Journal of Agrometeorology 23 (3) : 324-329 (September 2021)

Performance of rainfed chilli crop in Tamil Nadu under climate change in RCP4.5 **

N. KOWSHIKA[*2], S. PANNEERSELVAM[1], V. GEETHALAKSHMI[1], T. ARUMUGAM[1] and R. JAGADEESWARAN[1]

[1]*Tamil Nadu Agricultural University, Coimbatore, India*
[2]*National Agro Foundation, Chengalpattu, India*
[*]Corresponding Author email: *kowshirajanagmet@gmail.com*

ABSTRACT

Dry chilli, which stands third in production from the spice industry, has influenced the Indian diet to a greater extent . The impact of climate change conditions on chilli crop could, in turn, impart the economy deeply. Hence, the future projection of dry chilli production will surely enrich knowledge about crop performance. Climate data from CCSM4 being downscaled from RegCM 4.4 was used in yield projection till the end of 21st century through DSSAT crop simulation for two major cultivars of chilli in Tamilnadu *viz.*, TNAU chilli hybrid CO1 and K1 variety under rainfed conditions. TNAU chilli hybrid CO1 and K1 varieties have shown negative yield deviations for all the agroclimatic zones of Tamilnadu under variable time scales. However, southern zone was exclusive in exhibting positive yield by 7 percent and 5 percent, respectively, during the end of century.

Key words: Chilli, rainfed, climate change, DSSAT

Climate change is a process of immense importance since 20th century that could affect the livelihood of humans and other living organisms. Apart from natural causes, anthropogenic activities drive the rate of climate change. The 5th Assessment Report (AR5) of Intergovernmental Panel on Climate Change (IPCC) focuses on Representative Concentration Pathways (RCPs) for future projections, which is given by RCP2.6, RCP4.5, RCP6 and RCP8.5 conditions. Projected climate for India would indicate an overall temperature increase of 2.0 – 4.0°C (Kavikumar, 2010) along with erratic rainfall and frequent droughts on regional scale (Prabhakar *et al.*, 2017).

It is sure to affect the horticultural sector also, especially for a crop like chilli, which is both vegetable and spice. Extreme temperatures and precipitation events along with summer droughts would reduce chilli production (Hwang and Tae, 2001). Chilli is affected by drought and high temperatures causing 70 per cent yield loss on the industrial scale (Fernandez *et al*., 2005). Researches have revealed that chilli crop had been influenced more by increase in minimum temperature than maximum temperature due to the changes in biomass partitioning to yield (Abhayapala *et al.*, 2018). Using crop simulation models to estimate yield projections of chilli crop tends to fill the research gap in horticultural crops. Boote and Scholberg (2006) have suggested using the CROPGRO module in the DSSAT model for tomato and bell pepper. Keeping in view of the importance of chilli crop in Tamilnadu in the rainfed regions of Southern Zone districts (Spices Board, 2017), the study was undertaken.

MATERIALS AND METHODS

Study domain

The research was conducted and represented entire state of Tamilnadu which lies between 08° 00’ - 13° 30’ North latitudes and 76° 15’ - 80° 18’ East longitudes with an area of 1,30,058 sq.km. Future climate projections on RCP4.5 were generated for a period of 94 years starting from 2006 to 2099 during which climate change impact assessment for chilli crop was studied. Performance of two chilli varieties *viz*., TNAU chilli hybrid CO1 and K1 variety under rainfed conditions were analysed. Irrigation requirement of TNAU chilli Hybrid CO1 is more then K1 variety which is a completely rainfed one. Comparing the performance of both under rainfed conditions would pave

