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COMPARISON OF EVAPORATIVE COOLING SYSTEM PERFORMANCE USING SEAWATER AND FRESHWATER FOR GROWING BARLEY

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ABSTRACT: Water scarcity is one of the most critical problems confronting many countries, including Egypt. One issue is that agricultural evaporative cooling systems use a lot of water, so water conservation is essential. The goal of this study is to alleviate pressure on freshwater uses in the agricultural sector by using saline water instead of freshwater for the evaporative cooling process. To achieve this objective, a wooden-framed greenhouse covered by a layer of single polyethylene sheet with a thickness of 130 μm was constructed to provide the environmental conditions for barley production during the summer season. Two sources of water (freshwater and seawater) were used to evaluate the use of seawater with an evaporative cooling system and investigate the impact of using seawater on the system's performance. The results indicated that the average indoor temperature ranged from 21.76 C° to 25.16 C° by freshwater with 71.90% and 60.68% average cooling efficiency and coefficient of performance of energy use, respectively while the average indoor temperature by seawater ranged from 22.18 C° to 25.81 C° with 68.08% and 59.09 % average cooling efficiency and coefficient of performance respectively. The results also revealed that the impact of seawater on the physical and chemical properties of barley and the system's performance was negligible when contrasted with the use of fresh water in evaporative cooling. This study demonstrates the viability of evaporative cooling with seawater, which is a significant benefit for evaporative cooling applied in specifically coastal areas for saving freshwater.

Keywords: Environmental control; Greenhouse; Evaporative cooling; Seawater; Barley.

INTRODUCTION

Food and energy resources are critical components for human social and economic growth. Rapid population and urban growth, combined with global economic development, have put significant strain on our planet's limited resources, including water, energy, food, land, and ecosystems, since the turn of the twenty-first century. However, due to global climate change, harsh weather events, uneven distribution of water resources, and carbon emission requirements, the strategic planning and development of food, energy, and water resources will face additional obstacles. (Liu *et al.*, 2018). The term "climate change" is currently of great interest to the global community, both scientifically and politically. Climate has been changing since the beginning of time, but the rate of change in recent years is alarming, and it may be one of the most serious threats to the whole planet (Owusu *et al.*, 2016). The increasing food demand and the change to more complex and accurate food production technologies known as controlled environment agriculture (CEA) have become more critical than ever before. (Vatistas *et al.*, 2022). Controlled environment agriculture (CEA) is a high-tech farming approach in which the plant and its surroundings are subjected to some level of control in order to increase yields and production efficiency. CEA is crucial because of its effects on food availability and costs as severe food insecurity increases (Archambault *et al.*, 2023). Controlled environment agriculture (CEA), which includes greenhouses, high tunnels, vertical farms (vertical or horizontal),

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and plant factories, is increasingly seen as a significant solution to address global food issues. (Ojo and Zahid, 2022).

Evaporative cooling systems are the best alternatives for advantageous air-cooling operation in climate conditions (high temperature and low or medium relative humidity) due to their lower startup and operating costs (Balyani *et al.,* 2015). Evaporative cooling is an energy-efficient, ecologically friendly, and sustainable air-conditioning technique that is rapidly being used in residential and commercial buildings, particularly in hot and arid climates (Rafique *et al.,* 2015). Evaporative cooling is commonly utilized to maintain the environment in agricultural buildings. Its methods include fan-pad, misting, and fogging systems, which are all governed by factors such as pad material, density, design, size, and airflow rate and velocity. (Khalifa *et al.,* 2018). ASABE (2008) recommended air speed values and minimum water flow rates for four different types of pads. In severe conditions, aspen fiber pads of 50 and 100 mm thickness mounted vertically should be operated at 0.76 m s^{-1} airspeed and 5 L min^{-1} m^{-1} minimum water flow rate per unit length of the pad, whereas corrugated cellulose pads of 100 and 150 mm thickness should be operated at 1.27 and 1.78 m s^{-1} airspeed and 6.2 and 9.9 L min^{-1} m^{-1} minimum water flow rate per unit length of the pad, respectively.

