Current Journal of Applied Science and Technology

40(22): 1-7, 2021; Article no.CJAST.72285
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Cooling and Qualitative Study of Evaporative Cool Hydroponically Grown Maize Crop

Sanjay Kumar Singh[1], Amit Kumar Patil[1*], Sheshrao Kautkar[2], P. N. Dwivedi[1] and A. K. Singh[3]

[1]Farm Machinery and Post-Harvest Technology Division, ICAR-Indian Grassland and Fodder Research Institute, Jhansi-284003, India.
[2]ICAR- Central Institute for Research on Cotton Technology, Mumbai, India.
[3]Seed Technology Division, ICAR-Indian Grassland and Fodder Research Institute, Jhansi-284003, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2021/v40i2231474
Editor(s):
(1) Dr. Ahmed Fawzy Yousef, Desert Research Center, Egypt.
Reviewers:
(1) El Bouzdoudi Brahim, Abdelmalek Essaadi University, Morocco.
(2) Joselito Nardy Ribeiro, Federal University, Brazil.
(3) Theeranat Suwanaruang , Kalasin University, Thailand
Complete Peer review History: https://www.sdiarticle4.com/review-history/72285

Original Research Article

Received 18 June 2021
Accepted 24 August 2021
Published 06 September 2021

ABSTRACT

A study of evaporative cool hydroponic chamber was made with respect to its cooling and qualitative evaluation for growth of maize. The daily average temperature and RH range of 35.5 to 36.1 0C and 37–77% respectively were observed under Evaporative Cool Hydroponic Chamber (ECHC). The cooling efficiency of ECHC varied from 57.61% to 83.33% with an average value of 74.06%. Fresh biomass yield of fodder maize was observed as 1.2kg/ft2 of tray area. Crude protein and crude fibre on dry matter basis of hydroponic maize fodder ranged from 13.1-13.08% and 15.30-15.31% respectively. The ECHC can be used as an alternative of high cost hydroponic fodder machines which can be locally fabricated and operated by semi-skilled manpower.

Keywords: Hydroponic; evaporative; fodder; maize; temperature; humidity.

**Corresponding author: E-mail: amitpatilbetul@gmail.com;*

1. INTRODUCTION

India has emerged as the biggest producer of milk in the world producing 187.7 MT of milk in the year 2018-19 [1] and the reason is its vast livestock population. Production of fodder is a challenging task for the farmers in adverse conditions or even in suitable growing seasons because of uncertainty in rainfall, less land holdings, enormous climatic changes and pressure of producing food crops. Because of less area available for fodder production, the urban vacant areas and residential yards may be utilized for fodder production, as an alternative of fertile land. This lack of area for fodder production increases the gap between supply and demand of green fodder in India, which is expected to reach 687.4 MT and 911.6 MT respectively in 2030 (IGFRI vision-2050), which indicates 24.59% deficit of green fodder. Evaporative cool hydroponics is a structure used for growing green fodder without soil under at least partially controlled environment [2,3]. The fodder grown hydroponically is known as hydroponics fodder or sprouted grains or sprouted fodder [4]. Al-Karaki and Al-Hashimi [5] evaluated for barley, cowpea, sorghum and wheat for green fodder production under temperature-controlled hydroponic conditions (24 ± 1◦C) and natural window illumination at growth room of Soilless Culture Laboratory, Arabian Gulf University, Manama, Bahrain. Highest yields for hydroponic fodder after 8 days for cowpea, barley and alfalfa were 217, 200, and 194 tons/ha, respectively. In India, hydroponic fodder maize is preferred because of its easy availability of seed, good biomass production and fast growing habit. Girma and Gebremariam [6] concluded that the dry matter content of 11-14%, yields of 5-6 folds on fresh basis for hydroponics maize and 8-13% increase in milk production. Naik et al*.,* [7] observed the highest values of crude protein (13.57%) for hydroponics fodder maize on 7th day of growth which was higher than the conventional green fodder maize (10.67%).

