SEMINAR REPORT

MICROCLIMATE MODIFICATION USING CARBON DIOXIDE ENRICHMENT TECHNOLOGIES AND CROP RESPONSES

By

HARITHALEKSHMI V

(2018-11-067)

Presented on 21/11/2019

Submitted in partial fulfillment of requirement of the course

AGM 591: Masters' Seminar (0+1)

DEPARTMENT OF AGRICULTURAL METEOROLOGY

COLLEGE OF HORTICULTURE

KERALA AGRICULTURAL UNIVERSITY

VELLANIKKARA

THRISSUR, KERALA - 680656

DECLARATION

I, Harithalekshmi V. hereby declare that the seminar entitled “**Microclimate modification using Carbon dioxide Enrichment Technologies (CET) and crop responses"** has been prepared by me, after going through various references cited at the end and has not been copied from any of my fellow students.

Vellanikkara

Harithalekshmi V.
(2018-11-067)

CERTIFICATE

This is to certify that the seminar report entitled "**Microclimate modification using Carbon dioxide Enrichment Technologies (CET) and crop responses"** has been solely prepared by **Harithalekshmi V.**, under my guidance and has not been copied from seminar reports of any seniors, juniors or fellow students.

Vellanikkara | **Dr. B. Ajithkumar**

25/01/2020 | Major Advisor

Assistant Professor & Head

Department of Agrl Meteorology

CERTIFICATE

Certified that the seminar report entitled "**Microclimate modification using Carbon dioxide Enrichment Technologies (CET) and crop responses"** is a record of the seminar presented by **Harithalekshmi V (2018-11-067)** on 21-11-2018 and is submitted for partial fulfillment of requirement of the course AGM 591.

Vellanikkara

25/01/2020

Dr. Anil Kuruvila

Professor

Dept. of Agricultural Economics

Dr. Reshmi Vijayaraghavan

Assistant Professor

Dept. of Plant Pathology

Dr. Sangeeta Kutty M.

Assistant Professor

Dept. of Vegetable Science

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

1.Introduction

Carbon dioxide (CO_2) is the 5th most abundant gas in the atmosphere and most important greenhouse gases. Atmospheric carbon dioxide is increasing at an accelerating rate. Its concentration has reached a peak of 418.7 ppm on 15th May 2019, which was the highest recorded value ever since the history of mankind (ESRL, 2019). Life on earth would not be possible without photosynthesis. We survive because of the oxygen and food (sugars) produced by photosynthesis. CO_2 is the major component of photosynthesis. Therefore, it is of critical importance to look at the plant responses under elevated CO_2, because the CO_2 concentration in the atmosphere is increasing.

The impact of rising atmospheric CO_2 on crop production has emerged as a major research area during the past decades. The possible impacts of elevated carbon dioxide on crops can be understood by conducting experiments that modify crop microclimate by elevating carbon dioxide concentrations by means of carbon dioxide enrichment technology.

1.1 Measurement of atmospheric carbon dioxide (CO_2)

Atmospheric carbon dioxide is increasing at an accelerating rate. Its concentration has reached a peak of 418.7 ppm on 15th May 2019, which was the highest recorded value ever since the history of mankind (ESRL, 2019). Natural increases in carbon dioxide concentrations have periodically warmed earth's temperature during ice age cycles over the past million years or more. Based on air bubbles trapped in mile-thick ice cores (and other paleoclimate evidence), we know that during the ice age cycles of the past million years or so, carbon dioxide never exceeded 300 ppm. Before the industrial revolution started in the mid-1700s, the global average amount of carbon dioxide was about 280 ppm. Dr. Charles David Keeling was the first scientist who gave a scientific proof of increasing CO_2 in the atmosphere. He started measurement of atmospheric CO_2 since 1958 at *Mauna loa* observatory. He was the one who made foundation for modern climate change research. Mauna loa earth observatory, Hawai is an atmospheric baseline station where continuous monitoring and collection of atmospheric data is done. The *Mauna Loa* atmospheric CO_2 measurements constitute the longest continuous record of atmospheric CO_2 concentrations available in the world. The *Mauna Loa* site is considered as one of the most favorable locations for measuring undisturbed air because possible local influences of vegetation or human activities on atmospheric CO_2 concentrations are minimal and any influences from volcanic vents may be excluded from the records.

