Available online at
www.agrospheresmagazine.com

ISSN: 2582 – 7022

Agrospheres:e-Newsletter, (2021) *2*(12), 9-12

Article ID: 330

Response of Rice Crop to the Interaction of Elevated CO_2 and Temperature-A Review

Parishmita Das*, R.L. Deka

Department of Agrometeorology
Assam Agricultural University
Jorhat-785013, Assam

Open Access

*Corresponding Author
Parishmita Das*

Article History
Received: 17. 12.2021
Revised: 24. 12.2021
Accepted: 27. 12.2021

This article is published under the terms of the Creative Commons Attribution License 4.0.

INTRODUCTION

Unabated climate change resulting from the increasing greenhouse gases and its dreaded impacts has turned out to be the most concerned issue worldwide. Among the greenhouse gases, CO_2 is considered to be one of the major contributors to climate change as it can persist in the atmosphere for a very long time. Growing at the current rate of about 2.4 ppm per year, atmospheric CO_2 concentration has increased from a pre-industrial concentration of 280 ppm to about 412 ppm in 2019 (NOAA, 2019) and is projected to reach 540-970 ppm by the end of the 21st century (IPCC, 2014). CO_2, due to its high absorbance in several wavelengths of earth's Infrared radiation, has a direct influence in increasing the earth's surface temperature. The Intergovernmental Panel on Climate Change (IPCC) has estimated a global warming of 1°C above pre-industrial levels and future projections indicate a rise of 1.5°C between 2030 and 2052, primarily due to anthropogenic activities. Global mean surface temperature for the decade 2011-2020 was observed to be 1.09°C higher than the average over the 1850-1900 period (IPCC, 2021). Since climate is the key determinant of a successful harvest, therefore, agricultural sector becomes the most discernible area which is likely to be affected by either direct or indirect impacts of the long term fluctuations of weather variables, even if the agricultural crops are supplemented by other inputs.

CO_2 particularly plays a pivotal role in crop growth, development and yield while temperature determines the timing and duration of different phenological phases (Bahuguna and Jagadish, 2015). Increases in atmospheric CO_2 concentration and associated further warming are likely to severely affect the food grain production of tropical and subtropical countries including India (Satapathy *et al*., 2015) thereby threatening agricultural productivity and food security in the near future.

ISSN: 2582 - 7022

However, the impacts of climate change on agricultural crops will vary with different crop physiological mechanism, with C_3 crops benefitting more than the crops with C_4 mechanism. This is due to the fact that current CO_2 concentration is insufficient to saturate the CO_2 binding site of Ribulose 1, 5 biphosphate (RuBP) carboxylase/ oxygenase (Rubisco) and elevated CO_2 would lead to increase in carboxylation and competitive inhibition of the oxygenase activity of the enzyme thereby suppressing photorespiration in the C_3 plants (Long *et al*., 2006). There is rising evidence suggesting that elevated CO_2 levels promote productivity of most of the C_3 plants by 10-45%, mainly due to fertilization effect and photosynthesis enhancement, and C_4 plants by 5-10% due to water stress reduction (Deryng *et al*., 2016). In contrast, elevated temperature shortens crop growth duration by increasing crop respiration and altering photosynthate partitioning to economic products and hence, negatively impacts crop productivity (Ruchita & Rohit, 2017).

Impact of elevated CO_2 and temperature on Rice-a brief overview

Rice, which is a C_3 plant, is the most important cereal crop in the world with an annual production of 0.6 billion tonnes during 2017 (FAO, 2018). India ranks 2nd in rice production after China, with an annual production of 165 million tonnes in 2016-17 from an area of about 45 million ha (Puntia, 2017). Though yield of rice is likely to increase due to doubling of CO_2 under non-stressful temperature conditions, however under the present scenario of climate change, rice yield is likely to be negatively impacted by rising temperature as duration of each phenological phase of rice is temperature dependent. Rice crop requires an optimum temperature of 36°C during vegetative stage, 33°C during reproductive stage and 23-26°C during maturity for maximum grain yield (Baker *et al*., 1995). High temperature accelerates grain filling rate but temperatures higher than 33°C during anthesis may be lead to anther dehiscense, poor germination of pollen grains and thus induces spikelet sterility thereby reducing grain yield (Kim and You, 2010). Increase in minimum (night) temperatures are equally detrimental to rice production as it affects the translocation of C and N, thereby offsetting positive impacts of elevated CO_2 on rice crop (Cheng *et al*., 2010).