The available low cost structures are not suitable for the regions of hot and dry climate where the relative humidity stays to lower side during 7-8 months in a year. Also, these structures are not strong enough to use for longer periods, there are chances of growth of fungi because of unhygienic environment and there is no scientific data available in terms of literature on thermal variation under these structures. Evaporative cooling technique is effective in overcoming this problem upto some extent. In hot and dry climate "evaporative cooling" refers to the cooling obtained solely by the evaporation of water in air. Air surrounding the structure gives up its heat energy to evaporate water and gets cool [8]. This eco-friendly technology can reduce temperature by 10-15^{0}C. However, in mild climatic conditions, the evaporative cooling is not very much effective. Maximum temperature drop under fan pad cooled greenhouse in Bangalore, Karnataka (India) during peak summer and overall cooling efficiency of 7.3^{0}C and 53.6% were observed by Singh et al. [9]. Several studies on the zero energy cool chamber using evaporative cooling technique shows its importance with reference to its low cost, eco-friendly and energy saving [10-13]. However, to the best of our knowledge, environmentally controlled small and medium size evaporative cool hydroponic system for fodder production, that can operate in hot and dry regions does not exist. Therefore, a study was made to evaluate an evaporative cool hydroponic chamber for cooling and qualitative performance of maize crop.

2. MATERIALS AND METHODS

An expérimental setup of evaporative cool hydroponic chamber (ECHC) of 1.5m x 1.5m x 1.2m dimension was developed as shown in Fig. 1. The chamber consists of a double wall (inner and outer wall), a filler (evaporating medium), inside the double wall, fogging system to increase the humidity, drip system for watering the filler and a shading curtain. The outer and inner walls of the ECHC were made of solid clay bricks. The gap between the outside and inside wall was 5 cm packed with filler consisting of a mixture of sand (80%) and gravel (20%). Sand was used to increase the water retention capacity and gravel stone was used to enhance the evapo-transpiration rate. The tap water from tank was supplied to the filler material through low pressure drippers placed on the walls and to the fogger having solid cone nozzle (capacity: 1.0 l/h with 0.8m spray dia) inside the chamber. The bottom of the cool chamber was covered with gunny bags. A shading curtain that reduces solar radiation by 80% was also used to cover the entire structure including water tank.

Testing of evaporative cool hydroponic chamber for growth of maize: Testing of ECHC was done continuously from 15th to 21st June 2020 during summer. The maize (variety: maize hybrid seed 'ASC-555',

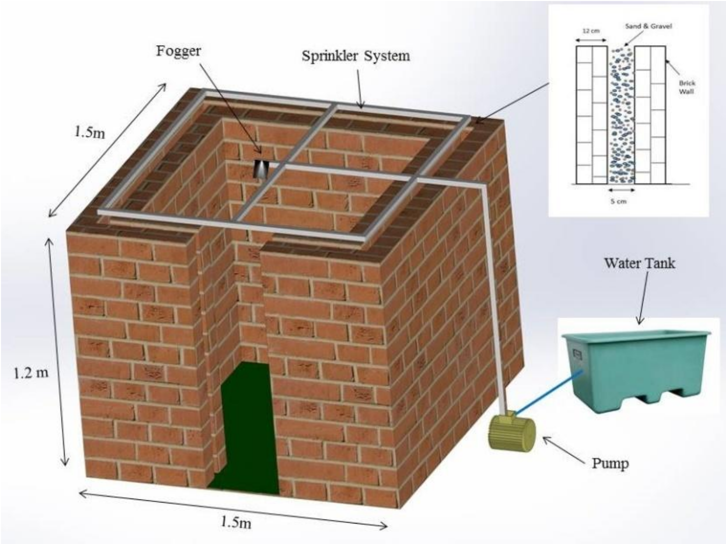

Fig. 1. Experimental set up of evaporative cool hydroponic chamber

Ajanta Seed Corporation) seeds were cleaned and soaked in water for 24h and then packed tightly in gunny bag for 12h to sprout the seeds. The sprouted seeds were spread in three hydroponic trays each of size 35.6 cm x 26.10 cm, at the seed rate of 300 g/m^2 and the trays were placed in the ECHC on 15th June 2020. Spraying of water was done only in day time in an interval of 2h. Inside the ECHC, the plants were allowed to grow for seven days and harvested at the end of seventh day.

