

Effect of elevated CO₂ induced high temperature on yield and quality parameters in crops, with preference to tomato: A review

ABSTRACT

Rising CO₂ levels in the atmosphere, a major contributor to climate change, has a wide range of consequences. CO₂ can absorb and radiate heat energy resulting in the hike of earth's average temperature. The elevated CO₂ induced temperature rise in atmosphere has a severe impact on agricultural crop productivity, as temperature is one of the important abiotic factors which influence crop growth and development. So the high temperature and drought that accompany climate change will decrease the food production and threaten food security globally.

Keywords: Climate change, Elevated CO₂, Flowering, Fruiting, Tomato

INTRODUCTION

Climate change is a global phenomenon of climate transformation especially caused by human activities and characterized by the alterations in climate pattern regarding temperature, precipitation and wind. It is a serious threat to future mankind and global economy. The increase in the levels of GHGs (greenhouse gases) will cause global warming [1] and the climate change will ultimately cause a decline in crop yields and productions. Climate change is one of the important concerns associated with India's food security challenges. It significantly affects agriculture and food production by influencing the cropping seasons [2][3][4] and water availability [5][6][7].

The current atmospheric carbon dioxide (CO₂) concentration has reached 414 ppm according to NOAA, National Oceanic and Atmospheric Administration and the sixth assessment report from IPCC, Intergovernmental Panel on Climate Change gives a warning of global warming of 1.5^o C between 2030 and 2052 [8]. The IPCC projected that there will be an increase in surface air temperature by 1.1^oC to 6.4^oC by last of the 21st century, due to increased emanations of CO₂ and other greenhouse gases into the atmosphere. So elevated CO₂ and associated high temperature can alter the physiology and chemical composition of plants and have direct influence on agricultural production.

Tomato is an important vegetable crop in India with an average production of 18.40 million tonnes. It is rich in antioxidants, micronutrients, phenolic compounds, carboxylic acids, vitamins and minerals. The fluctuations in environmental factors like temperature, light and water availability can drastically affect the mineral and phytochemical content in tomato [9]. Heat stress is a major abiotic factor that limits tomato production by influencing various physiological processes such as

photosynthetic activities, transpiration, photorespiration, darkrespiration aswell as vegetativegrowth and reproductivedevelopment. Elevated temperaturewill causedistortion ofpollenandfloralstructures and willimpirepollen germinationand furtherdevelopment causingdecreased fruit set andyield [10]. So floweringand fruitset are most affected underhigh temperature stressconditions intomato.

Effectof elevated CO₂ on observationsrelated toflowering

Floweringis a criticalmilestone in thelife cycleof plants for it's reproductive successandfruitset. Since CO₂andtemperature are thekey factors forplantgrowth and developmentthe CO₂ inducedhigh temperatureaffects various flowering relatedevents such as floral initiation, floraldevelopment,fruit set and fruit growth.So the climatechange have a significantimpact onflowering relatedevents in plants.Addressing the effects of these environmentalfactors on timeofanthesis andflowering time is criticaltounderstand the adaptationof plants/ cropsto climatechange.

ElevatedCO₂ and increasingambient temperature isa major climaticfactor that advances floweringtime incertain crops. It reportedan increase in the flower numberunder increased CO₂ condition[11]. Anexperiment reported thatthe increased numberof flowers and fruits togetherwith higher fruit set led to higher fruit yield at ECconcentrations (EC 550 and 700 ppm)[12]. It isreported that plants grown under high CO₂reached flowering 8 dayssooner than those grownunder ambientcondition[13].