** Paper presented in National Seminar “AGMET 2020” held at KAU, Thrissur during 20-22 January 2020.

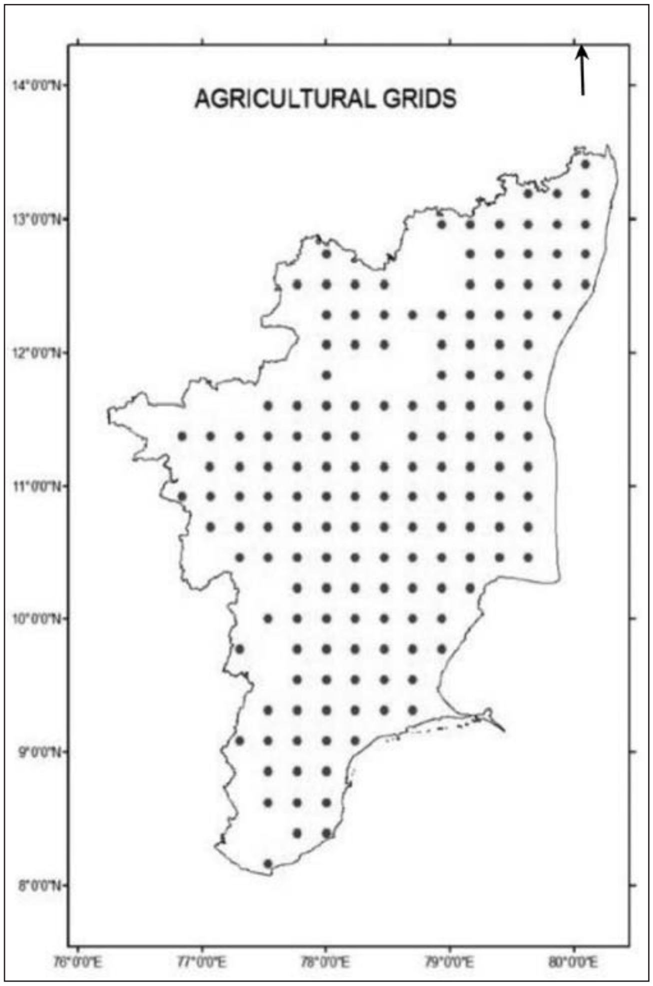

Fig. 1: Agricultural grids used in the study

way in understanding the suitable variety for sustainable use. The details of these varieties have been given in Table 1.

Crop Simulation - Developing Genetic Coefficients

Field trials were conducted during 2018-2019 to collect the required crop data for calibration and validation of DSSAT crop simulation model. Multi locational trials were taken up obtaining 11 experiments in three seasons – 8 for calibration and 3 for validation of the genetic coefficients. Crop biometric observations on plant height, number of leaves, leaf area index, plant dry matter production, number of fruits per plant, number of fruits per m^2 and dry fruit weight at 20 days interval were taken regularly from the field trials. Soil data on pH, EC, bulk density, organic carbon, cation exchange capacity, NPK nutrient content, and physical composition were estimated. Weather data of field locations for the cropping period were obtained from the Automatic Weather Stations (AWS) installed at block level where 2018-2019 data from TNAU for Sundapalayam, Palladam block for Palladam field and Kovilpatti block for Kovilapatti field were used.

Decision Support System for Agrotechnology Transfer (DSSAT) CROPGRO module was used to evaluate the performance of chilli's both cultivars after developing genetic coefficients using GENCALC tool for calibration, followed by validation. Weatherman tool in DSSAT model was employed to convert daily weather data on maximum temperature, minimum temperature, solar radiation and rainfall. Soil observations from Department of Remote Sensing and GIS, TNAU was also used to construct soil profile of the locations through S Build tool, while the experimental files based on crop observations were created in X Build tool.

Climate change impact assessment

Climate change impact assessment of chilli production was carried out by downscaling of GCM model CCSM4 using regional climate model RegCM4.4. The downscaling for future climate change was done for the period of 2006-2100 under RCP4.5 scenario. A historical run was also carried through the model as mentioned earlier for obtaining base year data from 1971 to 2005 (BASE). The daily weather variables such as maximum and minimum temperatures, rainfall and solar radiation were used for the historical runs, whereas for the future projections, three-time scales *viz*., near-century (NEAR: 2010-2040), mid-century (MID: 2041-2070) and end of the century (END: 2071-2099) derived from model output under RCP4.5 scenario were incorporated into DSSAT crop simulation model. The effect of CO_2 fertilisation was included in the study by keeping environmental modification treatments using the observations from Keeling *et al*. (2001). The agricultural grid points were grouped into respective Agro Climatic Zones where high rainfall zones and hilly regions were not considered for the study. The crop model was run to assess the impact of climate change on chilli production for entire Tamil Nadu.

Percentage relative difference (R.D.%)

Percentage relative difference from base year (BASE: 1971-2005) for chilli production was worked out for near century (NEAR: 2010-2039), mid-century (MID: 2040-2069) and end of the century (END: 2070-2099)

Table 1: Chilli cultivar details

Varieties	Parentage	Year of release	Duration (days)	Dry fruit yield (t ha^{-1})	Special features
TNAU Chilli Hybrid CO1	Selection 1 x CA 97	2010	195-205	6.74	Moderately resistant to fruit rot disease.
K1	Pure line selection from an Assam type B 72 A	1964	210	1.8	Suitable for rainfed cultivation.