Cooling Performance: Hourly data such as time, temperature and RH were recorded for 24 hour and the data were analysed. The cooling efficiency was calculated using the following equation as used by Singh et al. [14], Sabeh et al. [15] and Oz et al. [16].

$$\eta = (T_o - T_i) \times 100 / (T_o - T_{wb}) \qquad (1.0)$$

Where, T_o = Ambient air temperature, ^{0}C; T_i = Temperature inside the chamber, ^{0}C; and T_{wb} = Ambient wet bulb temperature, ^{0}C.

Qualitative Performance: Nutritional quality (proximate analysis) of green fodder produced in developed hydroponic structure was carried out. The chemical composition like moisture content, Dry Matter (DM), Organic Matter (OM), Crude Protein (CP), Crude Fibre (CF), Ether Exract (EE), Total Ash (TA) and Acid Insoluble Ash (AIA) were determined.

Moisture content: The moisture content of fresh and dry fodder was computed through mass balance. For this purpose, mass of the samples during drying were recorded at predetermined time interval. The following formulae were used to calculate the moisture content [17,18].

MC% (w.b.) = weight of moisture **/** weight of the sample

$$\text{MC\% (w.b.)} = \frac{(W+W_1) - W_2}{W} \text{x}100 \qquad (2.0)$$

Where, W = Net weight of sample taken, g; W_1= Weight of the dish, g; W_2= Weight of dish and oven dried sample, g

Crude protein: The crude protein in hydroponic fodder was determined by using micro Kjeldhal method (AOAC 2000).

$$\text{Protein,\%} = \frac{\text{T.V. x 0.014 x 100(ml) x 0.01 x 100 x 6.25}}{\text{Weight of sample (g) x aliquot used in distillation (ml)}} \qquad (3.0)$$

Where, T.V. = Titre value

Crude fibre: The crude fibre was determined by the sequential acid and alkali hydrolysis method (AOAC, 2000).

$$\text{Cruder fibre, \%} = \frac{(W_1\text{-}W_2)\ \text{x}100}{W} \qquad (4.0)$$

Where, W_1 = Weight of sample before ashing (g); W_2 = Weight of sample after ashing (g)
W = Weight of sample before acid and alkali treatment.

Ether extract and total ash: Ether extract was done using soxhlet apparatus and principle involved for ash is that when a known weight of feed is ignited to ash. The weight of ash thus obtained is expressed in terms of percentage.

3. RESULTS AND DISCUSSION

Cooling performance of the chamber: The data related to results of daily Dry Bulb Temperature (DBT), Wet Bulb Temperature (WBT), RH of ambient condition and DBT, temperature decrease and cooling efficiency under ECHC during the period of experimentation are presented in Table 1. The highest T and lowest RH of the ambient were observed at 2 PM. The wet bulb depression (WBD), which represents the cooling potential, varied from minimum of 7.2^{0}C to maximum of 9.2^{0}C. Maximum 6.7^{0}C decrease in T inside the ECHC was observed as compared to ambient conditions. Watering lowered the inside T to 25.4^{0}C and increased the RH from 52 to 88% under an ambient T of 28.5^{0}C to 41.4^{0}C. The cooling efficiency (ɳ) of the evaporative cooling system varied from 57.61% to 83.33% with an average value of 74.06%. Evaporative cooling decreases the inside temperature of the ECHC below the dry bulb temperature. The cooling below DBT inside ECHC was due to combined moist wall of the ECHC and mist used for irrigation and to increase the humidity level of the ECHC. Islam et al. [19], also observed reduction of inside temperature of zero energy cool chamber to 12.07^{0}C as compared to average outside T of 31.5^{0}C. On the other hand, the solar radiations were blocked at the tune of 80% by shade net, which also contributes to lower the temperature [19]. On an average, the T of the ambient was higher than inside the ECHC, particularly in day light. The ambient highest T and minimum RH at peak sunshine hour (2 PM) were 41.4^{0}C and 37% respectively, and the corresponding values for inside ECHC were 34.3^{0}C and 52% respectively. This result was also consistent with a study of Islam and Morimoto 2012 in which the temperature of zero energy cool chamber was lower than the outside one. Higher evaporative cooling was also observed under fan – pad cooled greenhouses in summer months as compared to winter season and cloudy days by Singh et al., [9].