Pollen viability

Theimpairedpollen developmentand reducedpollen viabilitywill decrease the yieldof crops at hightemperature.ElevatedCO₂andassociated heatstress at meiosis reduced pollen viability,spikelet numberand grain yieldper spike inwheat[14]. It showedthat the pollenviabilityofquinoa has reduced between 30% and 70% underheat stress [15]. Continuousexposure of tomatoto high temperature reduced thenumber ofpollen grains per flowerand decreasedviability because of thealterations in carbohydratemetabolism in various parts of theanther during itsdevelopment[16]. It reported that the CO₂ enrichmentand associatedhigh temperature had anegative effecton pollen viabilityof green gramdue to degenerationof tapetum layer[17]. Pollenviability was found tobe theleast (8.37% decrease) under elevated CO₂ conditions comparedto controlconditions in pea plants[18]. Theheat stress duringmale reproductivedevelopment reducespollen viability and function[19]

Pollen morphology

Duringplantdevelopment,theimportant heat sensitivestage is thepollen development[20]. It is reported that high temperature stress due to elevated CO₂ will negativelyaffect the pollendevelopment[21]. Pollenproduced by flowers in soybeangrown underelevated CO₂ conditions appeared shriveled withoutapertures and with disturbed exine orientation [22]. In quinoa, theheat stress increasedthe pollen wall thickness[23].The pollen of soyabeanflowers appeared shriveledwithout apertures and withdisturbed exine ornamentationat elevated CO₂conditions[24].

High temperature stress lead to disruption of meiotic cell division, abnormal pollen morphology and size [25].

Effect of elevated CO₂ on yield parameters

The high CO₂ concentration increases the photosynthetic rate and yield of crops. It is reported that the beneficial effects of CO₂ enrichment on yield of tomato by increasing the no of flowers and fruit per plant [26]. But the higher temperature can negatively affect the tomato yield. In an experiment on the combined effects of CO₂ and the temperature on the grain yield, it is observed that a temperature of 27⁰C or higher applied mid way through anthesis could result in a high number of sterile grains and resulted in considerable yield losses [27]. Increased number of flowers and fruits together with higher fruit set leading to higher fruit yield in tomato was observed at elevated CO₂ condition (700 ppm and 500 ppm) compared to control condition, the highest yield being obtained under 700 ppm of CO₂ [28]. It is reported that the increase in average daily temperatures of 25-29⁰C will decrease the fruit set percentage, number of fruits and fruit weight per plant in tomato [29]. It is reported a reduction in fruit set and delay in fruit color development at temperature above 35⁰C [30].

Effect of elevated CO₂ on quality parameters

In vegetables, the elevated CO₂ concentration improves yield but it decreases the nutritional quality. In the meta analysis of vegetables, it is concluded that the concentration of fructose, glucose, TSS, phenols, total flavanoids, vitamin C and calcium increased in edible part of vegetables but the concentrations of protein, nitrate, magnesium, iron and zinc get decreased [31]. At the same time elevated CO₂ did not have any effect on titratable acidity, total chlorophyll, carotenoids, lycopene, anthocyanin, potassium, phosphorus, sulphur, copper and manganese. It is reported the positive effect of elevated CO₂ on quality parameters such as TSS, total sugars, total reducing sugars and ascorbic acid contents of tomato fruits, but the CO₂ concentration above 700 ppm caused a reduction [32]. It is reported that the chickpea seeds harvested from high CO₂ condition showed a reduced seed protein (7%), total phenol (13%) and thiobarbituric acid reactive substances (12%) and increased starch content (21%) and water uptake rate as compared to seed harvested from ambient CO₂ Condition [33]. It is reported that the quality parameters of tomato fruit such as ascorbic acid, carotene, lycopene improved at 550 ppm and decreased at 700 ppm. but at 550 ppm, the antioxidant capacity and flavonoids were found decreased [34].

CONCLUSION

Climate change has become the focus of social and scientific attention. The increase in carbon dioxide (CO₂) in the atmosphere is one of the most visible and undesirable indicators of global

climate change. In vegetables, especially in tomato, the increased CO₂ concentration improves yield, but reduces quality. Many research efforts focus on these stresses to shield the plants from harmful circumstances. The plants need to be given the best circumstances for growth at each stage. Germination, vegetative stage, reproductive stage, and the yield are all impacted by high temperature stress and it is critically necessary to find innovative ways to adapt crops to these changes.

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