Phenology of rice as affected by elevated CO_2 and temperature

Rice crop accumulates biomass faster when exposed to elevated CO_2 conditions, particularly during vegetative and grain filling stages (De Costa *et al*., 2003). Similarly, elevated temperature induces early maturity in rice. Thus, CO_2-temperature enrichment causes a significant reduction in the duration of vegetative phase which ultimately leads to shorter crop duration (Das *et al*., 2020). Through an experiment conducted under temperature control chamber in Tamil Nadu, Rani and Maragatham (2013) demonstrated that nearly 96 and 102 days were required by *kharif* rice to attain maturity when the crop was exposed to 4°C and 2°C higher temperature than the ambient respectively for the entire crop growth period. The crop took about 108 days to mature when it was grown under ambient temperature conditions. The AGDD values were also found to be higher under temperature elevation of 4°C (1641) and 2°C (1583).

Growth and yield of rice as affected by elevated CO_2 and temperature

Rice responds positively to elevated CO_2 conditions in terms of its height, tiller number, leaf number, leaf area, stomatal conductance, etc. However, elevated CO_2 when combined with variations in temperature may show contrasting results. Maity *et al.* (2019) studied the growth and yield parameters of rice at IARI, New Delhi inside the OTCs (Open Top Chambers) and found that growth of the crop was enhanced under an elevated CO_2 treatment of 550±25ppm but it was reduced when the crop was exposed to a temperature of 2°C higher than the ambient. In a similar study conducted under temperature gradient tunnels (TGTs), Das *et al.* (2020) observed better performance of *kharif* rice in terms of tiller number, number of panicles per hill, 1000 grain weight, etc. when it was exposed to a temperature of 2°C greater than the ambient and CO_2 concentration of 50% more than the ambient, though number of filled grains per panicle reduced on account of exposure of the reproductive and maturity phases of the crop to a comparatively higher temperature leading to spikelet sterility.

Regional disparities in India to the impact of elevated CO_2 and temperature on rice

Rice crop has a wide physiological adaptability over various climate zones. However, impact of climate change on yield of rice is location-specific, due to the varying temperature sensitivity of the crop in different agroclimatic regions in India. In India, more than 60% of the cropped area is under rainfed agriculture and the impacts of climate change are projected to be wider in case of rainfed than that over irrigated conditions. Rice yields in eastern and western India were found to be less affected due to increase in temperature, moderately affected in northern parts and severely affected in southern parts of India as stated by Aggarwal and Mall (2002). Within eastern India, considerable variations were reflected in yield predictions among different locations with an increasing trend for rice yield in Jorhat but declining trend in Cuttack and Bhubaneshwar under elevated temperature conditions at the current CO_2 level (Krishnan *et al.*, 2007). In contradiction to the above findings, certain simulation studies projected increase in rainfed rice yield in South Indian states of Andhra Pradesh, Tamil Nadu and Karnataka whereas, in most parts of central and east India including Maharashtra, Orissa, Chhattisgarh and Assam, rice yield is projected to decrease by around 6-18% (Soora *et al.*, 2013) under different climate change scenarios.

CONCLUSION

Rice being a tropical crop is adapted to high temperature conditions. However, it has become unequivocal from the findings that in the event of climate change, as manifested by increase in atmospheric CO_2 and temperature, there would be a profound negative impact on rice yield across the states. This increase in temperature may be beneficial for rice production in areas with comparatively low temperature regime in the near future. To overcome the challenges of climate change, some adaptation strategies already in practice are adoption of climate resilient rice varieties, efficient use of fertilizers and efficient water management practices, etc. However, efforts are needed to explore more opportunities to ensure greater adaptability of rice under the current scenario of climate change.

REFERENCES

Aggarwal, P. K. and Mall, R. K. (2002). Climate change and rice yields in diverse agro-environments of India. II. Effect of uncertainties in scenarios and crop models on impact assessment. *Clim. Change*. **52**(3): 331-343.

