Forage Res., **47**(4) : pp. 513-516 (2022) **http://forageresearch.in**

OPEN TOP CHAMBER: AN INNOVATIVE SCREENING TECHNIQUE FOR TEMPERATURE STRESS TOLERANCE IN FORAGE OAT (*AVENA SATIVA*)

SEVA NAYAK DHEERAVATHU, PRABHA SINGH, SRINIVASAN RAMAKRISHNAN AND VIJAY KUMAR YADAV

ICAR- Indian Grassland and Fodder Research Institute, Jhansi-284003 (Uttar Pradesh), India
**(e-mail : sevanayak2005@gmail.com)*
(Received : 3 March 2022; Accepted : 30 March 2022)

SUMMARY

Temperature manipulation experiments are effective ways for testing plant responses to future climate conditions, especially for predicting shifts in plant phenological events. There is little available information about the effect of elevated temperature on morpho-physiological parameters and green fodder yield of fodder crops. To identify fodder crops with high green fodder yield suitable for elevated temperature, proper screening technique is needed. Forage oat is an important annual forage cereal crop. It was grown in ambient as well as elevated (>2 °C than ambient) temperatures at vegetative to reproductive stage in open top chambers. Elevated temperature decreased oat plant height. Days to 50% flowering was shortened under elevated temperature compared to ambient condition. Standardized Open Top Chamber facility is more useful for screening number of varieties in oat and other forage crops for temperature stress tolerance and to address the demand of fodder seed production at present and future as well.

Key words : Ambient, elevated temperature, oat, open top chamber

Global climate change in the coming future will pose a serious challenge to plant growth and development affecting crop production across the world. One of the important components of global climate change is increase in the Earth's near-surface temperatures. The mean global surface temperature exhibited an increase over the past decade with particularly sharp increase since the 1970's (Gadgil, 1996). Mean annual temperature derived from 73 stations of India showed a significant warming of 0.4ºC over the last 100 years, which is comparable to global mean trend of 0.3ºC increase per hundred years (Hingane *et al.,* 1985). Temperature is a major factor affecting seed yield and quality in legumes (Ruell and Zachowski, 2010; Christophe *et al.,* 2011).

Food, fodder and nutritional security depends on quality seed. Many experiments conducted worldwide suggested that climate has a marked effect on fodder and fodder seed productivity and quality. Currently, India is facing net deficit of 61.1% green fodder, 21.9% dry crop residues and acute shortage (64%) in availability of seeds of many forage crops. At present seed availability of forage crops is only 15-20%. There is high demand for fodder seed production at present and future as well. A major challenge ahead for those involved in the seed industry, therefore, is to provide cultivars that can maximize future crop production in a changing climate (Ainsworth *et al.,* 2008; Bruins 2009; Ceccarelli *et al.,* 2010). Several methods have been utilized by the Indian and worldwide scientific community for assessing the impact of climate variability and climate change on agriculture such as crop growth, yield, pest and disease dynamics, nutrient dynamics and seed production. Controlled environment facilities, such as Open Top Chamber (OTC) technology, Free-Air Carbon Dioxide Enrichment (FACE) technology, Free Air Temperature Enrichment (FATE) Technology, phytotron and green house and growth chambers are now increasingly being used to understand the impact of temperature, on crop growth and productivity. Open Top Chamber is one of the best methods for studying effect of temperature on growth, forage yield and seed quality of forage crops. Keeping this in view and importance of forage crops in India, an attempt has been made to study and standardize weather parameters like raising temperature under controlled conditions for forage and forage seed production and further identification of different forage crops under different weather parameters, particularly raising temperature could help us to find out responsive/ adoptability of forage crops to new niches for fodder biomass and fodder seed production. In other words identification of different forage crops for different weather parameters will serve as immediate reservoir to combat climate change in future. Thus there is a need to study and standardize weather parameters like raising temperature under controlled conditions (Open Top Chamber) for green fodder yield and forage seed production. Here we have designed and developed the Open Top Chamber facility for studying the selected temperature under controlled conditions. Oat (*Avena sativa* L.) is the most important winter cereal (C_3) fodder crop, cultivated throughout the world as grain, feed, forage and cover crop. Oat ranks sixth in world cereal production following wheat, maize, rice, barley and sorghum. Globally, it is cultivated in an area of 27 mha with production of 40 mt. In India, it is cultivated in 0.5 mha occupying maximum area in Uttar Pradesh (34%), followed by Punjab (20%), Bihar (16%), Haryana (9%) and Madhya Pradesh (6%), Gujarat, Maharashtra, Orissa, Uttarakhand etc. (Pandey and Roy, 2011). Oat requires optimum growing temperature, around 16-20°C from germination till grain filling for maximum yield. Sorrells and Simons (1992) reported an optimum temperature of 13-19°C for high grain and straw yields. High temperature stress during post juvenile growth and development severely reduces grain yield and quality of oat.

