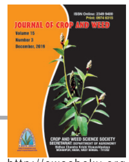
Journal of Crop and Weed, 18(1): 45-49 (2022)

ISSN- O : 2349 9400 ; P : 0974 6315



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Impact of nutrients and biofertilizers on flowering in tomato under elevated CO_2 induced high temperature condition

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Received : 16.01.2022 ; Revised : 23.03.2022 ; Accepted : 28.03.2022

DOI: https://doi.org/10.22271/09746315.2022.v18.i1.1531

ABSTRACT

The study aimed at investigating the effect of elevated CO_2 induced high temperature on flowering in tomato variety Vellayani Vijay and it's improvement through the application of various nutrients and biofertilizers. A pot culture study was done with treatments - 50 ppm B + 50 ppm Zn+ water spray (T1), 75 ppm B + 75 ppm Zn (T2), POP 150% N + 125 % P+ 125% K (T3), Azolla (Soil application)(T4), Azolla bio-fertilizer extract (20%) (foliar application)(T5), Azolla bio-fertilizer extract(20%)(seed treatment)(T6), POP, KAU + PGPR1(T7), Control (water spray)(T8), Absolute control(T9).The flowering was delayed and number of flower clusters were improved under elevated CO_2 condition.The foliar application of 50ppm Boron + 50 ppm Zinc + water spray, application of 50% extra N and 25% extra phosphorus and potassium each than the recommended doses as per package of practices (Kerala Agricultural University) and foliar application of 20% Azolla bio-fertilizer extract were found to improve the number of flower clusters and number of flowers per cluster.

***Keywords*:** Tomato, elevated CO_2, climate change, flowering, nutrients, biofertlizers

CO_2 is a key green house gas. Continuously increasing CO_2 concentration in the atmosphere has a great influence on global climate change. This prevalent gas can absorb and radiate heat energy and cause an increase in earth's average temperature (Lindsey *et al*., 2020). The National Oceanic and Atmospheric Administration reported that the current atmospheric carbon dioxide (CO_2) concentration has reached 414 ppm and the recent sixth assessment 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^{0}C to 6.4^{0}C by last of the 21st century, due to increased release of CO_2 and other green house gases into the atmosphere. As a result, increased CO_2 levels and related high temperatures can alter physiology and chemical composition of plants, affect agricultural production directly. In India, the changing environment has a negative impact on the national economy as well, because agriculture sector is a significant contributor to the national economy. Agriculture is a source of food as well as the source of raw materials for many agro-based companies. Kerala is a state which is having agrarian economy and the climate change will significantly affect the agriculture production scenario of the state.Weather anomalies have been discovered to have negative effects on perennial and seasonal crops in nature, which has an impact on the state's economy (Rao *et al*., 2008). The elevated CO_2 induced high temperature greatly influences the flowering and fruit set of crops due to reduced pollen viability and lower fruit setting percentage. In this context, the present study was conducted to evaluate the effect of various nutrients and bio-fertilizers on flowering in tomato under elevated CO_2condition (500ppm).

MATERIALS AND METHODS

The research work was carried out in the Department of Plant Physiology, College of Agriculture, Kerala Agricultural University, Vellayani, Kerala, India. A pot culture experiment was conducted using the Open Top Chamber (OTC) facility with elevated CO_2 levels (500 ppm CO_2) using the tomato variety Vellayani Vijay. One month old tomato seedlings were planted in pots and after establishment one set was transferred inside OTC and other was kept in open condition as control. Planting and after care was done as per package of practices recommended by Kerala Agricultural University (Estelitta, 2016). The measurement of the microclimate within the chamber was done using the real time sensors inside OTC chamber and outside weather also recorded. The experiment was laid out in CRD with nine treatments and three replications. The treatments comprised of T_1: 50 ppm B+50 ppm Zn+water spray, T_2: 75 ppm B+75 ppm Zn, T_3: POP 150 % N+125 % P+125%K, T_4: Azolla (soil application), T_5 : Azolla bio-fertilizer extract (20%) (foliar application),T_6 : Azolla bio-fertilizer extract (20%) (seed treatment), T_7 : POP, KAU+PGPR1, T_8: Control (water spray), T_9: Absolute control.