Qualitative performance of maize crop: The biomass yield and nutrient composition on percent dry matter basis is presented in Table 2. The range of shoot length varied from 26 cm to 33 cm and the maximum number of leaves per plant was three. Fresh biomass yields were observed as 1.2 kg/ sq. ft tray area and 4.00 kg/kg of seed which indicates increase in fresh green fodder biomass four times as compared to seed biomass. However, varieties of maize and seed rate also influence the hydroponic maize biomass yield [20]. Yields of 4-5 folds on fresh basis and Dry Matter (DM) content of 11-14% are common for hydroponic maize fodder. Sometimes dry matter up to 18% has also been observed [21]. The average DM content and moisture content were found as 13.45% and 86.55% respectively

Table 1. Daily DBT, WBT, RH of ambient condition and DBT, temperature decrease and cooling efficiency under ECHC during the period of experimentation (15.6.2020 to 21.6.2020)

Day	Ambient Conditions									Inside ECHC condition		
	DBT (^{0}C)			WBT (^{0}C)			WBD (^{0}C)	RH (%)		DBT (^{0}C)	Lower in T ^{0}C	ɳ (%)
	Min	Max	Avg	Min	Max	Avg		Min	Max			
Day 1	30.6	38.8	34.7	25.6	29.2	27.4	7.3	47	66	29.1	5.6	76.71
Day 2	28.5	40.5	34.5	25.0	25.6	25.3	9.2	40	77	29.2	5.3	57.61
Day 3	30.0	40.0	35.0	26.4	28.8	27.6	7.4	41	74	30.2	4.8	64.86
Day 4	30.4	40.6	35.5	26.8	28.8	27.8	7.7	39	74	29.2	6.3	81.81
Day 5	30.8	41.4	36.1	26.4	29.0	27.7	8.4	37	69	29.4	6.7	79.76
Day 6	30.0	40.4	35.2	26.0	28.8	27.4	7.8	40	71	29.4	5.8	74.35
Day 7	30.4	38.8	34.6	26.0	28.8	27.4	7.2	45	69	28.6	6.0	83.33

Table 2. Biomass yield and nutrient content in hydroponic fodder maize at the end of 7 days of growth

Parameters	Unit	R-1	R-2	R-3	Mean	Standard Deviation	Standard Error of Mean
Fresh bio mass yield	kg/sq. ft tray area	1.165	1.240	1.192	1.20	0.038	0.022
Fresh bio mass yield	kg/kg of seed	3.883	4.133	3.973	4.00	0.127	0.073
Dry Matter (DM)	%	13.38	13.51	13.47	13.45	0.067	0.038
Organic Matter (OM)	% DM basis	96.62	96.53	96.59	96.58	0.046	0.026
Crude Protein (CP)	% DM basis	13.08	13.16	13.06	13.10	0.053	0.031
Crude Fibre (CF)	% DM basis	15.28	15.35	15.30	15.31	0.036	0.021
Ether Extract (EE)	% DM basis	3.17	3.18	3.22	3.19	0.026	0.150
Total Ash (TA)	% DM basis	3.38	3.47	3.41	3.42	0.046	0.026
Acid insoluble ash (AIA)	% DM basis	0.29	0.32	0.26	0.29	0.030	0.017

