, m, V_{in} is the inlet air flow velocity, m/s.

IV. RESULTS OF CALCULATIONS

The temperature and humidity parameters of the air inside the greenhouse were measured during the operation of the evaporative air cooling system, as well as the relative humidity of the air (Table 1).
Under such conditions, the developed evaporative type coolers consistently increase their efficiency by lowering the air temperature in the greenhouse, or maintaining it at the desired level throughout the day using sensors installed in the greenhouse. A worn belt, while consuming the same (with a new belt) amount of energy, is not able to provide 100% fan performance. Even a 10% loss in capacity lead to decreasing about 3^{0}C of the cooling effect of evaporative cooling exhaust ventilation based on evaporative cooling. Dust sticking to the blades during operation can change the aerodynamic characteristics of the blades and reduce air exchange by 30%.

Table 1. Measurements of the temperature and humidity conditions during the operation of the evaporative cooling system in the flower farm in the Tashkent region 19.08.2022

Time	inside the greenhouse		outside the greenhouse	
	Temperature, ^{0}C	Humidity, %	Temperature, ^{0}C	Humidity, %
7.00	24	64	24	36
7.30	24	64	24	36
8.00	24.5	64	25	35
8.30	26.8	65	25	35
9.00	27.2	64	25	35
9.30	27	64	25	34
10.00	27.6	63	27	33
10.30	28.5	64	29	31
11.00	28.3	62	29	31
11.30	28	61	30	30
12.00	28.2	63	32	30
12.30	28.5	64	33	30
13.00	28.7	64	34	29
13.30	28.6	64	35	25
14.00	28.5	64	36	22
14.30	28.4	65	36	21
15.00	28.7	65	36	25
15.30	28.9	61	35	24
16.00	28.4	64	34	25
16.30	28	66	33	28
17.00	27	69	33	30
17.30	26.1	73	32	30
18.00	25.7	74	31	30
18.30	24.2	75	31	29

Relative humidity decreases as the temperature rises (Figure 4). The absolute amount of water vapor in the air varies slightly with temperature.

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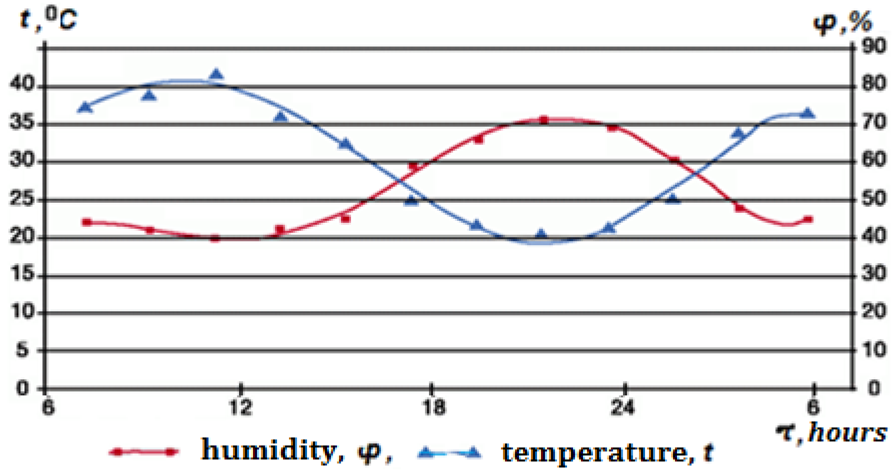

Figure 4. Air temperature and humidity cycle during the summer day inside the experimental greenhouse during operation of the evaporative cooling unit

V. CONCLUSION

Outdoor airflow at temperature 36^0C and relative humidity of 30% passes at the required speed through the "wet mats". The air temperature drops and the humidity level rises, causing the temperature to 26^0C at a relative humidity of 70%. Cooled air is supplied into the room, and the same volume of warm air is expelled from the room using exhaust ventilation.