1.2 Keeling curve

The Keeling curve is a graph that represents the concentration of carbon dioxide (CO_2) in earth's atmosphere since 1958. The Keeling curve is named after its creator, Dr. Charles David Keeling. The graphs shows an increasing trend of CO_2 . It has a saw tooth shape which shows the seasonal variations of CO_2. Maximum CO_2 concentration is observed during the month of may and after that crop growth season commences in northern hemisphere which leads to the decline in carbon dioxide concentration in the atmosphere as plants absorb atmospheric carbon dioxide

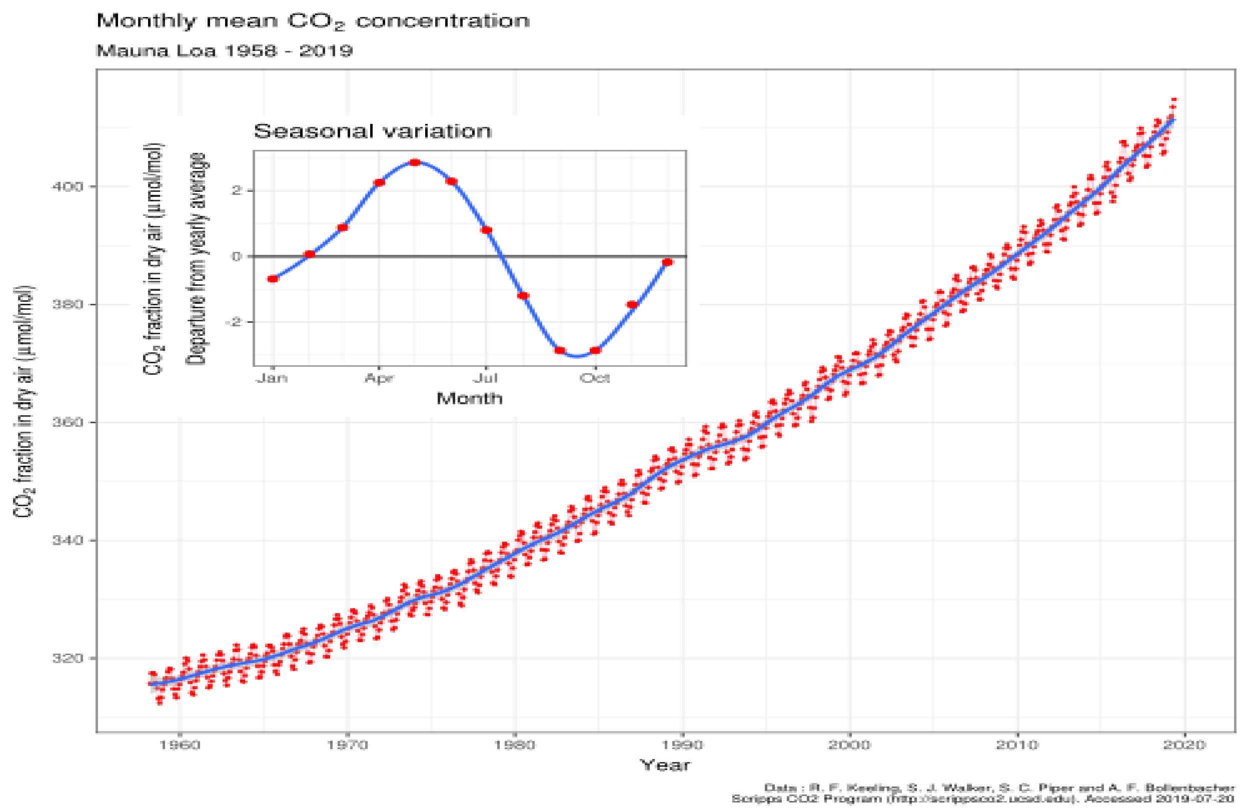


Fig 1: Keeling curve

2. Carbon dioxide enrichment technology (CET)

It is defined as the controlled environment and field based facilities to study crop responses to elevated carbon dioxide concentration (Uprety and Reddy, 2008). A number of technologies have been developed to study the impact of rising atmospheric CO_2 in agricultural systems. Earlier techniques were based on the controlled environment such as phytotrons, closed chambers, cuvettes *etc*, which are far from the natural environment, in which plants generally grow. However, technologies such as Soil Plant Atmosphere Research (SPAR), Carbon dioxide and Temperature Gradient Chamber (CTGC), Open Top Chamber (OTC), Free Air Carbon dioxide Enrichment (FACE) and Screen Aided Carbon dioxide Control (SACC) are most popular and efficient carbon dioxide enrichment technologies. Impact of elevated carbon dioxide on crops can be understood by conducting experiments with the help of these technologies.

2.1 Soil Plant Atmosphere Research (SPAR)

Enclosed structures where plants are grown under the controlled conditions of temperature, humidity and carbon dioxide as well as control and measurements of soil water and root conditions.