Table 2: Yield and relative yield deviation of TNAU chilli hybrid CO1 under rainfed condition over the five Agro Climatic Zones of Tamilnadu

Time period	CDZ		NEZ		NWZ		SZ		WZ	
	Yield (kg ha^{-1})	R.D (%)	Yield (kg ha^{-1})	R.D (%)	Yield (kg ha^{-1})	R.D (%)	Yield (kg ha^{-1})	R.D (%)	Yield (kg ha^{-1})	R.D (%)
BASE	1491		873		929		793		1684	
NEAR	1350	-9	785	-10	739	-20	713	-10	1490	-11
MID	1393	-7	810	-7	754	-19	708	-11	1561	-7
END	1363	-9	822	-6	797	-14	846	7	1462	-13

*CDZ Cauvery Delta Zone, NEZ- North Eastern Zone, NWZ- North Western Zone, SZ- Southern Zone, WZ-Western Zone, RD- Percentage relative difference

Table 3 : Yield and relative yield deviation of K1 variety under rainfed condition over the five Agro Climatic Zones of Tamilnadu

Time period	CDZ		NEZ		NWZ		SZ		WZ	
	Yield (kg ha^{-1})	R.D (%)	Yield (kg ha^{-1})	R.D (%)	Yield (kg ha^{-1})	R.D (%)	Yield (kg ha^{-1})	R.D (%)	Yield (kg ha^{-1})	R.D (%)
BASE	1642		999		1043		904		1827	
NEAR	1462	-11	904	-9	863	-17	831	-8	1619	-11
MID	1506	-8	931	-7	876	-16	830	-8	1677	-8
END	1465	-11	929	-7	900	-14	952	5	1563	-14

*CDZ Cauvery Delta Zone, NEZ- North Eastern Zone, NWZ- North Western Zone, SZ- Southern Zone, WZ-Western Zone, RD- Percentage relative difference

using the following formula.

$$\text{R.D. \%} = \frac{\text{Average predicted future years-Average predicted base years}}{\text{Average predicted base years}} \times 100$$

Mapping

Grid points with minimum 50 per cent agricultural area were chosen and the plotting was using ArcGIS 10.1. This gave 162 grid points (Fig. 1) to visualise the climate change impacts on chilli crop. Agricultural grid points were obtained from Department of Remote sensing and Geographical Information Systems, Tamil Nadu Agricultural University, Coimbatore.

RESULTS AND DISCUSSION

Result outcomes of climate change impacts on rainfed TNAU chilli hybrid CO1 and K1 variety yields have been given in Table 2 and Table 3. The yield and relative yield deviation of TNAU chilli hybrid CO1 during future projections denote that, mid-century is less affected than the remaining two time scales. Similarly, Cauvery Delta Zone was less affected compared to other Zones in the state. Among the different Agro Climatic Zones; North Western Zone had been experiencing highest yield reduction i.e. –20 per cent, -19 per cent and –14 per cent yield reductions in near, mid and end centuries, respectively. Though all the Agro Climate

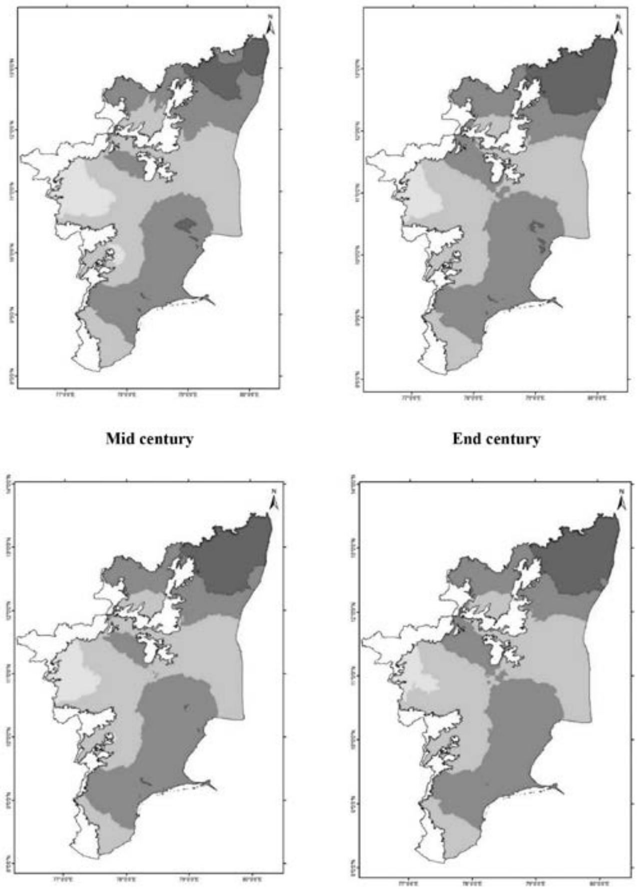

Fig. 2: Spatial distribution of TNAU chilli hybrid CO1 yield (kg ha^{-1})

Zones of Tamilnadu have been affected by the changing climate, southern zone had empowered 7 per cent yield increment in the rainfed crop at the end of century (Fig. 2).

