Review Article

Effect ofelevated CO_2 induced high temperatureon floweringand fruiting in crops, preferencetotomato:- A review

ABSTRACT:- *Rising CO_2 levels in the atmosphere, a major contributor to climate change, has a wide range of consequences. CO_2 can absorb and radiate heat energy resulting in the hike of earth's average temperature.The elevated CO_2 induced temperature rise in atmosphere has a severe impact on agricultural crop productivity, as temperature is one of the important abiotic factors which influencecrop growthand 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 CO_2, Flowering,Fruiting, Tomato*

Introduction

Climate change is a global phenomenon of climate transformation especially caused by human activities and characterized by the alterationsin climate pattern regarding temperature, precipitation and wind. It isa seriousthreat to future mankind and global economy. The increase in the levels of GHGs (greenhousegases) will cause global warming (Sundar*et al*., 2021) and the climate change will ultimately cause a decline in crop yields and productions. Climate change isone ofthe important concerns associated with India's food security challenges. It significantly affects agriculture and food production by influencing the cropping seasons (Fiwa*et al.,* 2014; Zhao *et al.*, 2015; Lemma *et al.,* 2016) water availability (Lobell*et al*., 2015; Saadi*et al*., 2015; Schaubberger*et al*., 2017)

The current atmospheric carbon dioxide(CO_2) concentration has reached 414ppm according toNOAA andthe sixthassessment report from IPCC gives a warning of global warming of 1.5^0 C between 2030 and 2052(IPCC,2021). The IPCC projected that there will be an increase in surface air temperature by 1.1^0C to 6.4^0C by last of the 21^{st} century, due to increased emanations of CO_2 and other green house gases into the atmosphere. So elevated $CO_2$and associated high temperature can alter the physiology and chemicalcomposition of plants and havedirect 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 (Nour*et al.,* 2013).Heat stress is a major abiotic factor that limits tomato production by influencing various physiological processes such as photosynthetic activities, transpiration, photorespiration, dark respirationas well as vegetative growth and reproductive development. Elevated temperature willcause distortionof pollen and floral structures and will impire pollengermination andfurther developmentcausing decreased fruit set and yield (Sato *et al*., 2000). So flowering andfruit set are most affected under high temperature stress conditionsin tomato.

Effect of elevated CO_2 on observations relatedto flowering

Flowering is a critical milestone in the lifecycle of plants for it's reproductive success and fruit set. Since $CO_2$and temperature are the key factors for plant growth and development, the CO_2induced hightemperature affects various flowering related events such as floral initiation, floral development, fruit set and fruit growth. So the climate changehave a significant impacton floweringrelated events in plants. Addressing the effects of these environmental factors on time of nthesisand flowering time is critical to understandthe adaptation of plants/ crops toclimate change.

Elevated CO_2 and increasing ambient temperature is a major climatic factor that advances flowering timein certain crops. Rangaswami*et al*. (2021) reported an increase in the flower number under increased CO_2 condition. An experimentconducted by Mamatha*et al*. (2014) reported that theincreased number of flowers and fruits together with higher fruit set led to higher fruit yield at EC concentrations(EC 550 and 700 ppm). It is reported that plants grown under high CO_2reached flowering 8 days sooner than those grown underambient condition(Lanoue*et al*., 2018).

Pollen viability

The impaired pollendevelopment andreduced pollenviability will decrease the yield of crops at high temperature. Elevated$CO_2$and associatedheat stress at meiosis reduced pollen viability, spikeletnumber and grain yield per spike in wheat (Bokshi*et al.,* 2021). Hinojosa *et al*., (2019) showed that the pollen viability of quinoa has reduced between 30% and 70% under heat stress. Continuous exposure of tomato to high temperature reduced the numberof pollen grains per flower anddecreased viability because of the alterations in carbohydrate metabolism in various parts of the anther during its development (Pressman *et al.,* 2002). Suzuki *et al*. (2001) reported that the CO_2enrichment andassociated high temperature had a negativeeffect on pollen viability of green gram due to degeneration of tapetum layer. Pollen viability was found to bethe least (8.37% decrease) under elevated CO_2 conditions compared tocontrol conditions in pea plants (Kumari*et al*., 2016). The heat stress during malereproductive developmentreduces pollen viability and function (Muller and Rieu, 2016).

