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Research Article

CARBON DIOXIDE ENRICHMENT INDUCED MODIFICATION IN THE DEVELOPMENTAL PATTERN OF COWPEA (*VIGNA UNGUICULATA* L.) VARIETY VELLAYANI JYOTHIKA

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Abstract: Climate change is one of the major challenges faced by life systems on earth. Carbon dioxide (CO_2) is one of the major components contributing to modification of environment and thereby influencing growth and development of plants. The present programme was an attempt to study the modifications brought in the developmental pattern of cowpea by elevated CO_2 concentration. The experiment was conducted using Open Top Chamber (OTC) system. Entire crop period (from germination till harvest) was completed under CO_2 concentration of 600ppm in OTC. Plant responses in terms of growth parameters, leaf characters and dry matter accumulation were analyzed. The present study showed that increasing CO_2 concentration in the atmosphere can have a positive influence on the plant growth and development.

Keywords: Elevated CO_2, Cowpea, Growth, Open Top Chambers

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Introduction

Climate change is one of the major challenges of our time and adds considerable stress to our society and to our environment. Since the beginning of industrial revolution around 1750, human activities have contributed substantially to climate change by adding heat trapping greenhouse gases to the atmosphere which are the most significant drivers of global warming. Among the greenhouse gases, CO_2 has contributed the most to climate change [1] mainly due to its relative forcing character, longer residence time in the atmosphere and also due to its relative abundance in the atmosphere. The global concentration of CO_2 in the atmosphere has reached 410ppm for the first time in the recorded history [2]. Projections suggest that atmospheric CO_2 will reach 700 ppm or more, whereas global temperature will increase by 1.8- 4°C by the end of this century. Increase in global average temperatures would further result in drastic shifts in the annual precipitation with a 20 percent reduction per year, and about 20 percent loss in soil moisture [3]. Being the major determinants of crop growth and development, increased atmospheric CO_2 and temperature can have significant impacts on productivity of crop plants. Cowpea is an important grain legume with a dual-purpose function as food and feed resources. It can grow throughout the year under Kerala condition. Considering the role of CO_2, in bringing about the projected changes in climate and importance of cowpea a study was undertaken to analyse the growth performances under elevated CO_2 conditions.

Materials and Methods

A pot culture experiment was conducted on cowpea variety Vellayani Jyothika at the Department of Plant Physiology, College of Agriculture, Vellayani, under Kerala Agricultural University. Technology used for creating CO_2 enriched environment is OTC. OTCs used for the present study are square type chambers constructed to maintain near natural conditions with elevated CO_2 concentration for experimental purposes. The basic structure of OTC is built of metal frame and installed in the experimental field. OTCs are covered with a 200 micron UV poly sheet. The chamber was constructed with 3 x 3 x 3 dimension, 460 slope and 1m^2 opening at the top. Two such chambers were built in the experimental field; one serves to impose CO_2 enrichment (Ec) and the other serves as control chamber (Ac) to study the chamber effects and in contrast one set of plants grown in open field condition (C) to mimic the natural environment. Potted plants were maintained in OTC from sowing to harvest. Pots were filled with potting mixture consisting of 1:1:1 ratios of farm yard manure, sand and soil. The period of CO_2 enrichment was from 9.00 am to 5.00 pm [Fig-1]. Elevated CO_2 was released into the chamber from a CO_2 cylinder in a controlled manner. Measurements of microclimatic parameters (temperature, humidity and light) were done within and outside the OTCs with the help of sensors on a real time basis. Observations were taken at the end of crop period. Total chlorophyll contents of leaf samples were estimated following the standard methodology [4] and expressed as mg g^{-1} of fresh weight. For calculating specific leaf area, third fully expanded leaf (from main stem apex) was collected. Leaflets were separated, petioles were discarded and area was measured. Leaflets were dried at 80°C for 2 days and the dry weight was taken. Specific leaf area was calculated using the formula. The roots of plants were cut at the base level and washed free of adhering soil with low jet of water. The roots were then oven dried and dry weight was recorded. Shoot weight was measured by weighing the above ground part of the plants in a weighing balance. The sum of root and shoot dry weights were taken as the total dry matter accumulation. Pod yield was determined at the time of harvest and was expressed on fresh weight basis.

$$SLA(cm^2/g) = \frac{leaf\ area}{dry\ weight}$$

Statistical analysis

The experiment used a CRD with three treatments and each treatment was analysed with three replications. Statistical analysis was performed using ANOVA. P values d ≤ 0.05 were considered as significant.

Results and Discussion

Alteration in growth performance of cowpea under elevated CO_2 studied by analyzing the parameters viz leaf number, leaf area, total pod weight, shoot weight, root weight and dry matter accumulation is presented in [Table-1]. Carbon

Table-1 *Effect of elevated CO_2 on growth parameters of cowpea Variety (Vellayani Jyothika)*

Treatments	Growth parameters					
	Number of leaves	Specific leaf area (cm^2)	Root weight (g)	Shoot weight (g)	Total pod weight (gm)	Dry matter accumulation (g)
OTC (Ec)	78	198.26	13.16	60.64	102.59	73.8
OTC (Ac)	65.75	196.87	8.5	56.77	70.15	66.27
Control (C)	70.75	197.01	9.79	57.71	81.68	67.51
CD (0.05):	1.99	0.019	1.884	3.995	3.345	3.943
SE (m)	0.816	0.008	0.77	1.632	1.367	1.611