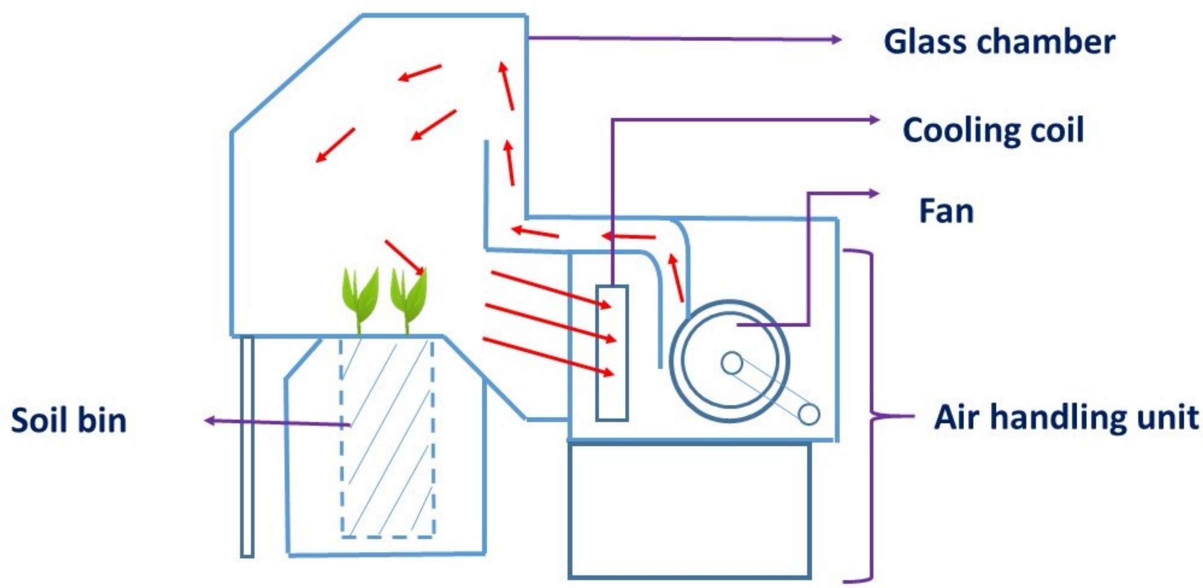


Fig. 2 : Components of SPAR

2.1.1 Components of SPAR

1) Sensors for measuring temperature (copper-constantan thermocouple)

2) IRGA for sensing CO_2

3) Dew point hygrometers for measuring humidity

4) Control devices such as heaters to regulate desired temperature and CO_2 injection valves for measuring CO_2 used in photosynthesis

5) Cooling coil flow for regulating dew point temperature

Components of SPAR is described in Fig. 2.

2.1.2 Working principle

Air in these SPAR chambers was circulated through the canopy from top to bottom and then goes out through ducts, where it was reconditioned before flown back to the canopy chamber. Sensors, air sampling ports and control devices were located within the ducts so that the air circulated to the top of the canopy had the experimentally prescribed set point of temperature, CO_2 concentration and humidity level.

2.2 Open Top Chamber (OTC)

Open Top Chambers (OTC) were extensively used as plant exposure units both in air pollution and in CO_2 response studies in the field. OTCs, which have been used to expose potted plants, annual crops and trees to a variety of aerial pollutants and CO_2.