Pollen morphology

During plant development, the important heat sensitive stage is the pollen development (Lohani*et al*., 2020). Kumari*et al.,* (2016) reported that high temperature stress due to elevated CO_2 will negatively affect the pollen development. Pollen produced by flowers in soybean grownunder elevated CO_2 conditions appeared shriveled without apertures and with disturbed exine orientation (Koti*et al.,* 2004). In quinoa, the heat stress increased the pollen wall thickness(Hinojosa *et al.,* 2019). The pollen of soyabean flowers appeared shrivelled without apertures and with disturbed exine ornamentation at elevated CO_2conditions (Koti*et al*., 2005). High temperature stress lead to disruption of meiotic cell division, abnormal pollen morphology and size(Begcy*et al.,* 2019).

Effect of elevated CO_2 on yield parameters

The high CO_2concentration increasesthe photosynthetic rate and yield of crops. Rangaswamy*et al.* (2021) reported the beneficial effects of CO_2 enrichment on yield of tomato by increasing the no of flowers and fruit

per plant. But the higher temperature can negatively affect the tomato yield. In an experiment on the combined effects of CO_2 and the temperature on the grain yield, Hemantaranjan*et al.*(2014) observed that a temperature of 27^0C or higher applied mid way through anthesis could result in a high number of sterile grains and resulted in considerable yield losses. Increased numberof flowers and fruits together with higher fruit set leading to higher fruit yield in tomato was observed at elevated CO_2 condition (700 ppm and 500 ppm) compared tocontrol condition, the highest yield being obtained under 700ppm of CO_2 (Mamata*et al.,* 2014). Harel*et al.,* (2014) reported that the increase in average daily temperatures of 25-29^{0}C will decrease the fruit set percentage, number of fruits and fruit weight per plant in tomato. Sato *et al.,*(2006) reporteda reduction in fruiset and delay in fruit color development at temperature above 35^0C.

Effect of elevated CO_2 on quality parameters

In vegetables, the elevated CO_2 concentration improves yield but it decreases the nutritional quality. In the meta analysis of vegetables, Dong *et al.*(2018) concluded that the concentration of fructose, glucose, TSS, phenols, totalflavanoids, vitamin C and calcium increased in edible part of vegetables but the concentrations of protein, nitrate, magnesium, iron and zinc get decreased. At thesame time elevated CO_2 did not have any effect on titratable acidity, total chlorophyll, carotenoids, lycopene, anthocyanin, potassium, phosphorus, sulphur, copper and manganese. Rangaswami*et al.,* 2021 reported the positive effect of elevated CO_2 on quality parameters suchas TSS, total sugars, total reducing sugars and ascorbic acid contents of tomato fruits, but the CO_2 concentration above 700 ppm caused a reduction. Lamichaney*et al.*,2021 reported that the chickpea seeds harvested from high CO_2 condition showed a reduced seed protein(7%), total phenol(13%) and thiobarbituric acid reactive substances (12%) and increased starch content (21%) andwater uptake rate as compared to seed harvested from ambient CO_2 Condition. Mamatha*et al.*(2014) reported that the qualityparameters of tomato fruit such as ascorbic acid, carotene, lycopene improved at 550ppm and decreased at 700 ppm. but at 550 ppm, the antioxidant capacity and flavonoids werefound decreased.

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 CO_2 concentration improves yield, but reduces quality. Manyresearch efforts focus on these stresses to shieldthe plants from harmfulcircumstances. The plants need to be giventhe best circumstancesfor growth at each stage. Germination,vegetative stage, reproductive stage, and the yield are all impacted by high temperature stressand it is critically necessary tofind innovative ways to adapt crops to these changes.

ETHICAL APPROVAL

This article does not contain any studies with human participants or animals performed by any of the authors.

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