for harvested hydroponic maize fodder. The high moisture content was due to crop grown in water and harvested at very early stage. The Crude Protein (CP) an important nutrient required to the ruminant diet was found higher (13.10% on DM basis) and low crude fibre (15.30% on DM basis) in hydroponic fodder was due to harvesting of plants at early stage before the development of fibrous tissues. Higher CP and lower Fibre Content (FC) in hydroponic maize fodder makes it nutritious and easily digestible for livestock.

The values of CP, CF, EE, and TA for commercially available maize fodder grown conventionally in the field condition on% DM basis as reported by Naik et al., [7], were 10.59, 28.40, 2.28, and 2.15%, respectively. Comparatively high fibre content in conventionally grown maize fodder was due to harvesting at mature fibrous stage. Earlier worker also supported that the hydroponic fodder is more nutritious and palatable than the conventional fodder [22]. There are reports of increase in milk yield of 9.3% and 13.7% with feeding of hydroponic green fodder to the livestock [22,23]. Hydroponic fodder provides high nutrients contents but we need regular sowing of seeds on 7-10 days interval. The growth of seven days fodder maize validates its biomass which is enough to feed the livestock. Hydroponic and conventional both systems have their own advantage and limitations. Rachel et al., [24,25] reported in similar line as described above that hydroponic method of fodder production yields fodder with better nutritional quality than conventional method.

4. CONCLUSION

An evaporative cool hydroponic chamber (ECHC) was developed using low cast locally available materials. The daily average minimum and maximum temperature and RH range from 25.4 - 34.3^{0}C and 52-88% were maintained inside ECHC. The cooling efficiency of the evaporative cooling system of ECHC varied from 57.61% to 83.33% with an average value of 74.06%. Fresh biomass yields for fodder maize were observed as 1.2 kg/ sq. ft tray area and 4.00 kg/kg of seed. High crude protein and low crude fibre values 13.10% and 15.30% on dry matter basis were observed in hydroponic fodder as compared to conventionally grown maize fodder.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Annual Report. Basic Animal Husbandry Statristics. Ministry of Fisheries, Animal Husbandry & Dairying, Government of India. New Delhi. 2019-20.