Davies *et al.* (2006) found that when an evaporative cooling system is utilized in a greenhouse, it typically consumes more fresh water than is required for irrigation. This is a big disadvantage in many hot areas since fresh water is in short supply. Even in greenhouses near the coast, using seawater for evaporative cooling is not standard practice nowadays. It is then worth analyzing the perceived or actual disadvantages of this method. The evaporative cooling efficacy of the indirect evaporative cooling IEC is also greatly influenced by the quality of water resources. The ideal possibility is freshwater with a low ion content, as salt crystal precipitation is avoided. However, this would limit the use of IEC to places with adequate freshwater supply. Using saline water, such as saltwater and wastewater, could increase the application areas of IEC, but would suffer from the problem of salt crystallization on the surface of the evaporator, which limits vapor diffusion and leads to a lower evaporation rate. (Li *et al.,* 2024). Gude (2016) estimated that the amount of water consumed in energy production had doubled between 1995 and 2030. Because of their big populations and high economic levels, coastal towns' need for freshwater is increasing, and there is a major shortage of freshwater. As a result, scientists began to employ seawater instead of freshwater for evaporative cooling to alleviate the pressure of freshwater scarcity in coastal regions. Yan *et al.* (2021) tested the cooling properties of freshwater and seawater in the setting of evaporative air conditioning. A low-speed wind tunnel was built to test the evaporative cooling properties of wet medium including seawater and freshwater, respectively. The investigation used CELdek7060 medium with thicknesses of 100 and 300 mm. Sea salt was used to create concentrations that were 0.5, 1, and 1.5 times those of seawater. Freshwater was derived from ordinary tap water. It was discovered that the pressure drop values induced by varying quantities of seawater and freshwater are comparable at the same water flow rate and thick medium. The cooling efficiency of seawater is slightly lower than that of freshwater, and it declines as seawater concentrations rise. At air speeds of 0.45-3.03 m s^{-1} and a water flow rate of 62 L min^{-1} m^{-2}, seawater (1 times its concentration) showed cooling effectiveness values 2.8-7% and 2.8-4.9% lower than freshwater, respectively. This study demonstrates the viability of evaporative cooling using saltwater, which is a huge advantage for evaporative cooling in coastal locations to save freshwater. Al-Busaidi and Al-Mulla (2013) conducted an experimental study on two different greenhouses, a seawater greenhouse (SWGH) and a conventional greenhouse (CGH), in an arid region of Oman. Both greenhouses use fans and pad evaporative cooling systems, but SWGH uses seawater instead of fresh water for cooling purposes. Furthermore, the cooling SWGH incorporated a desalination unit to create fresh water for the irrigation of cucumbers grown inside the greenhouse. SWGH lowered greenhouse temperature by 4.8°C, whilst conventional greenhouses reduced temperature by 7.4°C when compared to the surrounding ambient. It was also discovered that most of the time, CGH could not keep the indoor humidity above 60%, whereas SWGH could.

The rising competition between animal fodder and human food on Egypt's restricted agricultural system has resulted in higher pricing for raw materials used in fodder production. On the other side, there is an alternate way for producing low-cost fodder with less work, no electricity, and less water usage (Elsoury *et al.*, 2015). A well-designed hydroponics chamber may generate a huge amount of plant material in a short period of time, which can be used for both domestic and industrial purposes. The yield is high because germination and growing conditions may be tailored to the needs (Kamel *et al.*, 2021). Sprouted barley is a new method of creating feed forages that does not require soil, has a high germination rate, and grows quickly. This strategy could be especially useful in areas where water scarcity and seasonality of fodder are major difficulties for cattle farmers. Sprouted grains digest more efficiently than grain seeds due to increased activation of hydrolytic enzymes during germination (Lemmens *et al.*, 2019). According to Fazaeli *et al.* (2012), hydrolytic enzymes break down proteins, starch, and fat into simpler amino acids, sugars, and fatty acids. Furthermore, sprouting increases the level of crude fiber and mineral chelates while decreasing the content of phytic acid, protease inhibitors, and a variety of other anti-nutrients. Furthermore, sprouted barley production requires less water than typical production systems. Germination has been shown to be an economical (low-cost) and sustainable technique that enhances grain nutrient quality and functional component content, as well as palatability, digestibility, and bioavailability. However, the amount of germination-induced alterations varies according to grain variety and germination conditions. According to AlKaraki (2010), 1.5-2 liters are required to create 1 kg of green fodder hydroponically, whereas 73.5, 85.5, and 167 liters are required to produce 1 kg of green fodder from forage barley, Lucerne, and Rhodes grass in the field.

MATERIALS AND METHODS

1. Experimental study

The study was carried out to investigate a smart greenhouse cooling by the evaporative cooling system using seawater to grow barley during the summer season to conserve water and produce food. In this study, an evaporative cooling system was employed to cool the greenhouse, and the cooling pad was wetted with two sources of water (freshwater and seawater) to quantify the impact of using seawater on the system's performance. The experiment was carried out at the Agricultural Engineering and Bio Systems Department, Faculty of Agriculture, Shebin El-Kom, Menoufia University, Egypt, in August 2023. Geographically, the experiment place's latitude angle was 30º 54' north. The experiment was conducted for 7 days using freshwater and 7 days using seawater within 8 to 19 hours.

2. Detailed description of the greenhouse

To achieve the aim of this study, a small experimental greenhouse was constructed with dimensions of 0.80 × 0.55 × 0.60 m in length, width, and height, respectively. The frame of the experimental greenhouse was made of wood. The greenhouse was covered with a single 130 μm polyethylene sheet. The experimental greenhouse was oriented to the north-south direction. The experimental greenhouse construction is shown in Fig. 1 and Table (1).