Experimental design, plant material and growth conditions

This study was conducted on research field at Seed Technology Division of ICAR- Indian Grassland and Fodder Research Institute, Jhansi (25°29'48.4" N, 78°33'35.6" E, and 233 m above the mean sea level), during *rabi* (sown second week of November) 2020-2021. Forage oat was grown in soil inside Open Top Chambers. Oat seeds were surface sterilized with 0.01% mercuric chloride (w/v) for 10 min to avoid fungal invasion, followed by washing with distilled water and these seeds were used in this experiment. Seeds were sown in a micro randomized block design and replicated thrice. Excess seedlings were thinned. Farmyard manure at the rate of 15 t/ha along with 25 kg N/ha and 55 kg P_2O_5/ha were mixed in the soil before sowing and irrigation was given as and when required. The following simulated environment was created for experiment i.e., first treatment (T_1-Control) was Ambient and second treatment was (T_2- Elevated temperature >2°C than ambient). The OTC (3 m diameter, 3 m length and 4 m height)] lines with a multi-layered UV protected polycarbonate (6 mm) sheets of more than 85% transparency level were used to grow oat variety under natural conditions. Temperature sensor (Pt100 element) with RTD transmitter from H K Tempson (Sensography) (India) and humidity sensors (Rotronic Switzerland) was fitted inside both OTC chambers along with Ceramic infrared heaters. Temperature enrichment was done with an artificially induced temperature inside OTCs. The system simulated warming in a small ecosystem of limited height (162 cm height and it was adjustable upto 100 cm up and down) with uniformity of the thermal radiation and canopy temperature across the plot. Galvanized iron (GI) structure with infrared heating systems and controller were used to enrich ambient temperature up to + 2 to 4.5ºC. IR heating system is electromagnetic radiation with wavelength between 780 nm to 1000 nm. It can increase air temperature ambient plus 2 to 4.5ºC as it emits IR electromagnetic waves. Monitoring and control of temperature in OTC was fully automatic and desired level of temperature was maintained throughout the experimental period in OTC with the help of supervisory control and data received from data scanner was recorded by SCADA system in Excel sheet. The system monitors desired parameters and control based on the output options of various sensors. Instruments/tools like temperature, RH sensors, relay card, relay module, data logger were also used for control strategy. Signals from each sensor were obtained and transmitted to control room through four core shielded cable for data logging and control (The entire system was built by Genesis Technologies, Mumbai, India). Elevated temperature was maintained from 85 days after crop sown and maintained up to maturity stage. As global human as well as livestock population continue to increase, crops yields and forage crops yields must increase proportionally to meet the future demand for food and fodder (Myers *et al.,* 2017). Considering the adverse effects of temperature stress on crop growth and productivity, development of temperature stress tolerant crop varieties/ genotypes/ lines and particularly temperature stress tolerant forage oat could play a major role in sustaining livestock production in the semi-arid area of India and would also be helpful in future breeding programs. Only little information is available on forage oat tolerant to temperature stress. Therefore, the present investigation was carried out to study performance of forage oat morpho-physiological parameters under open top chambers for temperature stress tolerance.

Reduction in performance relative to Control (% ROC) was calculated as follows:

$$\%ROC = \frac{\text{Value for Control} - \text{Value for stressed plants}}{\text{Value for Control}} \times 100$$

Statistical analysis

Whole data were computed on Microsoft Excel

Measurements of growth parameters

Elevated temperature was imposed at 85 days after sowing and the observations, shoot fresh weight, 50% flowering, Chlorophyll SPAD- reading, and panicle length were recorded at 30 days after imposition of elevated temperature.

RESULTS AND DISCUSSION

Effect of elevated temperature on plant biomass, 50% flowering, chlorophyll SPAD- reading, panicle length in forage oat

Plant biomass, 50% flowering, chlorophyll SPAD- reading and panicle length were reduced at elevated temperature compared to ambient condition in forage oat. Reduction in shoot biomass (22.6% ROC) and shortening the life cycle at 50% of flowering stage (14% ROC), chlorophyll SPAD- reading (0.9 % ROC) and panicle length (15.5% ROC) were observed in forage oat at elevated temperature compared to ambient condition (Table 1 and Fig. 1). Stress is an altered physiological response of living organisms caused by physical, chemical or biotic environmental factors that tend to shift their equilibrium away from its optimal thermodynamic state (Singh *et al.,* 2010., Gaspar *et al.,* 2002; Strasser, 1988). Soil or water pollution, climate change or other anthropogenic effects can cause severe abiotic or biotic stress for forage crop plants and natural vegetation. Our findings showed that active warming equipment resulted in an average achieved warming of 2^{o}C under OTC and that the warming effect varied over time. It was strongly reduced by rain and also partly influenced by air temperature and wind. Relative air humidity in general showed opposite patterns compared to temperature changes. Reduction in shoot height, leaf area and number of leaves in sensitive genotypes under drought/ saline conditions may be due to their leaves having lower relative water content and membrane stability index (Singh *et al.*, 2020, Dheeravathu *et al.,*2021b and 2021c., Dheeravathu *et al.,* 2017a and 2017b). These results corroborate with other studies that