2. Naik PK, Singh NP. Hydroponics fodder production: an alternative technology for sustainable livestock production against impeding climate change. In: compendium of Model Training Course 'Management Strategies for Sustainable Livestock Production against Impending Climate Change', held during November 18-25, 2013. Southern Regional Station, National Dairy Research Institute, Adugodi, Bengaluru, India. 2013;70-75.
3. Naik PK, Swain BK, Singh NP. Production and utilisation of hydroponics fodder. Indian Journal of Animal Nutrition. 2015;32(1):1-9.
4. Dung DD, Godwin IR, Nolan JV. Nutrient content and in sacco degradation of hydroponic barley sprouts grown using nutrient solution or tapwater. Journal of Animal and Veterinary Advances. 2010;9(18):2432-2436.
5. Al-Karaki GN, Al-Hashimi M. Green fodder production and water use efficiency of some forage crops under hydroponic conditions. International Scholarly Research Network. 2012;1-5.
6. Girma F, Gebremariam B. Review on hydroponic feed value to livestock production. Journal of Scientific and Innovative Research. 2018;7(4):106-109.
7. Naik PK, Dhuri RB, Swain BK, Singh NP. Nutrient changes with the growth of hydroponics fodder maize. Indian Journal of Animal Nutrition. 2012;29:161-163.
8. Bokade SD, Varghe AP, Ghumde AA. Fabrication and experimental study of new zero energy cooling chamber with a solar-driven adsorption refrigerator. International Journal of Engineering Development and Research. 2017;5(4):24-31.
9. Singh,KP, Singh SK, Pitam Chandra, Mandhar SC. Temperature and humidity regimes in naturally ventilated and fan-pad cooled greenhouses under mild climatic conditions. Journal of Ornamental Horticulture. 2005;8(3):173-179.
10. Islam MP, Morimoto T. Zero energy cool chamber for extending the shelf life of tomato and eggplant. Japan Agricultural Research Quarterly. 2012;46:257-67.
11. Ganesan M, Balasubramanian K, Bhavani RV. Effect of water on the shelf life of brinjal in zero energy cool chamber. Journal of Indian Institute of Science. 2004;84:1-7.
12. Singh RKP, Satapathy KK. Performance evaluation of zero energy cool chamber in hilly region. Agricultural Engineering Today. 2006;30(5&6):47-56.
13. Rajeswari D, Nautiyal MC, Sharma SK. Effect of pedicel retention and zero energy cool chamber on storage behaviour of Malta fruits. International Journal of Agricultural Sciences. 2011;3(2):78-81.
14. Singh SK, Singh BR, Samsher, Jaivir Singh. Training Manual on Greenhouse Practices. S. V. B. P. University of Agriculture & Technology, Meerut. 2007;1-79.
15. Sabeh NC, Giacomelli GA, Kubota C. Water use for pad and fan evaporative cooling of a greenhouse in a semi – arid climate. Acta Horticulture. 2006;719:409-416.
16. Oz H, Atilgan Atilgan Buyuktas, Alagoz Taner. The efficiency of fan-pad cooling system in greenhouse and building up of internal greenhouse temperature map. African Journal of Biotechnology. 2009;8(20):5436-5444.
17. Singh, SK and Gangwar V. Drying behavior of osmo-convective drying of carrot slices and quality characteristics of dehydrated products. International Journal of Current Microbiology and Applied Sciences. 2020a;9(10):1424-1431. Available:https://doi.org/10.20546/ijcmas.2020.910.169.
18. Singh, Sanjay Kumar, Varshika Gangwar. Effect of temperature and concentration of osmotic solution on moisture loss and solid gain during osmotic dehydration of carrot. International Journal of Chemical Studies.2020b;8(5):2017-2022. Available:https://doi.org/10.22271/chemi.2020.v8.i5ab.10598
19. Islam MP, Morimoto T, Hatou K, Optimization of watering for minimizing the inside temperature of zero energy cool chamber for storing fruits and vegetables. IFAC Proc. 2013;46:17-22.
20. Getachew Assefa, Urge Mengistu, Animut Getachew, Assefa Getnet. Effect of variety and seed rate on hyroponic maize fodder biomass yield, chemical composition and water use efficiency. Biotechnology in Animal Husbandry. 2020;36(1):87-100.
21. Naik PK, Gaikwad SP, Gupta MJ, Dhuri RB, Dhumal GM, NP Singh. Low cost devices for hydroponics fodder production. Indian Dairyman. 2013;65:68-72.

22. Naik PK, Dhuri RB, Karunakaran M, Swain BK, Singh NP. Effect of feeding hydroponics maize fodder on digestibility of nutrients and milk production in lactating cows. Indian Journal of Animal Sciences. 2014;84(8):880-883.
23. Reddy GVN, Reddy MR, Reddy KK. Nutrient utilization by milch cattle fed on a rations containing artificially grown fodder. Indian Journal of Animal Nutrition. 1988;5(1):19-22.
24. Rachel Jemimah E, Tensingh Gnanaraj P, Siva Kumar T, Gopinathan A, Meenakshi Sundaram S. Productivity and nutritional composition of maize fodder grown by hydroponic and conventional methods. Journal of Pharmacognosy and Phytochemistry. 2020;9(3):321-325.
25. Sanjay SK, Patil Amit Kumar, Kautkar Sheshrao, and Dwivedi P N. Thermal Performance for Hydroponic Maize Fodder Production. The Bioscan. 2021:16(1): 199-202.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/72285