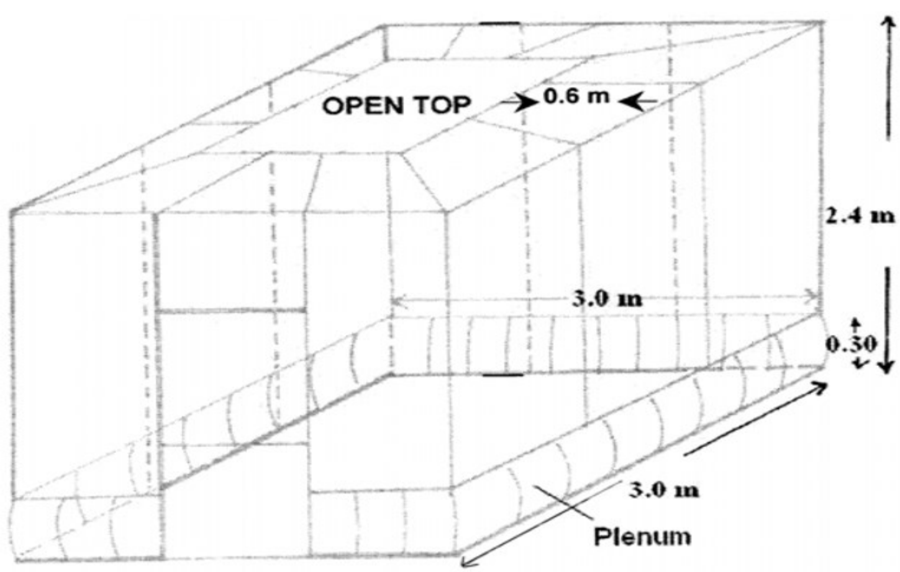


Fig. 3: Structure of OTC

2.2.1 Structure of OTC

Open top chamber (Fig. 3) having the dimension of 3m*3m*3m were made of an aluminum frame installed on the ground. Chamber is kept open to provide the near natural conditions. These chambers had a characteristic slender shape and were covered with a 0.15 mm thick transparent polyvinyl chloride (PVC) sheet. Chambers are equipped with a frustum at the top to deflect air and prevent dilution of the desired CO_2 concentrations within the chamber. There was a cylindrical double walled plenum around the base for uniform CO_2 circulation. Inner side of the plenum was provided numerous gas outlets of different sizes, small being nearest to the gas inlet pipe.

2.2.2 Working principle

Commercial CO_2 was added in the upstream of frame to ensure adequate mixing and to create the desired concentration. Blowers were used to distribute CO_2 enriched air uniformly throughout the plant canopy. CO_2 gas was supplied to the chamber from gas cylinders using a manifold, gas regulators and pressure gauze pipelines. Gas cylinders were fitted in a row with thick copper outlet pipe. CO_2 gas was released from cylinders to chamber through a manifold and underground pipe and injected into the chamber along with the ambient air using a blower. Air blowers are used for maintaining desired concentration of CO_2 into chamber tunnel. Blower also helped in maintaining inside air temperature closure to that of outside ambient atmosphere. Daily observations on temperature and relative humidity were monitored in the chambers and recorded in thermo hygrograph. Diurnal variations in temperature, light intensity and CO_2 concentration inside and outside the chambers are recorded regularly. Carbon dioxide concentration inside the OTC chamber is maintained by the carbon dioxide control and monitoring system. Accuracy of an experiment conducted by OTC system depends on how efficiently the carbon dioxide concentrations are maintained inside the system (Fig. 4)

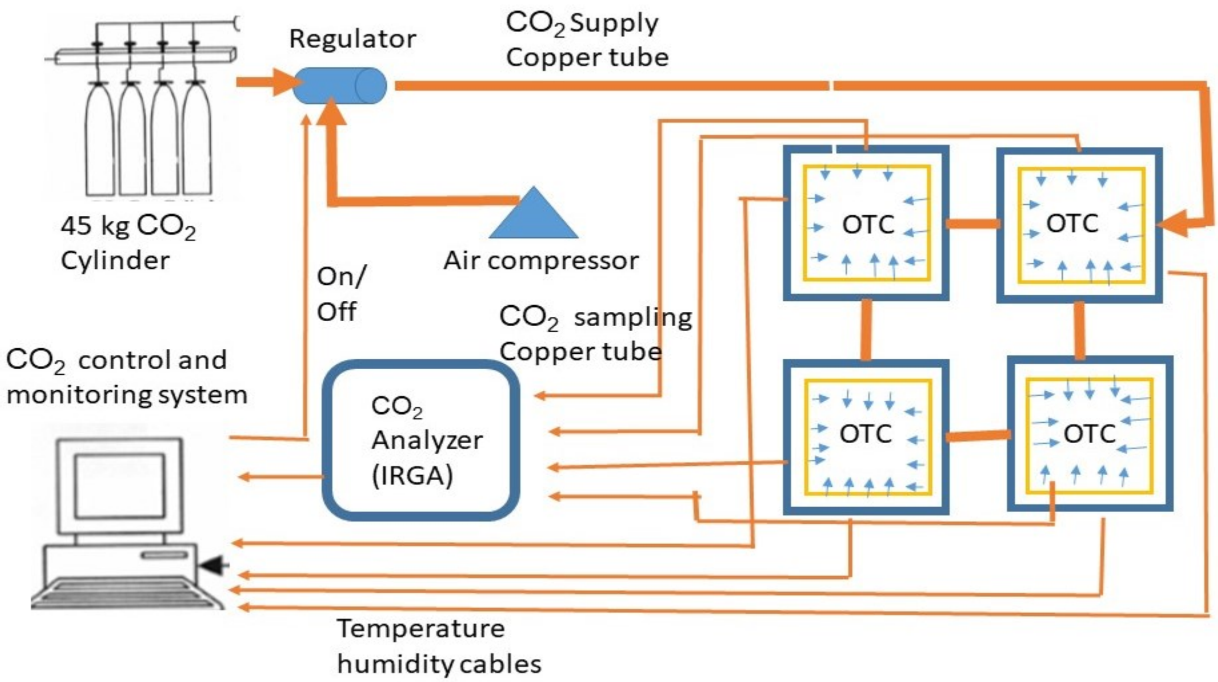


Fig 4: Carbon dioxide control and monitoring system

2.3 Free Air CO_2 Enrichment Technology (FACE)

Free-air carbon dioxide enrichment (FACE) experiments allow studying the effects of elevated atmospheric CO_2 on plants grown under natural conditions. In this system CO_2 enriched air is released into the ambient environment without causing appreciable changes in other environmental variables. A low-cost free-air carbon dioxide enrichment (FACE) system has been developed at the Indian Agricultural Research Institute, for assessing the climate change impacts on crops (Chakrabart *et al.*, 2012).