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Preparation of Azolla bio-fertilizer extract (20%)

Azolla bio-fertilizer extract was prepared by boiling 1kg Azolla with 1 litre of distilled water for 30 minutes and filtered. The filtrate was taken as 100% concentration of the Azolla extract and added 80% distilled water to get 20% Azolla bio-fertilizer extract (Hanafy and Gehan, 2018). Foliar application was done after transplanting at an interval of 15 days.

The parameters related to flowering were recorded as below.

Days to first flowering

The number of days from sowing to the production of first flower was recorded.

Number of flower clusters per plant

The total number of flower clusters during the peak flowering time was observed per plant.

Flowers per cluster

The total number of flowers of 5 clusters per plant was recorded and average taken.

RESULTS AND DISCUSSION

Days to first flowering

Application of various nutrients and biofertilizers did not show significant variation in days to first flowering. However, a significant delay (2days) in days to first flowering was noticed in plants kept inside OTC (elevated CO_2 condition) compared to open condition (Table 1).

Number of flower clusters per plant

A significant increase in the number of flower clusters per plant was observed with the application of various treatments. Among the treatments maximum number of flower clusters per plant was noticed in plants under treatment T_3 (6.67) which was on par with T_5 (6.51), T_1 (5.76), T_2 (5.18) and T_4 (5.10) compared to absolute control (3.73).

Elevated CO_2 resulted in significant increase in the number of flower clusters per plant. Number of flower clusters per plant was recorded to be 5.96 under elevated CO_2 compared to control condition with mean number of flower clusters as 4.12 (Table 2).

Number of flowers per cluster

There was a significant improvement in the number of flowers per cluster with the application of various treatments. The significantly higher number of flowers per cluster was noticed in T_1(6), which is on par with T_3 (5.97). Lowest number of flowers was reported in T_9 (3.57). Elevated CO_2 reduced the number of flowers per cluster. Number of flowers per cluster was recorded to be 1.94 inside OTC compared to open condition with mean number of flowers per cluster as 7.54 (Table 3).

The effect of elevated CO_2 and induced high temperature on flowering responses is specific to plant species. In the current experiment, a significant delay (2 days) in first flowering in tomato was observed under elevated CO_2 condition (Fig. 1). The higher CO_2 concentration and induced high temperature improves CO_2 uptake of plants and resulting in increased photosynthesis (Reddy *et al*., 2010). The accumulation of excess foliar sugar under elevated CO_2 delayed flowering in several species. The flowering in Arabidops is was delayed in elevated CO_2 with increase in 41% foliar sucrose and105% foliar starch content (Bae and Sicher, 2004). The foliar application of Azolla bio-fertilizer extract and application of extra NPK significantly improved the number of flower clusters inside OTC by

Table 1: Effect of nutrients and biofertilizer application on days to first flowering in tomato under elevated CO_2 condition

Treatments		Open	OTCOTC	Mean
T_1	50 ppm B + 50 ppm Zn + water spray	55	57	56
T_2	75 ppm B + 75 ppm Zn	55	57	56
T_3	POP 150% N : 125 % P:125% K	55	57	56
T_4	Azolla (Soil application)	55	57	56
T_5	Azollabiofertilizer extract (20%) (Foliar application)	55	57	56
T_6	Azollabiofertilizer extract (20%) (Seed treatment)	55	57	56
T_7	POP, KAU + PGPR1	55	57	56
T_8	Control (water spray)	55	57	56
T_9	Absolute control	55	57	56
	MEAN	**55**	**57**	
		T	**E**	**T×E**
	SEm(±)	**0.87**	**0.44**	**1.23**
	LSD(0.05)	**NS**	**1.26**	**NS**