After scrutinising the result outcomes of K1 variety, yield and relative yield deviation in the five Agro Climatic Zones of Tamilnadu it could be visualised (Figure 3) that the mid- century had been relatively sustainable even with the negative yield deviation in the Cauvery Delta Zone (-8%), North Eastern Zone (-7%) and Western Zone (-8%). But the North Western Zone had a higher negative influence in near century (-17%) going through an improvement in mid-century (-16%) and end century (-14%). Southern Zone's major chilli tract has maintained consistency by negative yield deviation in both the near and mid-centuries by -8 per cent (Table 2). Intuitively the Southern Zone invigorated the yield by 5 percent from the base period in the end century. The most probable reason for such deviation are explained herein that the excess water condition could lead to flower drop and reduced fruit set (Doorenbos and Kassam, 1979). Moreover excess rainfall and submerged condition will damage any crop through reduced oxygen in rhizosphere, finally making into anaerobic state (La Pena and Hughes, 2007). Heavy rainfall conditions in Bangladesh has affected the chilli production in the country tremendously since the crop cannot tolerate severe rainfall (Ashrafuzzaman *et al.*, 2011). Ramraj (2014) have predicted excess rainfall conditions during the mid-century time period. So, invariably excessive rainfall during mid-century would leave the chilli plants deprived of photosynthates in yielding fruits. This could be the possible reason for the higher levels of yield loss from North western Zone. Kumar *et al.* (2007) anticipated good amount of North East monsoon over dry Southern Zone districts of Tamilnadu which would surely prosper the crop unlike other zones which would receive too much rainfall to lodge chilli plants. Kumari *et al.* (2019) had a complimentary statement where the effect of enriched CO_2 had been beneficial to bell pepper under greenhouse condition. But during the interaction between elevated CO_2 and temperature the increasing temperature levels

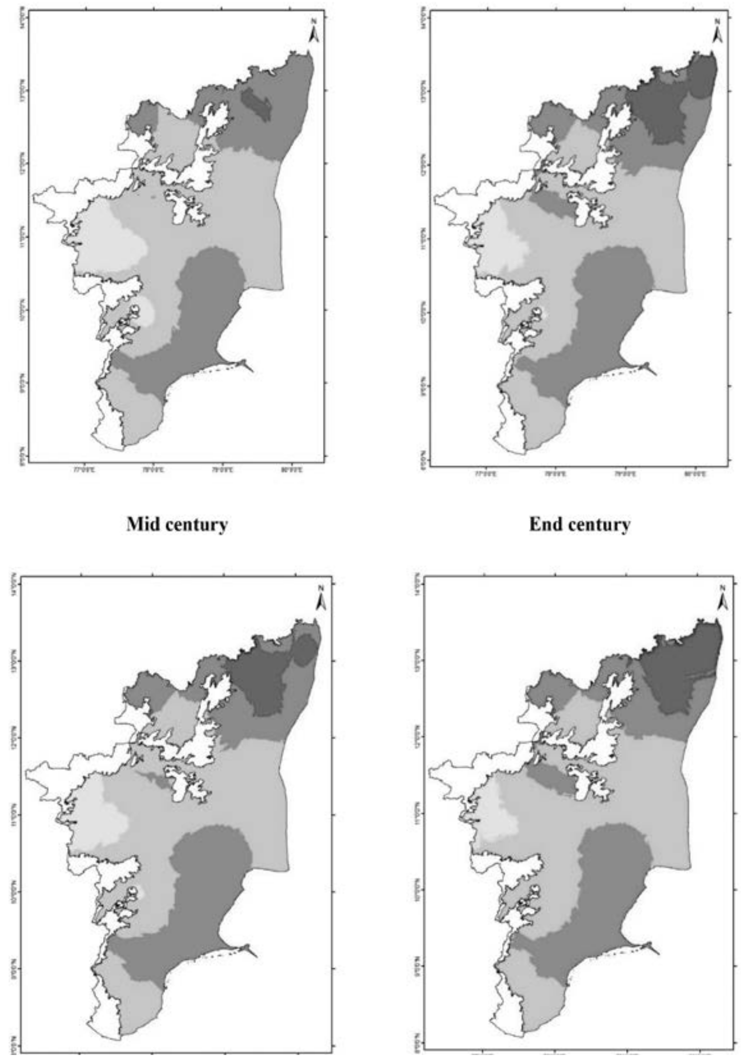

Fig. 3: Spatial distribution of K1 variety yield (kg ha^{-1})

negated the positive effect of CO_2 enrichment. This could be understood in other words that the increased CO_2 would truly be progressive against rising temperature levels. These researches have been taken into support that the enrichment of CO_2 in future would benefit the chilli crop (Fig. 2 and Fig. 3).