2.3.1 Components of FACE

a) FACE ring : A typical FACE is a circular array of vertical or horizontal pipes that release CO_2 or air enriched with CO_2 to the crop canopy. The system we developed consists of a ring (plenum) made up of eight horizontal polyvinyl chloride (PVC) pipes each with a length of 2 m and diameter of 20 cm (arm). The diameter of the ring is 8 m. These pipes arranged in octagonal shape and placed on a height-adjustable stand at 40 cm interval up to 1.20 m. Each arm of the plenum was fitted with centrifugal air-blower at one end, whereas the other end of the pipe was closed. In order to disperse the air, the pipes were perforated with holes of 3 mm diameter facing the inner side of the ring. Holes were placed at equidistance in three rows with one set of holes parallel to the treatment plot and the other two rows at 40° apart.

b) Sensors : The FACE ring has temperature and humidity sensors fitted with transmitters and weather shielding. The sensor used for measurement of temperature was resistance temperature detector (RTD) type and the resistance material used was platinum. The humidity sensor is a solid-state capacity-type sensor. Sensors record ambient air temperature and humidity at regular intervals. Range of operation of temperature sensors was –40°C to +50°C, with resolution of 0.1°C. Wind speed and direction were measured in the same plane by a sensitive three-cup rotor anemometer and wind vane. Wind direction was recorded in degrees from north and wind speed in m s^{-1}. Output of both wind vane and anemometer was converted into current signals and was read out in a three-digit LED (light-emitting diode) display.

c) CO_2 supply system : The CO_2 supply system consists of CO_2 storage cylinders, CO_2 manifold, pressure guage regulator, flow meter, compressor, mixing chamber and solenoid valves.

d) CO_2 monitoring system: For monitoring CO_2 concentration inside the FACE ring, the air sample was sucked from three points (centre, 1 m and 2 m from the centre) in the FACE ring. Supervisory Control Data Acquisition (SCADA) software monitors the CO_2 concentration inside the face ring. It enables us to set the desired CO_2 level, minimum and maximum wind speed at which the release and cut-off of CO_2 supply should take place, as well as the time interval for data logging.

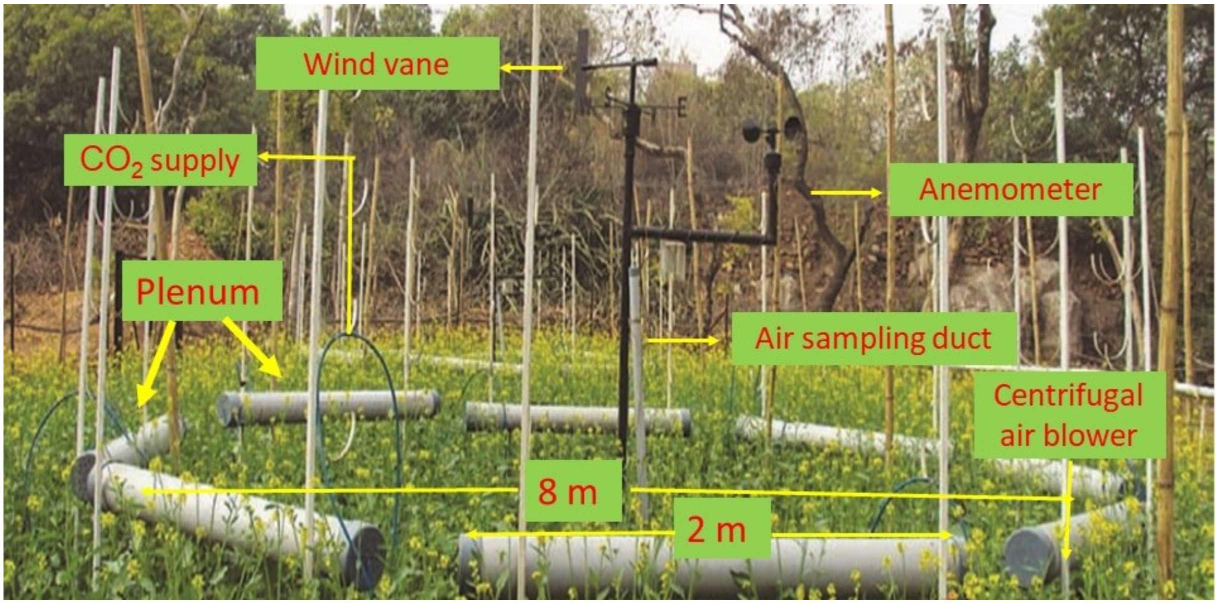


Plate 1 : Component of FACE

2.3.2 Working principle

When the FACE system was switched on, the air was sampled from three points inside the FACE ring through a pipe to measure CO_2 concentration. Wind speed and wind direction are measured. CO_2 is released into the chamber as a function of wind speed and wind velocity.