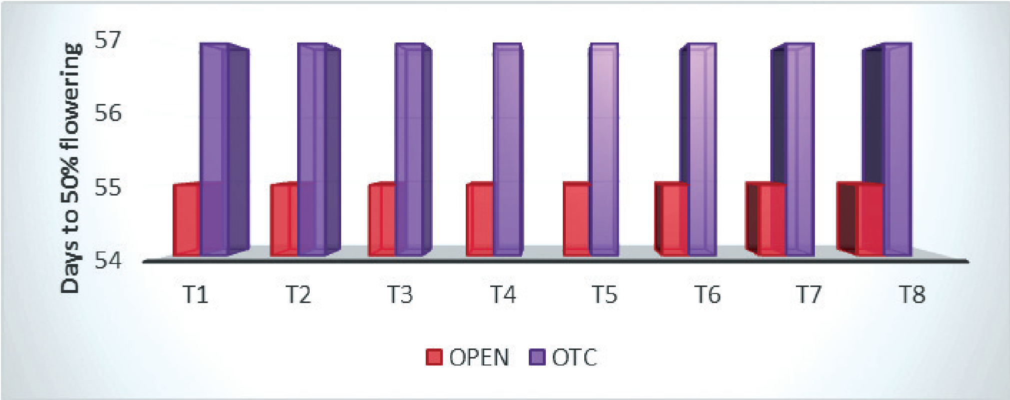

Fig. 1 : Impact of elevated CO_2 on days to first flowering in tomato

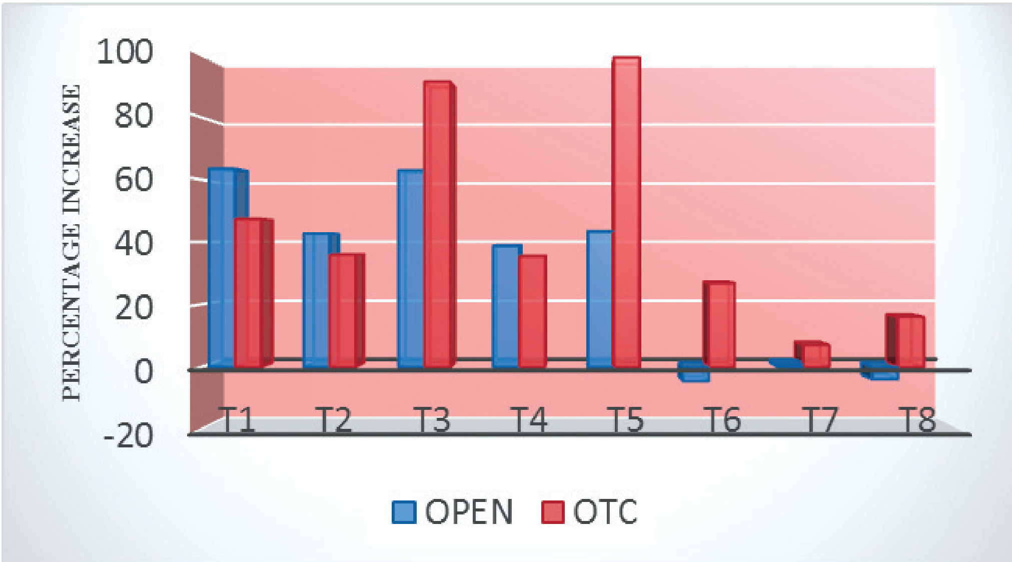

Fig. 2 : Impact of elevated CO_2 on number of flower clusters per plant

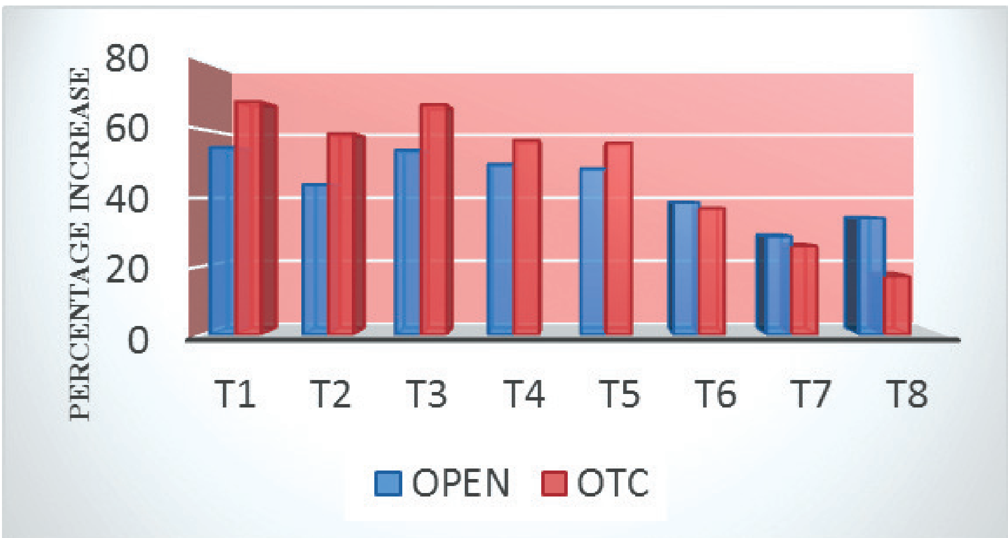

Fig. 3 : Impact of elevated CO_2 on number of flowers per cluster per plant

Table 2: Effect of nutrients and biofertilizer application on number of flower clusters per plant

Treatments		Open	OTC	Mean
T_1	50 ppm B + 50 ppm Zn + water spray	5.35	6.16	5.76
T_2	75 ppm B + 75 ppm Zn	4.67	5.68	5.18
T_3	POP 150% N + 125 % P+ 125% K	5.33	8	6.67
T_4	Azolla (Soil application)	4.54	5.66	5.10
T_5	Azolla biofertilizer extract (20%) (Foliar application)	4.69	8.32	6.51
T_6	Azolla biofertilizer extract (20%) (Seed treatment)	3.12	6.34	4.73
T_7	POP, KAU + PGPR1	3	4.47	3.74
T_8	Control (water spray)	3.14	4.85	3.99
T_9	Absolute control	3.27	4.18	3.73
	MEAN	**4.12**	**5.96**	
		T	**E**	**T×E**
	SEm(±)	**0.47**	**0.23**	**0.67**
	LSD(0.05)	**1.34**	**0.67**	**1.91**

Table 3: Effect of nutrients and biofertilizer application on number of flowers per cluster

Treatments		Open	OTC	Mean
T_1	50 ppm B + 50 ppm Zn + water spray	9.34	2.66	6.00
T_2	75 ppm B + 75 ppm Zn	8.19	2.41	5.30
T_3	POP 150% N + 125 % P+ 125% K	8.41	3.53	5.97
T_4	Azolla (Soil application)	7.12	2.00	4.56
T_5	Azolla biofertilizer extract (20%) (Foliar application)	8.32	1.33	4.83
T_6	Azolla biofertilizer extract (20%) (Seed treatment)	7.37	1.50	4.44
T_7	POP, KAU + PGPR1	6.81	1.68	4.25
T_8	Control (water spray)	6.35	1.27	3.81
T_9	Absolute control	6.00	1.13	3.57
	MEAN	**7.54**	**1.94**	
		T	**E**	**T×E**
	SEm(±)	**1.22**	**0.60**	**1.72**
	LSD(0.05)	**0.42**	**0.21**	**0.59**