TABLE 1
Effect of elevated temperature on Plant biomass, 50% flowering, Chlorophyll SPAD- reading, panicle length in forage oat

S. No.	Plant biomass (g)	SPAD reading	Days to 50 flowering (in days) stage	Panicle length (cm)
Ambient	106±12	51.07±5.4	114.5±16+	50.5±8
Elevated	82±7	50.60±7	98.50±6	42.67±5.5
A-E	24.0	0.5	16	7.8
% ROC	22.6	0.9	14.0	15.5

The data are the mean + SE (5plants data), A: Ambient, E:Elevated , % ROC: % reduction over the control.

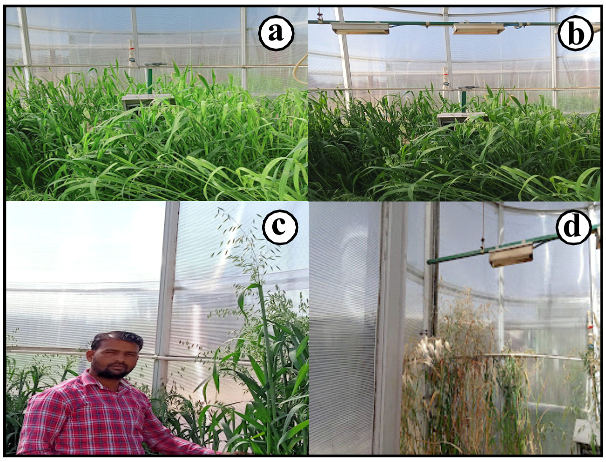

Fig. 1. Effect of temperature stress on forage Oat morphology under Open Top Chamber (OTC), (a) vegetative stage - ambient (b) vegetative stage-elevated temperature, (c) reproductive stage - ambient (d) reproductive-maturity stage- elevated temperature.

decreased fresh and dry weight in berseem and sweet William (*Dianthus barbatus*) (Azizi *et al.,* 2011; Dheeravathu *et al.,* 2021a). Global warming is predicted to have a general negative effect on plant growth due to the damaging effect of high temperatures on plant growth and development. Our results are in conformity with Ali *et al.,* (2019), Balota *et al.,* (2008), Bindumadhava *et al.,* (2018) who reported that high temperature stress decreased shoot length and shoot biomass in wheat genotype. This standardized Open Top Chamber technology is more useful for screening varieties of forage oat and other forage crops to meet the demand of fodder seed production at present and in future if the temperature stress becomes inevitable.

CONCLUSION

The results of this study showed that forage oat shoot fresh weight, SPAD reading, days to 50% flowering and panicle length were reduced and the crop plant's life cycle was shortened under elevated temperature compared to ambient condition. The open top chamber based innovative screening technique is found most useful for identifying temperature stress tolerant forage oat varieties. This technique can also be used to screen more number of crops in a calendar year under tropical and sub tropical conditions.

ACKNOWLEDGEMENTS

The authors acknowledge Indian Council of Agricultural Research (ICAR) and ICAR– Indian Grassland and Fodder Research Institute, Jhansi for financial support for conducting the experiment.

REFERENCES

Ali, M., C.M., Ayyub, M, Amjad, R. Ahmad, 2019 : Evaluation of thermotolerance potential in cucumber genotypes under heat stress. *Pak. J. Agric. Sci.,* **56** : 53-61.

Azizi, M. M., S. M, Chehrazi., Zahedi, 2011 : Effects of salinity stress on germination and early growth of sweet William (*Dianthus barbatus*). *Asian J. Agric. Res.,*$\mathbf{3}$: 453-458.

Bita, C.E and T. Gerats, 2013: Plant tolerance to high temperature in a changing environment: scientific fundamentals and production of heat tolerance crops. *Front. Plant Sci.,***4** : 273.

Bindumadhava, H. L., R. M. Sharma., H, Nair., Nayyar., J. J, Riley.,W, Easdown, 2018 : High temperature-tolerant mungbean (*Vigna radiata* L.) lines produce better yields when exposed to higher CO_2 levels. *J. Crop Improv.,* 1439132.