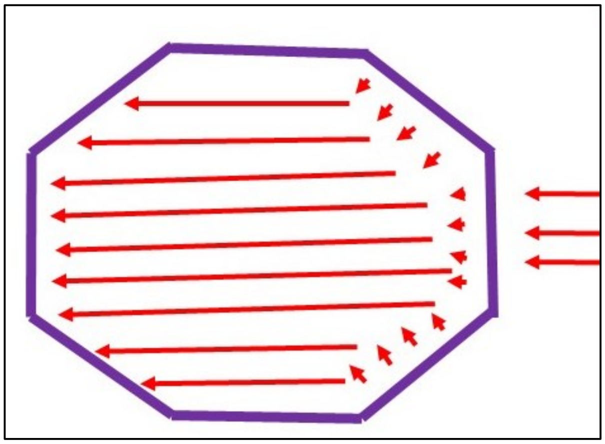


Fig. 5 : Three adjacent plenum arms in the windward direction will be opened

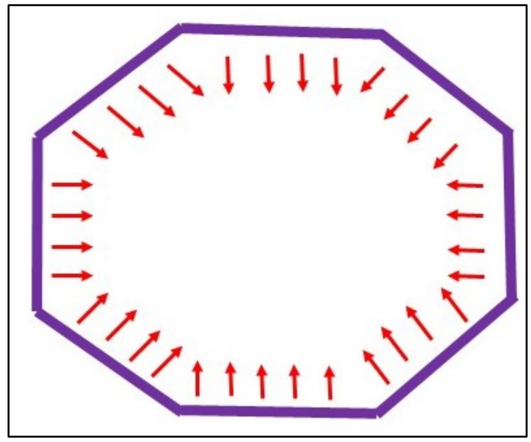


Fig. 6 : All valves are closed

a) If wind speed is 1 m/s – 5 m/s : Three adjacent plenum arms in the windward direction will be opened (Fig. 5)

b) If wind speed is < 1 m/s : Every valve on the arms are opened (Fig. 6)

c) If wind speed is > 5 m/s : Every valves are closed

A study was done to understand the effect of wind speed on the functioning of FACE at Indian Agricultural Research Institute, daily values (medium-term) of CO_2 concentration for July were correlated with daily wind speed. July month was selected because the month is windy. Wind speed during this month varied from 0.1 to 4.44 m s^{-1}. CO_2 level was within 10% of the target (550 ppm) during 62–82% of the time. Deviation was more under high wind speed conditions. Carbon dioxide concentration inside the ring remained within 10% of the desired level (550 ppm) for maximum time (82%) when mean wind speed was 0.81 m s^{-1}. This shows that less wind speed helps in maintaining CO_2 level inside the FACE ring, whereas higher wind velocity dissipates the CO_2 released through the pipes resulting in low CO_2 concentration and more loss of CO_2 in the ring.