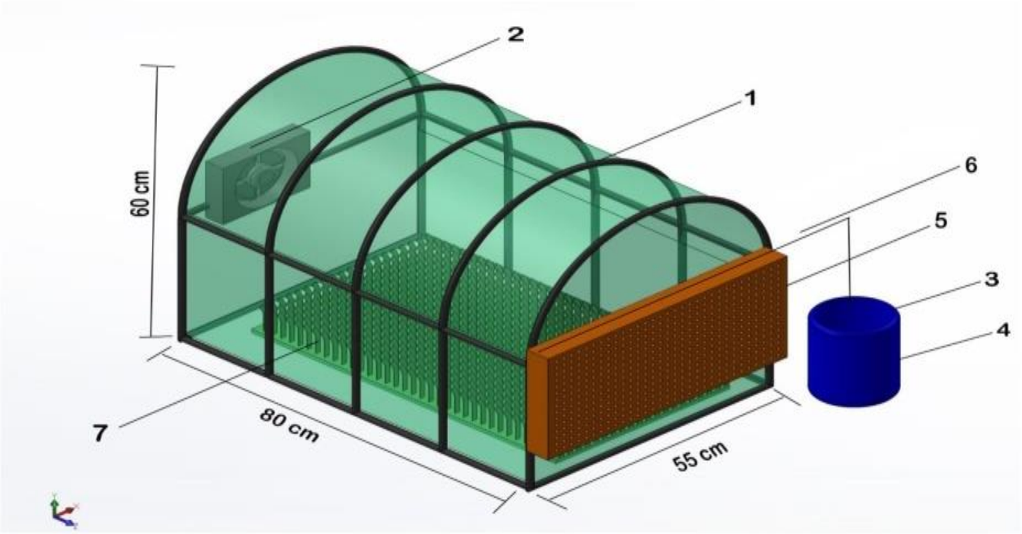

Fig. 1: Schematic diagram of the greenhouse

Table (1): Definition of items in the greenhouse schematic diagram.

Item	The definition	Item	The definition
1	The greenhouse construction	5	The cooling pad
2	Ventilation fan	6	Water distribution pipe
3	Water pump	7	Barley germination tray
4	Water tank		

3. Description of the evaporative cooling system

An evaporative cooling unit equipped with a pad and a fan was installed. The cooling pad was placed on the northern side of the greenhouse to take advantage of the wind direction. It measures 0.80 × 0.55 × 0.15 m in length, width, and thickness. The fan on the opposite side removes air from the inside, reducing internal pressure and forcing outside air through the pads. A water pump of 25 W power and 80 L h^{-1} discharge rate) was used to raise the water on the pad with a 12.31 L h^{-1} m^{-2} water flow rate according to Andrea *et al.* (2018) which was distributed on a horizontal perforated pipe installed on the pad. The experimental work applied an air velocity of 0.7 m s^{-1} by a fan of 30 W power according to ASABE (2008).

4. Water source

The water used in this experiment is Mediterranean seawater with a salt concentration of 38000–41000 ppm (59.4–64 mS.cm^{-1}) compared to freshwater with a salt concentration of 270 ppm (0.42 mS.cm^{-1}).

5. Barley

This study used the GIZA 131 variety of barley obtained from the Agronomy Department. Barley germination was carried out on a tray measuring 0.5x0.20 m in length and width.

6. Control system

A control system was employed to continuously collect data from numerous sensors, monitor sensor information, and manage the system. Furthermore, the system can warn the user if an abnormality happens in the system and automatically resolve the issues. In general, a smart automatic control system consists of sensors that measure process variables, actuating devices and controllers, interface modules, communication systems, and power sources. A mobile application has been created on the Android system that displays the values of the live sensors upon which the user can remotely control the actuators, and the operator can modify the operating values.

7. Measurements.

7.1. Dry bulb temperature and relative humidity

Hourly dry bulb temperature and relative humidity inside and outside the room were measured using a DHT22 sensor. The range and accuracy of that were Humidity 0–100% RH; Temperature -40~80 °C and Humidity ±2% RH; Temperature <± 0.5 °C, respectively. Average temperatures and relative humidity were taken during the working period.

7.2. Air velocity

The air velocity was measured before the cooling pad in the evaporative cooling system using UT363BT Mini digital Anemometer to determine the specific air velocity over working time. The range and accuracy of the instrument were 0-30 ms^{-1} and ±5%, respectively.

7.3. Water consumption

Using two water flow rate sensors, YF-S201, the amount of water that evaporated was determined. One sensor was installed on the inlet water pipe, and the other was placed on the outlet water pipe. The amount of water evaporated was determined by calculating the difference between them.

7.4. Water electrical conductivity (EC)

Electrical conductivity analysis, or EC determination, is one of the tests to determine the quality of water. Conductivity shows the ability of water to conduct electrical current. The presence of dissolved salts in water contributes to its conductivity, thus enabling EC analysis to provide insights into the concentration of ions and the overall purity of the water. A Consort meter model C933 was used to measure salt concentration in water. The range and accuracy of that were 0 to 2000 mS cm^{-1} and 0.5%, respectively. The salinity of the air inside the greenhouse was measured by condensing the air vapor by placing a bottle of snow inside the greenhouse and measuring the salinity of the resulting water by the Consort meter C933.

7.5. Cooling efficiency

An evaporative cooling system's performance is assessed by its cooling impact, wet-bulb depression, heat transfer rate from air to water, and water consumption during the evaporation process. Balyani et al. (2015) propose the following equation for calculating cooling efficiency based on cooling impact and wet bulb depression:

$$\eta = \frac{T_{do} - T_{di}}{T_{do} - T_{wo}} \times 100 \qquad (1)$$

Where, η is cooling efficiency (%), T_{do} is the dry-bulb temperature of the outdoor air (C°), T_{di} is the dry-bulb temperature of the indoor air (C°), T_{wo} is the wet-bulb temperature of the outdoor air (C°).