REFERENCES

[1] Anarbaev, A., Tursunov, O., Kodirov, D., Nazaraliev, D., Obidjanov, D. Determination of model parameters of water-nutritional processes in soil for nitrogen compounds. IOP Conference Series: Earth and Environmental Science, 2021, 939(1), 012086
[2] Anarbaev, A., Tursunov, O., Kodirov, D., Davronov, Q., Davirov, A. UV treatment of agricultural plants in territories subject to salination of soil. IOP Conference Series: Earth and Environmental Science, 2021, 939(1), 012087
[3] Anarbaev, A., Tursunov, O., Kodirov, D., Shipilova, K., Obidjanov, D. Intensification of nitrification processes in soil by ultraviolet (UV) irradiation IOP Conference Series: Earth and Environmental Sciencethis link is disabled, 2021, 939(1), 012015
[4] Anarbaev, A., Koroly, M. Autonomous hybrid solar-heat pump for system heat-cooling in buildings. IOP Conference Series: Materials Science and Engineering, 2021, 1030(1), 01217
[5] Anarbaev, A., Tursunov, O., Zakhidov, R., Tuhtaeva, G., Babaev, A. Determination the installation efficiency of the evaporative air cooling in the greenhouse by temperature-moisture regime. IOP Conference Series: Earth and Environmental Sciencethis link is disabled, 2020, 614(1), 012026
[6] Deziani M., Rahmani Kh., Mirrezaei Roudaki S. J., Kordloo M. Feasibility study for reduce water evaporative loss in a power plant cooling tower by using air to Air heat exchanger with auxiliary Fan. Desalination. Volume 40616 (March 2017) 119-124
[7] Okanlawon S.A., Olorunnisola A.O. Development of passive evaporative cooling systems for tomatoes Part 1: construction material characterization, Agric. Eng. Intern.: CIGR J. 19 (1) (2017) 178–186.
[8] Saltveit M.E. Respiratory metabolism, Postharvest Physiol. Biochem. Fruit Veg. 4 (2018) 73–91.
[9] Ndukwu M.C., Manuwa S.I. Review of research and application of evaporative cooling in preservation of fresh produce, Agric. Eng. Intern.: CIGR J. 7(5) (2014) 85–102.
[10] Korir M.K., Mutwiwa U.N., Kituu G.M., Sila D.N. Effect of near infrared reflection and evaporative cooling on quality of mangoes, Agric. Eng. Intern.: CIGR J. 19 (1) (2017) 162–168.
[11] Amer O., Boukhanouf R., Ibrahim H.G. A review of evaporative cooling technologies, Int J Environ. sci. dev. 6(2) (2015) 111–117.
[12] Misra D., Ghosh S. Evaporative cooling technologies for greenhouses: a comprehensive review, Agric. Eng. Intern.: CIGR J. 20(11) (2018) 1–14.
[13] Chijioke O.V. Review on evaporative cooling systems, J. Greener Sci. Eng. Technol. Res. 7(1) (2017) 1–20.
[14] Zakari M.D., Abubakar Y.S., Muhammad Y.B., Shanono N.J., Nasidi N.M., Abubakar M.S., Muhammed A.I., Lawan I., Ahmad R.K. Design and construction of an evaporative cooling system for the storage of fresh tomatoes, Asian Res. publish. netw. (ARPN) J Eng. Appl. sci. 11 (4) (2016) 2340–2348.
[15] Deoraj S., Ekwue E. I., Birch R. An evaporative cooler for the storage of fresh fruits and vegetables, J. West Indian Eng. 38(1) (2015) 86–95.
[16] Ogbuagu N.J., Green I.A., Anyanwu C.N., Ume J.I. Performance evaluation of a composite-padded evaporative storage bin, Nigeria J. Technol. (NIJOTECH) 36(1) (2017) 302–307.
[17] Sibanda S., Workneh T.S. Effects of Indirect air-cooling combined with direct evaporative cooling on the quality of stored tomato fruit, CyTA - J. Food 17 (1) (2019) 603–612.
[18] GSES Solar-powered pumping in agriculture, in: A Guide to System Selection and Design, NSW Farmers, New South wales, Australia, 2015.
[19] Ndukwu M.C., Manuwa S.I., Olukunle O.J., Oluwalana I.B. Development of an active evaporative cooling system for short-term storage of fruits and vegetables in a tropical climate, Agric. Eng. Intern.: CIGR J. 15 (4) (2013) 307–313.
[20] Babaremu K.O., Omodara M.A., Fayomi S.I., Okokpujie I.P., Oluwafemi J.O. Design and optimization of an active evaporative cooling system, Int. J. Mech. Eng.Technol. 9 (10) (2018) 1051–1061.