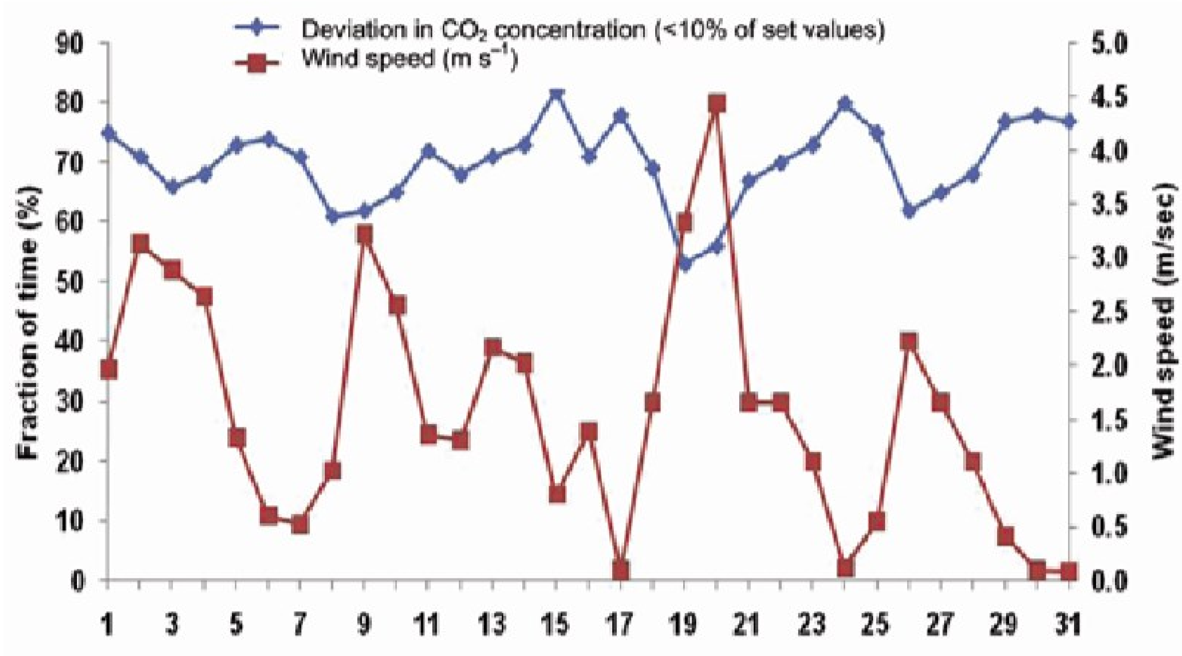


Fig. 7: Deviation in CO2 concentration (<10%) in both the rings in July

2.3.3 CO_2 control and monitoring system of FACE

CO_2 control and monitoring system of FACE is almost similar to that of OTC. The main difference is that here the carbon dioxide releasing rate is controlled by wind speed and wind direction.

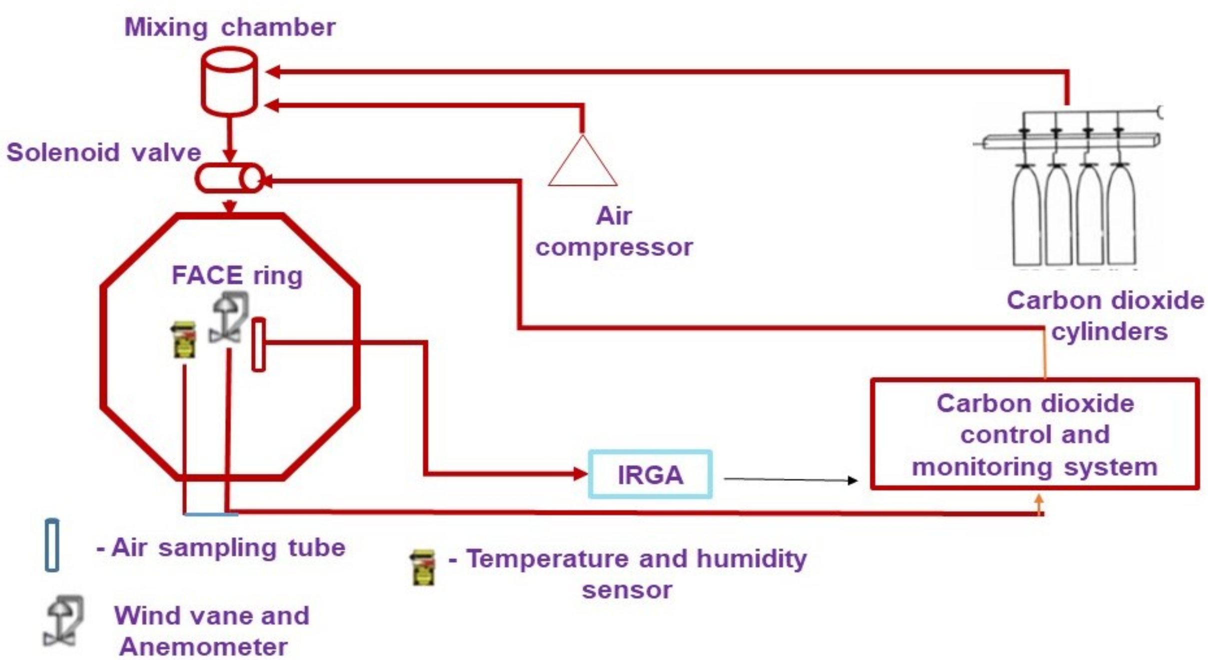


Fig. 8: CO_2 control and monitoring system of FACE

2.4 A comparison between OTC and FACE

Among all the carbon dioxide enrichment technologies FACE and OTC are most widely used. Various studies are done to compare both technologies, most of the studies suggest that FACE method is most accurate provided that proper monitoring should be done, but OTC is cost effective (Machacova, 2009).