CONCLUSION

Climate change impact on chilli crop was evident on both the cultivars. TNAU chilli hybrid CO1 crop has been through less affect of the future change whereas unlike the other zones Southern Zone alone being benefitted with 7 per cent productivity boost at the end of the century. Compared to the other cultivar, K1 variety was highly affected by climate change conditions. However, the cultivar gave 5 per cent yield increment in Southern Zone probability aided by the CO_2 enrichment during the end of century.

Conflict of Interest Statement : The author(s) declare(s) that there is no conflict of interest.

Disclaimer : The contents, opinions, and views expressed in the research article published in the Journal of Agrometeorology are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

Publisher's Note : The periodical remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

REFERENCES

Abhayapala, R., Janendra De Costa, Wasantha M., Kumara, A., Suriyagoda, L. and Fonseka, R. (2018). Exploitation of differential temperature-sensitivities of crops for improved resilience of tropical smallholder cropping systems to climate change: A case study with temperature responses of tomato and chilli.” *Agric., Ecosys. Environ.*, 261:103-114.

Ashrafuzzaman, M., Abdul H. M., Mohd R. I., Shahidullah, S.M. and Alamgir H.M. (2011). Effect of plastic mulch on growth and yield of chilli (*Capsicum annuum* L.). *Brazilian Arch. Biology Tech.*, 5 (2):321-330.

Boote, K.J. and Scholberg, J.M.S. (2006). Developing, parameterizing, and testing of dynamic crop growth models for horticultural crops. III International Symposium on Models for Plant Growth, Environmental Control and Farm Management in Protected Cultivation, 718: 23-24.

Doorenbos, J, and Kassam, A.H. (1979). Yield response to water. *Irrig. Drain. paper*, 33:257.

Fernandez, M.D., Gallardo, M., Bonachela, S., Orgaz, F., Thompson, R.B. and Fereres, E. (2005). Water use and production of a greenhouse pepper crop under optimum and limited water supply. *J. Hort. Sci. Biotech.*, 80(1):87-96.

Hwang, J.M., and Tae, G.S. (2001). Changes in the growth of red pepper (*Capsicum annuum* L.) and soil moisture according to irrigation and cultivating methods. *J. Korean Soc. Hort. Sci.*, 42(3): 295-299.

Kavikumar, K.S. (2010). Climate sensitivity of Indian Agriculture: Role of Technological Development and Information Diffusion, in Lead Papers-National Symposium on Climate Change and Rainfed Agriculture, Indian Society of Dryland Agriculture”, CRIDA, Hyderabad, February 18-20, p.1-18.

Keeling, C. D., Stephen C. P., Robert B. B., Martin W., Timothy P. W., Martin H. and Harro A. M. (2001). Exchanges of atmospheric CO_2 and $^{13}CO_2$ with the terrestrial biosphere and oceans from 1978 to 2000. I. Global aspects. *UC San Diego: Library – Scripps Digital Collection. Retrieved from https://escholarship.org/uc/item/09v319r9*

Kumar, P., Rupa Kumar, K., Rajeevan, M. and Sahai, A.K. (2007). On the recent strengthening of the relationship between ENSO and northeast monsoon rainfall over South Asia. *Clim. Dynamics*, 28(6):649-660.

Kumari, M., Verma, S.C. and Bhardwaj, S.K. (2019). Effect of elevated CO_2 and temperature on crop growth and yield attributes of bell pepper (*Capsicum annuum* L.). *J. Agrometeorol.*, 21(1): 1-6.

La Pena, R de, and Hughes, J. (2007). Improving vegetable productivity in a variable and changing climate. *SAT eJournal*, 4 (1): 1-22.

Prabhakar, A.K., Singh, K.K., Lohani, A.K. and Chandniha, S.K. (2017). Long term rainfall variability assessment using modified Mann-Kendall test over Champua watershed, Odisha. *J. Agrometeorol.*, 19(3): 288-289.

Ramraj, A.P. (2014). Integrated assessment of cascading uncertainty in climate and crop models. PhD Thesis, Agro Climate Research Centre, Tamil Nadu Agricultural University.

Spices Board. (2017). Horticulture at a Glance 2017. Horticulture Statistics Division.

Received : January 2021 : Accepted : June 2021