7.6. Coefficient of performance

The performance analysis was also determined using the coefficient of performance (COP), which can be defined as the cooling capacity (P_{pad}) related to the electric input power due to the pump (P_{fan}) and fan (P_{pump}) according to Laknizi Azzeddine *et al.* (2019):

$$\mathrm{COP} = \frac{P_{pad}}{P_{fan} + p_{pump}} \qquad (2)$$

Where COP is the coefficient of performance (%), P_{pad} is the cooling energy (w), P_{fan} is the fan power consumed (w), and P_{pump} is Pump power consumed (w).

7.7. Cooling energy

The cooling energy (P_{pad}) was calculated based on Andrea *et al.* (2018) through the following equations:

$$p_{pad} = V_{tv}.C_{air}.(T_{do} - T_{di}).\frac{\rho_{air}}{3600} \qquad (3)$$

Where, C_{air} is the specific heat of air (1.047, kJ kg^{-1} $k^{\circ-1}$), V_{tv} is the volumetric air flow rate (m^3 h^{-1}), ρ_{air} is the air density (1.28, kg m^{-3}).

7.8. Quality properties of barley

The length of barley plants was measured from the first day to the seventh day of growth. The nutritional components of barley (crude protein - crude fiber - starch - fat - digestible energy - calcium - potassium - manganese - phosphorus) were estimated in the central laboratory at the Faculty of Agriculture, Menoufia University, to evaluate the nutritional properties of barley.

RESULTS AND DISCUSSION

1. Indoor temperature and relative humidity

The ambient temperature and relative humidity are considered very important environmental conditions affecting agricultural production. Fig. 2 shows the average indoor temperature and relative humidity using fresh and seawater. The indoor temperature was compared with the ambient temperature. The results indicate that the average hourly relative humidity of the air decreased gradually until it reached its peak and then increased during the period from 8:00 to 19:00. The experimental results showed that the indoor temperature and relative humidity change by increasing and decreasing together, which are affected by both outdoor temperature and relative humidity.

It was noted that average indoor temperature ranged between 21.76 C° and 25.16 C° using freshwater, while it ranged between 22.18 C° to 25.81 C° by seawater, compared to the average outdoor temperature, which ranged between 24.92 to 38.57 C° and 25.57 to 38.01 C°, respectively. The results indicated that the difference between the highest average indoor and outdoor temperature was 13.41 C° when using freshwater, while it was 12.19 C° in case of seawater. The largest variation in the highest and lowest average indoor temperature was 3.4 C° while by using seawater it was 3.62 C°. The reason is that seawater is occupied with salt ions that prevent the evaporation of water molecules because they obstruct the passage of air through the pad. Also, the saturated vapor pressure of seawater is less than the saturated sea pressure of freshwater, as the reduction of vapor pressure is proportional to the salt content of seawater and thus decreasing the effectiveness of cooling and reducing temperature. This result agrees with Yan *et al.* (2021).

Comparing the average outdoor relative humidity, it is obvious that there is an increase in the relative humidity inside the greenhouse, and it’s affected by the evaporation, as the average indoor relative humidity by freshwater and seawater decreased from 90.53 to 46.95% and from 83.11 to 41.52% between 8.00 to 15.00, respectively. Accordingly, the average outdoor relative humidity of freshwater and seawater decreased from 65.06 to 17.31% and from 61.66 to 18.51%. The average indoor relative humidity by freshwater and seawater increased from 46.95 to 63.02% and from 41.52 to 55.97% between 15:00 and 17.00, respectively. Accordingly, the average outdoor relative humidity by fresh water and seawater increased from 17.31 to 36.8% and 61.66 to 34.58%. The increase in relative humidity using freshwater over seawater could be attributed to an increase in the evaporation rate, as salts in seawater work to close the pores of the cooling pad and reduce the evaporation of water molecules.

2. Cooling efficiency

Cooling efficiency is an important indicator of a wet medium evaporative cooling system because it shows the degree of air saturation after evaporative cooling; thus, higher cooling efficiency has a greater cooling effect. Fig.3 shows the effect of using seawater on cooling efficiency compared to fresh water. It was noted that by using fresh and seawater the highest cooling efficiency was 75.01 % and 71.25% respectively. The lowest efficient cooling using fresh and seawater was 69.11% and 64.57% respectively. The average cooling efficiency with fresh water was 71.90% while it was 68.08% with seawater with an increase of 3.82%. This can be attributed to the decrease in the rate of water evaporation due to the accumulation of salt on the pad and the latent heat of evaporation of seawater is lower, so it takes longer to evaporate. This result agrees with the results obtained by Yan *et al.* (2021).