Treatments found Significant at 1% and 5% level of significance, OTC Ec –Open top chamber with Elevated CO_2 Concentration, OTC Ac - Open top chamber with Ambient CO_2 Concentration

Fig-1 Open Top Chamber for CO_2 enrichment

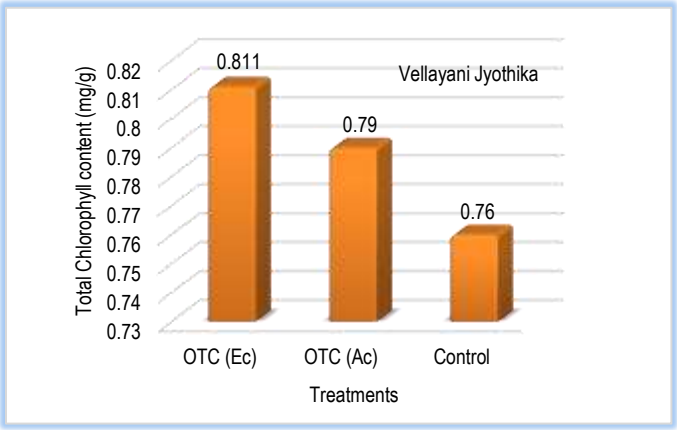

Fig-2 Effect of elevated CO_2 on total chlorophyll (mg/g) of cowpea

Experimental plants of cowpea recorded higher number of leaves under elevated CO_2 condition (78.00) which was significantly higher compared to open control (70.75). The results were same as where maximum number of leaves was observed in black pepper *(Piper nigrum* L.) plants under 500 ppm. [5]. A significantly increase in leaf area (198.26 cm^2) was recorded under elevated CO_2. Percent increase in leaf area under elevated CO_2 was evident in OTC (Ec) chamber when compared to control plants. Exposure of plants to elevated CO2 stimulates cell division at the shoot apical meristem either directly or indirectly [6]. Plants respond to increases in the air's CO_2 content by displaying reduced stomatal conductance, which typically leads to reduced rates of transpirational water loss [7]. Leaf growth is frequently altered by differences in plant water potential [8]. Growth under elevated CO_2 enhances the efficiency of water use which results in increased leaf expansion. Chlorophyll molecules absorb light energy present in photosystem and reaction centres convert it to chemical energy through photosynthesis [9]. Under elevated CO_2 photosynthetic activity increase by increasing chlorophyll content and it is suggested to be an adaptation of plants for elevated CO_2 condition [10]. Bring in improved chlorophyll, leaf accumulation, stimulation of photosynthesis and better dry matter accumulation. In the present study conducted on cowpea the total chlorophyll content was found to be highest under elevated CO_2 having higher mean value of (0.811 mg g^{-1}) of fresh weight [Fig-2]. The higher chlorophyll under elevated CO_2, grown plants could be explained by the larger size and number of chloroplasts present in the tissues exposed to high CO_2 levels [11]. Exposure of plant canopies to higher CO_2 concentration often stimulates growth of shoots and roots. Root production showed the higher value of (13.16g) under elevated CO_2 and when compared to absolute control condition (9.79 g). Stimulation of root growth was as a result of cell expansion caused by cell wall loosening in concert with higher cell turgor pressure and increased cell division. Increased translocation of photosynthates to roots under elevated CO_2 [12]. The general consensus is that photosynthesis and C allocation to plant roots increases as atmospheric CO_2 rises which leads to an increase in above and below biomass [13]. Shoot weights were found to be superior under elevated CO_2, condition (60.64 g) compared to absolute control (57.71g). Dry matter accumulation also showed a significant increase under elevated CO_2 with highest dry matter content of 73.8 g in OTC (Ec) chamber. Elevated CO_2 stimulates photosynthesis in various intensities during different phenological phases [14] and its direct consequence in increased dry matter production [15]. Total pod weight showed a significant increase under elevated CO_2 with highest total pod weight (102.59 g) was found in OTC (Ec) chamber which were significantly high compared to open control (81.68 g) [16].

Conclusion

The present investigation was carried out with the objective to study the physiological and biochemical responses on cowpea and to study their modifications under elevated CO_2 environments. Considering all the growth parameters, it can be concluded that carbon dioxide enrichment has a positive response in the case of cowpea. All the growth parameters like leaf area, number of leaves, specific leaf area, shoot weight, root weight, total chlorophyll content and total dry matter accumulation responded positively to CO_2 enrichment. This can be contributed by the increase number of leaves and leaf area. Better light interception along with higher internal CO_2 concentration facilitated through the steeper gradient of CO_2 could have contributed to the better performances under elevated CO_2 concentration. This study shows that declining trend recently observed in the case of cowpea in Kerala is not due to direct impacts of increasing CO_2 concentration but due to the influence of increasing CO_2 concentration on the climatic factors like temperature and rainfall pattern which are very crucial as far as flowering in cowpea is concerned. Further of increasing are needed to understand the impacts of increasing CO_2 concentration on the critical stages and various growth and development stages of cowpea.

Application of research: Understanding response of Vellayani Jyothika the most popular variety of cowpea to the predicted environmental condition in terms of growth and development.

Research Category: Climate change (CO_2 enrichment- simulation study)

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Conflict of Interest: None declared

Study area / Sample Collection: OTC- Open Top Chamber
Cultivar / Variety name: Vellani Jyothika

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number:

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