Bahuguna, R. N. and Jagadish, S. V. K. (2015). Temperature regulation of plant phenological development. *Environ. Exp. Bot.* 111, 83–90. doi: 10.1016/j.envexpbot.2014.10.007

Baker, J.T., Boote, K.J. and Allen, L. H. Jr (1995) Potential climate change effects on rice: carbon dioxide and temperature. In: Rosenzweig C et al (eds) Climate change and agriculture: analysis of potential international impacts. ASA Spec. Publ.59. ASA, CSSA and SSSA, Madison, pp 31–47

Cheng, W., Sakai, H., Yagi, K. and Hasegawa, T. (2010) Combined effects of elevated CO_2 and high night temperature on carbon assimilation, nitrogen absorption, and the allocation of C and N by rice (Oryza sativa L.). *Agric. For Meteorol.* **150**:1174–1181

Das, P., Deka, R. L., Goswami, J. and Barua, S. (2020). Effect of elevated CO2 and temperature on growth and yield of winter rice under Jorhat condition. *J. Agrometeorol.* **22** (2) : 109-115.

De Costa, W. A. J. M.; Weerakoon, W. M. W.; Herath, H. M. L. K. and Abeywardena, R. M. I. (2003). Response of growth and yield of rice (*Oryza sativa*) to elevated atmospheric carbon dioxide in the subhumid zone of Sri Lanka. *J. Agron & Crop Sci.* **189**(2): 83-95.

Deryng, D., Elliott, J., Folberth, C. , Müller, C., Pugh, T.A.M., Boote, K.J., Conway, D. and Ruane, A.C. (2016). Regional disparities in the beneficial effects of rising CO2 concentrations on crop water productivity. *Nature Clim. Change* **6** (4) 1-8. 10.1038/NCLIMATE2995.

FAO, FAOSTATS (2018). Food and Agriculture Organization of the United Nations, Rome, http://faostat.fao.org/default.aspx.2018

IPCC (2014). Climate Change: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (eds Core Writing Team, Pachauri, R. K. and Meyer, L. A.), Inter-Governmental Panel on Climate Change, Geneva, Switzerland, 2014, p. 151.

IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press.

Kim, H. and You, Y. (2010). The effects of the elevated CO_2 concentration and increased temperature on growth, yield and physiological responses of rice (*Oryza sativa* L. cv. Junam). *Adv. Bio Res.* **1**(2): 46-50.

Krishnan, P.; Swain, D. K.; Bhaskar, B. C.; Nayak, S. K. and Dash, R. N. (2007). Impact of elevated CO_2 and temperature on rice yield and methods of adaptation as evaluated by crop simulation studies. *Agric. Ecosyst. Environ.* **122**(2): 233-242.

Long, S. P.; Ainsworth, E. A.; Leakey, A. D. B.; Nösberger, J and Ort, D. R. (2006). Food for thought: lower than expected crop yield stimulation with rising CO_2 concentrations. *Sci.* **312**(5782): 1918-1921.

Maity, P. P.; Chakrabarti, B.; Bhatia, A.; Purakayastha, T. J.; Saha, N. D.; Jatav, R. S.; Sharma, A.; Bhowmik, A.; Kumar, V. and Chakraborty, D. (2019). Effect of Elevated CO_2 and Temperature on Growth of Rice Crop. *Int. J. Curr. Microbiol. App. Sci.* **8**(1): 1906-1911.

National Oceanic and Atmospheric Administration, United States Department of Commerce, Global carbon dioxide growth in 2018 reached 4th highest on record, 22 March 2019; www.noaa.gov

Puntia, D. (2017). Interactive Effect of Elevated Carbon Dioxide and Temperature on Nitrogen Partitioning, Growth and Yield of Rice Varieties. M. Sc. Thesis, Centre for Environment Science and Climate Resilient Agriculture, Indian Agricultural Research Institute, New Delhi.

Rani, B. A. and Maragatham, N. (2013). Effect of elevated temperature on rice phenology and yield. *Indian J. Sci. & Technol.* **6**(8): 5095-5097.

Ruchita, S. and Rohit, S. (2017). Effect of Global warming on Indian Agriculture. *J. Climatol. & Weather Forecasting.* **5**(1): 195.

Satapathy, S. S.; Swain, D. K.; Pasupalak, S. and Bhadoria, P. B. S. (2015). Effect of elevated [CO2] and nutrient management on wet and dry season rice production in subtropical India. The Crop J., 3(6): 468-480.

Soora, N. K., Aggarwal, P. K., Saxena, R., Rani, S., Jain, S. and Chauhan, N. (2013). An assessment of regional vulnerability of rice to climate change in India. Clim. Change. **118**: 683-699. DOI 10.1007/s10584-013-0698-3