99.04 and 91.38% compared to absolute control whereas the elevated CO_2 significantly reduced the no of flowers per cluster (Fig. 2). Azolla is rich in proteins, essential amino acids, vitamins, and minerals. The benefits of Azolla use could be estimated both as reduction in the cost of the nitrogen fertilizers and on environmental protection as a consequence of the lower requirement of chemical inorganic nitrogen. Azolla does not act simply as a nitrogen source. There are presumably other factors, such as organic matter increase which improves the chemical and physical characteristics of the soils. In addition, the use of Azolla could be beneficial to the crop by providing growth stimulating compounds produced by the endosymbiotic cyanobacterium. Among the various nutrients and biofertilizers, application of extra NPK, which increased the number of flowers per cluster by 67.23% and the foliar application of 50 ppm B+50 ppm Zn + water spray improved the number of flowers per cluster by 68.07% compared to control (Fig. 3).This may be attributed to the favoured metabolic process and auxin activity.The flowering in gladiolus is significantly improved by the foliar spray of B and Zn (Sharma *et al.,* 2012). Also the vital role of nitrogen, phosphorus and potassium in bio-chemical and physiological functions significantly improves the plant growth, yield and quality (Leghari *et al*., 2016).

ACKNOWLEDGEMENT

Authors are thankful to Kerala State Planning Board for the financial support for establishing Open Top Chamber facility for CO_2 enrichment studies at Depatment of Plant Physiology, College of Agriculture Vellayani and Kerala Agricultural University.

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