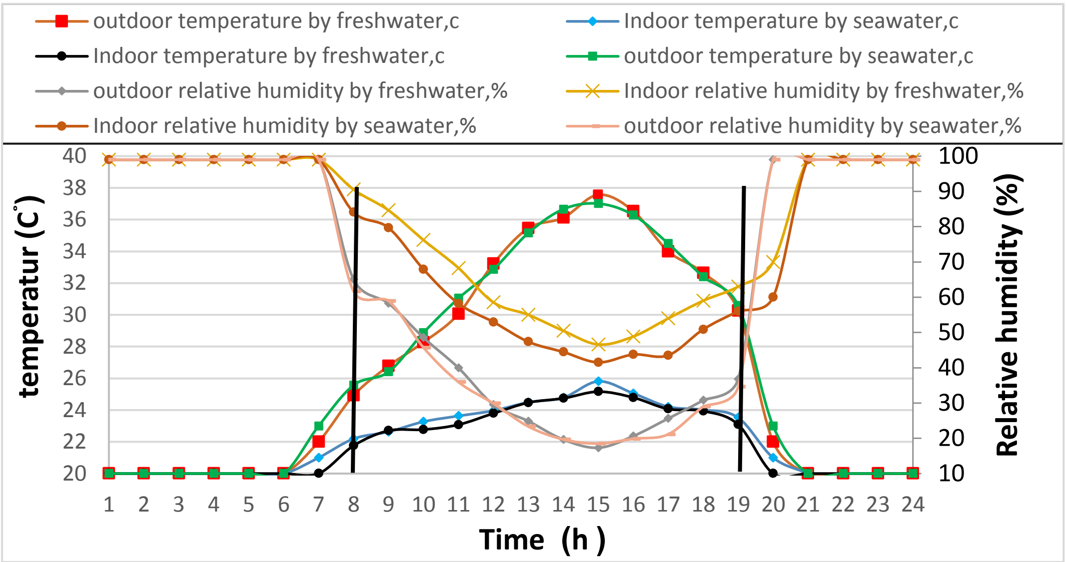

Fig. 2: Average indoor temperature and indoor relative humidity compared with outdoor temperature and outdoor relative humidity using fresh and seawater

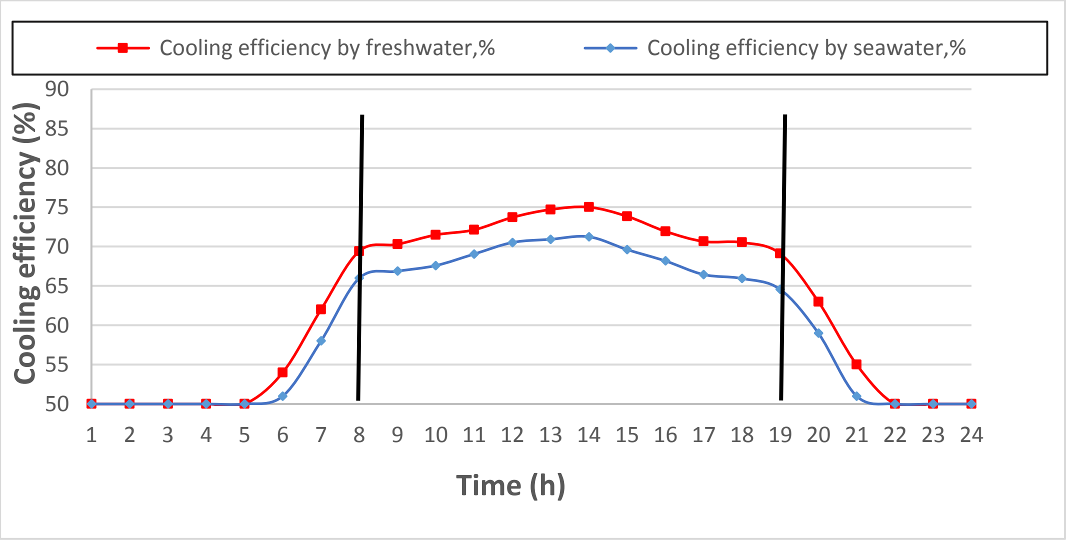

Fig. 3: Cooling efficiency by freshwater and seawater

3. Water consumed

According to previous research by Porumb *et al.* (2016), the factors affecting the water evaporation rate include air speed, air temperature, humidity, medium type, and dimension. Water consumption by using fresh and seawater was compared. It is clear from the data that the maximum fresh and seawater consumption was 5.88 Lh^{-1} and 5.11 Lh^{-1}, respectively, while the minimum consumption was 5.04 Lh^{-1} and 4.38 Lh^{-1}, respectively. The average daily fresh and seawater consumption was 5.49 Lh^{-1} and 4.71 Lh-1, respectively, with an increase of 0.78 Lh^{-1}. Water consumption by fresh water and seawater is presented on Fig. 4.

