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Light use Efficiency of various greenhouse systems in arid environment

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This work was presented in the XXXI International Horticultural Congress: IHC2022 in Angers, France in August 2022.

Background

Photosynthetically Active Radiation (PAR) is the driving force for photosynthesis and thus for the growth and production of plants. Plentiful solar radiation provides semi-arid and arid regions such as Saudi Arabia with great potential for agricultural operations. ESTIDAMAH carries out research with primary goal water saving techniques and greenhouse design adapted to the Saudi climate conditions. Increase in locally produced fresh vegetables can be the result of increasing the productivity of the cultivation systems, meaning achieving a higher efficiency of processes that convert sun radiation into marketable products. Light use efficiency can be used as a criterion to compare different production systems.

Objective

The purpose of this work is to examine how different factors related to the cultivation system affect the efficiency of conversion of solar radiation to marketable vegetables.

Methods

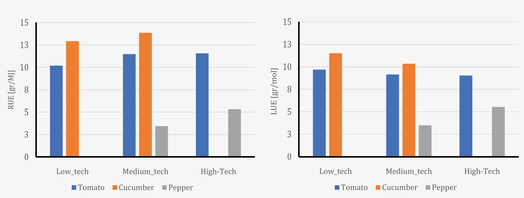
All experiments were carried out in 3 different greenhouse types at the National Research and Development Center for Sustainable Agriculture (ESTIDAMAH) in Riyadh, Saudi Arabia:

Greenhouse	Level of Technology	Featured Equipment	environment control
	**Low(er)**	Plastic tunnels Pad and fan	
	**Medium**	Venlo type Different cover materials Pad and fan	Heating Fogging Shading screen
	**High(er)**	Venlo type Glass cover Mechanical cooling	Heating Fogging Shading screen Dehumidification CO2 enrichment

Results

Level of Technology

Higher RUE (Radiation use efficiency) and LUE (light use efficiency) in H-Tech greenhouses compared to M-Tech mainly because of elevated CO2
Higher RUE but lower LUE in M-Tech greenhouses compared to L-Tech because of higher transmissivity.



CO_2 Enrichment

Higher LUE and RUE when CO2 concentration was 800 ppm compared to 400 ppm.

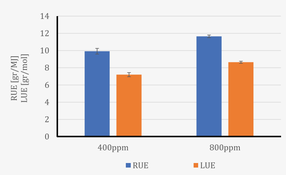


Figure 2. Achieved RUE and LUE with different CO2 concentration.

CO_2 Enrichment

Positive correlation between greenhouse cover transmissivity and RUE
LUE was reduced in M greenhouses with increased transmissivity, maybe CO2 becomes limiting

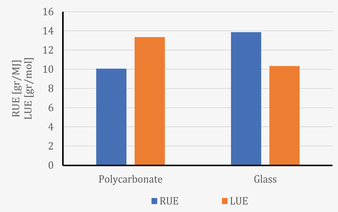


Figure 3. RUE (blue bars) and LUE (orange bars) achieved in greenhouses with lower (polycarbonate) and higher (glass) cover transmissivity.

The type of cover (diffuse vs clear)

No significant difference in LUE or RUE between clear and diffuse covers.

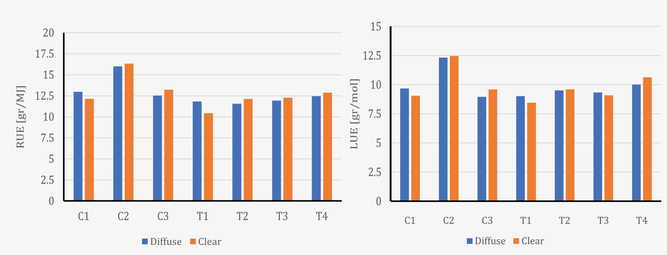


Figure 4. Achieved RUE (left) and LUE (right) in a series of 7 trials where cucumber was the crop grown at 3 trials (C1, C2 and C3) and tomato at 4 trials (T1, T2, T3 and T4). In each trial the crops were grown in 2 identical greenhouses, one covered with clear (orange bars) and one with diffuse glass (blue bars). Both types of glass had exactly the same hemispherical transmission (%82).

Artificial illumination

- Increased production
- Non significantly different overall RUE but significant increase during in period of application
- Lower LUE
  Short period of application

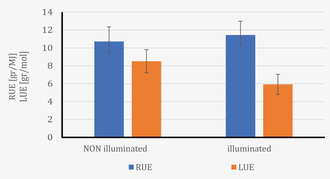


Figure 5. RUE and LUE in tomato trials with and without artificial illumination.

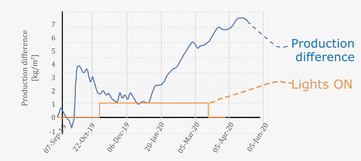


Figure 6. Difference in production between illuminated and non-illuminated tomato shows higher production for the illuminated crop, starting 8 weeks after the start using the artificial lighting

Discussion

Increasing the level of technology comes with a cost. It should be considered whether such a technological upgrade would be economically beneficial. On the other hand, the technological upgrade can have more advantages other than increased RUE, such as water saving and Integrated Pest Management (IPM).
It was shown that CO2 enrichment increases the production. CO2 enrichment is not common in the GCC countries as it is actually not practically applicable in the common greenhouse types in GCC area which are cooled by pad and fan systems due to the high exchange rates.
Increasing the transmissivity of greenhouse cover increased the RUE of the system. This conclusion is practically important as in countries with abundant sun radiation like Saudi Arabia one might think that light is not limiting; it was shown that this is clearly not the case. Sometimes, a less transmitting cover is chosen, or the transmissivity of the existing cover is intentionally (whitewashing) or unintentionally (poor cleaning) reduced in order to reduce the cooling requirements. Other research also performed in ESTIDAMAH has shown that the increase in production by increasing greenhouse transmissivity was relatively more than the increase in water required for evaporative cooling. This finally resulted in lower total amount of water use per kg of produced product in the greenhouse with higher transmittance.

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