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

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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 exhibiting 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
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 m² 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 CO₂ 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 | -7  | 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:

\[
\text{R.D.} \% = \left( \frac{\text{Average predicted future years} - \text{Average predicted base years}}{\text{Average predicted base years}} \right) \times 100
\]

**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
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 CO₂ had been beneficial to bell pepper under greenhouse condition. But during the interaction between elevated CO₂ and temperature the increasing temperature levels
negated the positive effect of CO₂ enrichment. This could be understood in other words that the increased CO₂ would truly be progressive against rising temperature levels. These researches have been taken into support that the enrichment of CO₂ 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 CO₂ enrichment during the end of century.

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

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