Christophe, S., A, Jean-Christophe., L, Annabelle., O, Alain.,P, Marion., V, Anne- Sophie, 2011 : Plant N fluxes and modulation by nitrogen, heat and water stresses: a review based on comparison of legumes and non-legume plants, in abiotic stress in plants–mechanisms and adaptations, eds A. Shanker and B. Venkateswarlu (Rijeka: Intech Open Access Publisher), 79-118.

Dheeravathu, S. N., K, Singh., P. W., Ramteke., Reetu., N., Dikshit., M, Prasad., D, Deb D., T. B,Vadithe, 2021b : Physiological responses of Bajra-Napier hybrids and a tri-specific hybrid to salinity stress.*Trop. Grassl.-Forrajes Trop.,* **9**(3) : 337-347.

Dheeravathu, S. N., V. C. Tyagi., C. K. Gupta., A. Antony, 2018 : Manual on Plant Stress Physiology. ICAR-Indian Grassland and Fodder Research Institute, Jhansi. Stress assessment formulas and stress related terminology. pp. 1-87.

Dheeravathu., S. N., A, Edna., R, V, Koti., M. B. Doddamani, 2017 : Salinity tolerance of forage range legumes during germination and early seedling growth. *Progressive Res. J.,* **12**(1): 1357-1360.

Dheeravathu, S. N., T. Singh., A, Radhakrishna, 2017 : Effect of drought stress on biomass and drought adaptive traits in Berseem (*Trifolium alexandrinum* L.), National symposium-new directions in managing forage resources and livestock productivity in 21st century: challenges and opportunity. pp 4-17.

Dheeravathu, S. N., T, Singh., A, Radhakrishna., Reetu., G, Rahul., S. R, Kantwa., H. A, Bhargavi, 2021a : Effect of salinity stress on different seed vigour indices in single and multi cut berseem (*Trifolium alexandrinum*) varieties. *Forage Res.,* **46**(4) : pp. 368-373.

Dheeravathu, S. N., M. H, Hanamant., T. B, Vadithe., S. N, Vadithe., K, Singh., N. Dikshit., T. N, Usha., T. Singh, Reetu and R, Gajghate, 2021c : Salinity tolerance of forage cowpea [*Vigna unguiculata* (L.) walp.] during germination and early seedling growth. *Forage Res.*, **47**(2) : 213-221.

FAOSTAT, 2016 : Food and agriculture organization of the United Nations Statistics Division. http://faostat3.fao.org/download/Q/QC/E.

Gadgil, S, 1996 : Climate change and agriculture-an Indian perspective. in climate variability and agriculture (eds. Abrol Y. P. *et al,*), Narosa Publishing House, New Delhi. pp. 1-18.

Hingane, L. S., K, Rupa., Kumar., B. H. V, RamnaMurty, 1985 : Long term trends of surface air temperature of in India. *Int. J. Climatol.,* **5** : 521-528.

Gaspar, T., T, Franck., B, Bisbis., C, Kevers., L, Jouve., J. F, Hausman., J, Dommes, 2002 : Concepts in plant stress physiology. Application to plant tissue cultures. *Plant Growth Regul.,* **37** : 263-285.

Myers, S. S., R, Matthew., S. S, Guth., D, Christopher., G. B, Vaitla., N. D, Mueller., A. D, Dangour., P, Huybers, 2017 : Climate change and global food systems: potential impacts on food security and under nutrition. *Annu. Rev. Public Health*., **38** : 259-77.

Pandey, K. C. and A. K., Roy, 2011 : Forage crop varieties, Indian Grassland and Fodder Research Institute (ICAR-IGFRI), Jhansi (India). pp 60-65.

Ruelland, E and Zachowski, A, 2010 : How plants sense temperature. *Environ. Exp. Bot.,* **69** : 225-232.

Singh, K., S. N, Dheeravathu., P. W, Ramteke., Reetu., N, Dikshit., T. B, Vadithe, 2020 : Effect of salt stress on morpho-physiological and green fodder yield of Bajra Napier Hybrids and Tri-Specific Hybrid. *Forage Res.,***46**(3): 241-247.

Singh, B., S. N. Dheeravathu, K. Usha, 2010 : Micronutrient Deficiency: A Global Challenge and Physiological Approach to Improve Grain Productivity under Low Zinc Availability*, In: Plant stress*. Global science book UK, Vol (Special issue -2) **4** : 76-93.

Strasser, R. J., 1988 : A concept for stress and its application in remote sensing. Applications of chlorophyll fluorescene. In: Photosynthesis research, stress physiology, hydrobiology and remote sensing. Springer, Dordrecht. pp. 333-337.

Sorrells, M. E. and Simons, S. R., 1992 : Influence of the environment on the development and adaptation of oat. In 'Oat Science and Technology'. (Eds H.G. Marshall and M.E. Sorrells) pp 115-63. The American Society of Agronomy, Wisconsin.