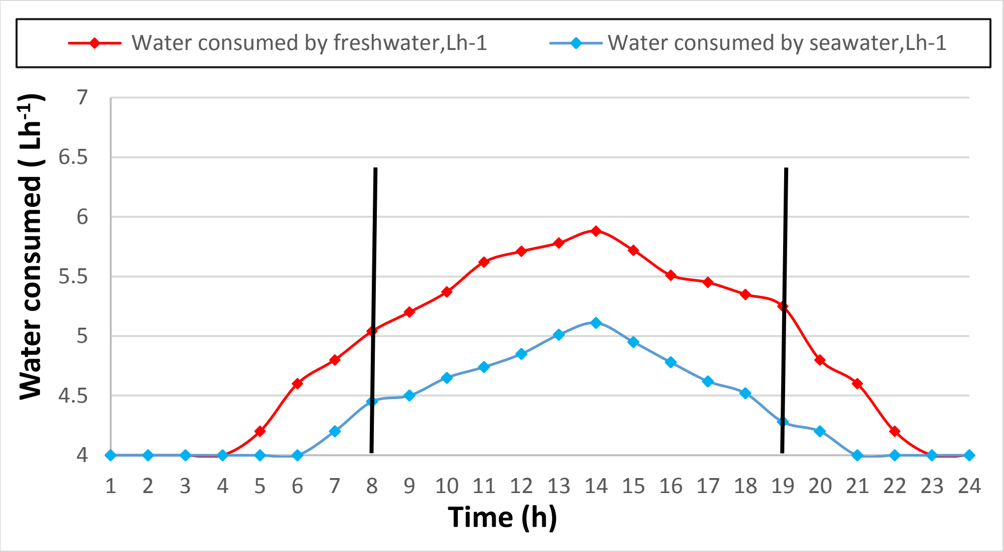

Fig. 4: Water consumption by freshwater and seawater

4. Salt concentration

The salt concentration in the seawater inlet and outlet of the cooling pad was measured from the 1st to the 7th day to show the effect of salt accumulation on cooling.

Fig. 5 shows the salt concentration at the inlet and outlet of the cooling pad. The results revealed an increase in salt concentration on the first day at the inlet from 61.7 to 78.6 mS cm^{-1} all day long, with an increase of 16.9 $mScm^{-1}$, while it increased at the outlet from 61.7 to 80.3 mS cm^{-1} with an increase of 18.6 mS cm^{-1}. This increase could be due to the evaporation of water in the evaporative cooling process, leaving salt to settle on the cooling pad. When water passes over it, part of this salinity is absorbed, causing an increase in the salinity concentration in the water tank. The salts increase at the inlet by a greater percentage than at the inlet, as they have not mixed with the water in the tank, but at the entrance, they are less as they have mixed with the tank water.

On the 7th day, the salinity increased from 61.7 to 82.4 mS cm^{-1} at the outlet with an increase of 20.7 mS cm^{-1}, while it increased from 64.6 to 86.8 at the outlet with an increase of 22.2 mS cm^{-1}. The percentage of salt increase on the 7th day was greater than on the 1st day, as the salt in the water increased gradually from the 1st to 7th day at the inlet and outlet due to the increased accumulation of salts on the pad during the operation of the cooling process as the water evaporates, which gradually reduces the efficiency of cooling. Therefore, the cooling pad must be cleaned with fresh water washing repeatedly to eliminate the effect of salt deposition on the pad.

To observe the impact of salt on the corrosion of the cooling pad material, a piece of the cooling pad was also soaked in a tank of seawater for two months. No change or corrosion was observed in the pad material due to the salts. This is a good indicator of the use of seawater in evaporative cooling, as it only needs to be cleaned by washing it from salt after a while and not changing it, which causes an increase in costs.

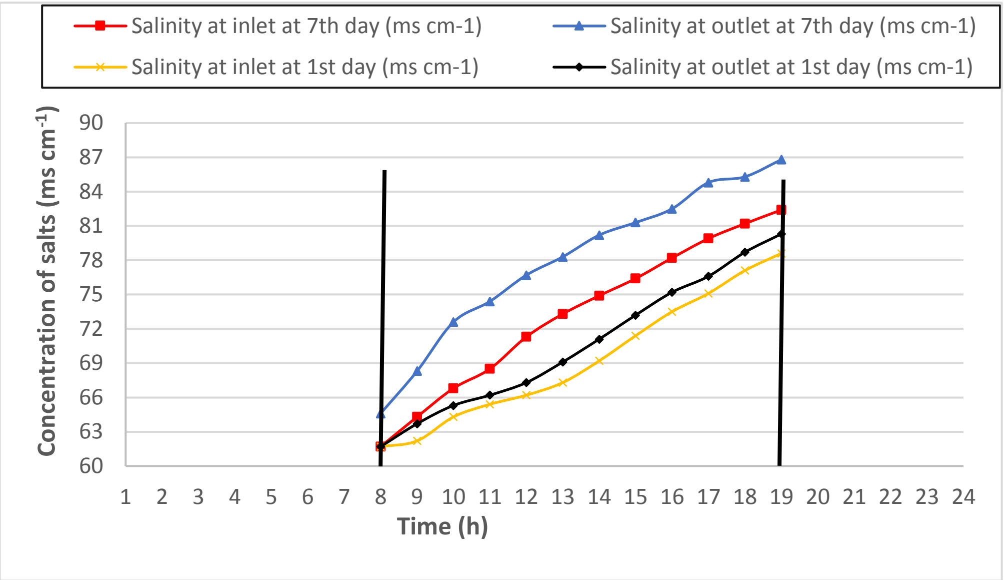

Fig. 5: concentration of salts at inlet and outlet of the cooling pad on 1st and 7th day

5. The coefficient of performance

Fig. 6 shows the coefficient of performance of energy use for the evaporative cooling system for both freshwater and seawater. It was observed that it reached 60.68% by freshwater while it decreased to 59.09% by seawater. This slight decrease is due to the decrease in the evaporation rate using seawater due to the accumulation of salts. This result is in line with Ali and Hoseyn (2017), which means that the energy efficiency was good and acceptable.

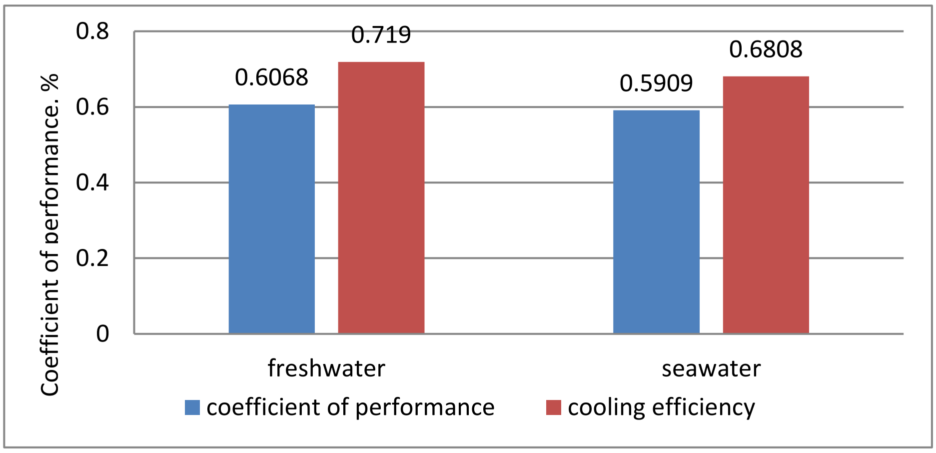

Fig. 6: Coefficient of performance and efficiency of energy use for evaporative cooling system.

6. Quality properties of barley

In this study, barley was grown in the designed greenhouse under the influence of salty water in an evaporative cooling system. The lengths and weights of barley were measured after 7 days of germination, and laboratory analysis of barley components was performed. The results showed that after 7 days of germination, the average barley length was 25 cm, and the barley yield was 7 kg of green fodder per kg of grain. Laboratory analysis results were good and acceptable consistent with Abdulrahman *et al.* (2019). Table (2) shows the results of laboratory analysis of random barley samples.

Table (2): The results of laboratory analysis of random barley samples

Component Type	protein crude	crude fiber	Fats	Starch	digestible energy, MJ kg^{-1}
Component ratio (%)	18.7	12.3	3.6	14.5	12.7

The obtained results showed that the effect of using salt water was not noticeable on both physical and chemical analysis of the properties of barley, as the percentage of salts present in the air was 2.4 mS cm^{-1}, which is a very small amount and within the permissible limits. Barley is also considered one of the plants that have a low sensitivity to salinity. From the previous results, it can be concluded that the use of salty water in the evaporative cooling process has no harmful effect on the plants grown inside the greenhouse unless there is a leakage of the water used in the cooling pad inside the greenhouse. This result agrees with Davies *et al.* (2006). Fig. 7 shows the Barley germination under the influence of salty water in evaporative cooling.

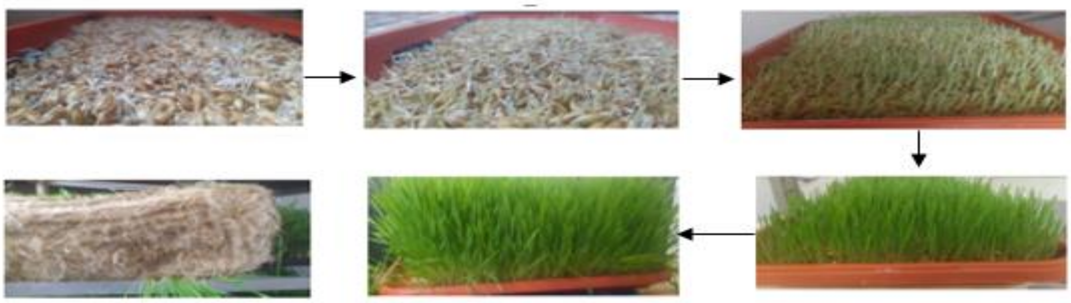

Fig. 7: Barley germination under the influence of salty water in evaporative cooling

This study demonstrates the viability of evaporative cooling with seawater, resulting in slightly decreased cooling performance and energy consumption with no harmful impact on plants.

CONCLUSIONS

This research investigated the potential of constructing a smart greenhouse for growing barley. The following points may be concluded:

- The average indoor temperature ranged between 21.76 C° to 25.16 C° using freshwater, while it ranged between 22.18 C° to 25.81 C° by seawater, compared to the average outdoor temperature, which ranged between 24.92 to 38.57 C° and 25.57 to 38.01 C°,
- The average indoor temperature ranged between 21.76C° to 25.16 C° using freshwater, while it ranged between 22.18 C° to 25.81 C° by seawater, compared to the average outdoor temperature, which ranged between 24.92 to 38.57 C° and 25.57 to 38.01 C°, respectively.
- The average cooling efficiency with fresh water was 71.90% while it was 68.08% with seawater with an increase of 3.82%.
- The average daily fresh and seawater consumption was 5.49 Lh^{-1} and 4.71 Lh^{-1}, respectively, with an increase of 0.78 Lh^{-1}.
- The salt concentration in the seawater inlet and outlet of the cooling pad at the first day ranged from 61.7 to 78.6 mS cm^{-1} and 61.7 to 80.3 mS cm^{-1}, respectively all day long while, the salt concentration in the seawater inlet and outlet of the cooling pad at the 7th day ranged from 61.7 to 82.4 mS cm^{-1} and 64.6 to 86.8 mS cm^{-1}, respectively.
- The coefficient of performance of energy use for an evaporative cooling system by freshwater and seawater was 60.68% and 59.09%, respectively.

- The results of laboratory analysis of random barley samples showed 18.7 % crude Protein, 12.3 % crude fiber, and 3.6 % fats with barley yield of 7 km green fodder per kg of grain.
- This study demonstrates the viability of evaporative cooling with seawater, resulting in slightly decreased cooling performance and energy consumption with no harmful impact on plants.

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مقارنة أداء نظام التبريد التبخيري باستخدام مياه البحر والمياه العذبة لزراعة الشعير

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الملخص العربي

تعد ندرة المياه من أهم المشاكل الملحة التي تواجهها أغلب الدول ومنها مصر، ويعد الاستهلاك المرتفع للمياه في أنظمة التبريد التبخيري المستخدمة في الزراعة من أهم تلك المشكلات، لذا كان إيجاد طريقة للمحافظة على المياه أمراً ضرورياً. فكان الهدف من هذه الدراسة هو تخفيف الضغط على استخدامات المياه العذبة في الزراعة من خلال استخدام المياه المالحة بدلاً من المياه العذبة في عملية التبريد التبخيري. ولتحقيق هذا الهدف تم إنشاء صوبة زراعية ذات إطار خشبي مغطاة بطبقة من البولي إيثيلين المفرد بسمك ١٣٠ ميللي ميكرون لتوفير الظروف البيئية لإنتاج الشعير خلال فصل الصيف حيث تم استخدام مصدرين للمياه (المياه العذبة ومياه البحر) لتقييم استخدام مياه البحر مع نظام التبريد التبخيري ودراسة تأثير استخدام مياه البحر على أداء النظام. تم إجراء هذه التجربة في قسم الهندسة الزراعية والنظم الحيوية، كلية الزراعة، شبين الكوم، جامعة المنوفية خلال الفترة من الاول حتى الرابع عشر من شهر اغسطس لعام ٢٠٢٣.

وكانت أهم النتائـج التـي تم الحصول عليها كما يلي :

- تراوحت متوسطات درجات الحرارة الداخلية ما بين ٢١,٧٦ درجة مئوية إلى ٢٥,١٦ درجة مئوية باستخدام المياه العذبة، بينما تراوحت ما بين ٢٢,١٨ درجة مئوية إلى ٢٥,٨١ درجة مئوية بمياه البحر، مقارنة بمتوسطات درجات الحرارة الخارجية التي تراوحت ما بين ٢٤,٩٢ درجة مئوية إلى ٣٨,٥٧ درجة مئوية و٢٥,٥٧ درجة مئوية إلى ٣٨,٠١ درجة مئوية، على التوالي.
- بلغ متوسطات كفاءة التبريد بالمياه العذبة حوالي ٧٢% بينما بلغ حوالي ٦٨% بمياه البحر بانخفاض مقداره حوالي ٤ % عند استخدام مياه البحر.
- بلغ متوسط الاستهلاك اليومي للمياه العذبة ومياه البحر ٥,٤٩ لتر/ساعة و ٤,٧١ لتر/ساعة على التوالي بانخفاض مقداره ٠,٧٨ لتر/ساعة عند استخدام مياه البحر.
- تراوح تركيز الاملاح عند مدخل ومخرج وسادة التبريد لمياه البحر في اليوم الأول من ٦١,٧ إلى ٧٨,٦ مللي موز لكل سم ومن ٦١,٧ إلى ٨٠,٣ مللي موز لكل سم على التوالي طوال اليوم بينما تراوح تركيز الاملاح عند مدخل ومخرج وسادة التبريد في اليوم السابع من ٦١,٧ إلى ٨٢,٤ مللي موز لكل سم ومن ٦٤,٦ إلى ٨٦,٨ مللي موز لكل سم على التوالي.
- بلغ معامل أداء استخدام الطاقة لنظام التبريد التبخيري بواسطة المياه العذبة ومياه البحر ٦٠,٦٨% و٥٩,٠٩% على التوالي.
- نتائج التحليل المعملي لعينات الشعير العشوائية ١٨,٧% بروتين، ١٢,٣% ألياف خام، ٣,٦% دهون مع انتاجية بلغت ٧ كيلو جرام علف اخضر لكل كيلو جرام حبوب.
- تثبت هذه الدراسة جدوى التبريد التبخيري باستخدام مياه البحر وتظهر الانخفاض البسيط في كفاءة عملية التبريد التبخيري وكذلك اداء استخدام الطاقة المستخدمة في التبريد دون أي تأثير ضار على النباتات.

الكلمات المفتاحية: التحكم البيئي - الصوبة الزراعية - التبريد التبخيري - ماء البحر - الشعير.