Table 1: Comparison between FACE and OTC

FACE	OTC
CO_2 enriched air is released to the top of the canopy	CO_2 enriched air is released to the bottom of the chamber
CO_2 consumption is more	Presence of side walls limits CO_2 consumption
Minimal effect on microclimate	Induces a significant impact on the microclimate
High cost	Cost is comparatively less

2.5 Screen-Aided CO_2 Control (SACC)

Screen-Aided CO_2 Control (SACC) technology uses much less CO_2 per experiment and per replicate than FACE and is superior to OTCs in terms of its effects on microclimate. A SACC unit consists of a thin metal frame, a clear plastic "screen", and a pipe at the base of the screen through which CO_2 enriched jets of air are directed into the unit. There is a gap between the ground and the bottom of the pipe and the screen is relatively short in comparison to the maximum height of the vegetation (Leadley *et al*., 1997).

2.5.1 Components of SACC

Each SACC unit consists of

1) Hexagonal, steel frame

2) Clear, polycarbonate "screen",

3) Air distribution duct (Fig.9)

Sheets of clear polycarbonate (1.5 mm thickness) were riveted to the steel frame so that the top of the sheets were 50 cm above the ground and the bottom of the sheets were 15 cm above the ground. The hexagonal air distribution duct was constructed of 11 cm diameter polyethylene pipe. The duct was drilled with ten 0.9 cm diameter holes on the inside face of each of the six sections and then the duct was mounted on the frame with the holes slightly below the bottom of the screen.

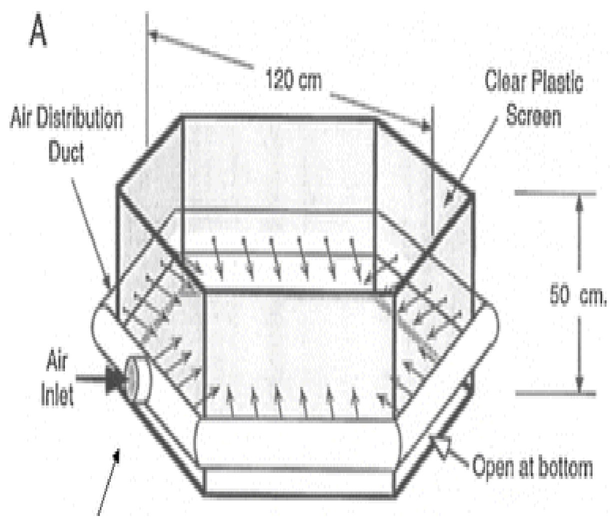


Fig 9: Basic structure of SACC

2.5.2 Working principle

Wind is obstructed by the screen and enter into the chamber through the opening present at the opening present at top and bottom of the screen and cause turbulent mixing. CO_2 released into the chamber is mixed with the outside air and distribute uniformly inside the chamber.

2.6 CO_2 and Temperature Gradient Chamber (CTGC)

It is a facility to study the interactive effects of CO_2 and temperature which are vital parameters of climate change (Lee, 2001). The chamber is with field like environment with higher CO_2 and warming conditions concurrently which influence the crop growth and insect pests. Very meagre data is available to assess the potential interactive impacts of elevated CO_2 and temperature under field like conditions. This facility is first of its kind to simulate the future climate change scenario conditions with both CO_2 enrichment and warming conditions. The scientific parameters generated from the experiments conducted using this facility are of with authenticity and of immense help to understand the impact of climate change on crop growth and biotic stresses.

2.6.1 Structure of CTGC

The CTGC facility has 8 chambers with 30 meters length, 6 meters width and 4 meters height at the centre (Rao *et al.*, 2018). The 8 chambers are categorized as follows:

1. Two chambers are with natural climate which serve as - 'Reference'

2. Two Chambers are with temperature gradient of 5 ± 0.5°C over reference and referred as elevated Temperature, - 'eTemp'

3. Two Chambers are with Temperature gradient 5 ± 0.5°C over reference with elevated CO_2 concentration of 550 ± 50 ppm – 'eTemp + eCO_2'

4. Two Chambers are with elevated CO_2 concentration of 550 ± 50 ppm which serve as - 'eCO_2'

Plate 2: CO_2 temperature gradient chambers at CRIDA

3. Crop responses to elevated CO_2

Elevated CO_2 have several impact on crop production, major effect of elevated CO_2 on crops are discussed below:

- Increased photosynthetic rate
- Decreased stomatal conductance
- Increased drought tolerance

- Reduction in nutritional quality
- Increased pest Attack

3.1 Increased photosynthetic rate

Elevated carbon dioxide increases carbon availability to plants. RuBisco enzyme has the affinity towards both oxygen and carbon dioxide. Under elevated CO_2 condition affinity of RuBisco towards carbon dioxide increases as a result photorespiration decreases and photosynthetic rate increases. Excess non structural carbohydrates accumulates in the roots and it induces production of auxin which lead to increased shoot and root growth.

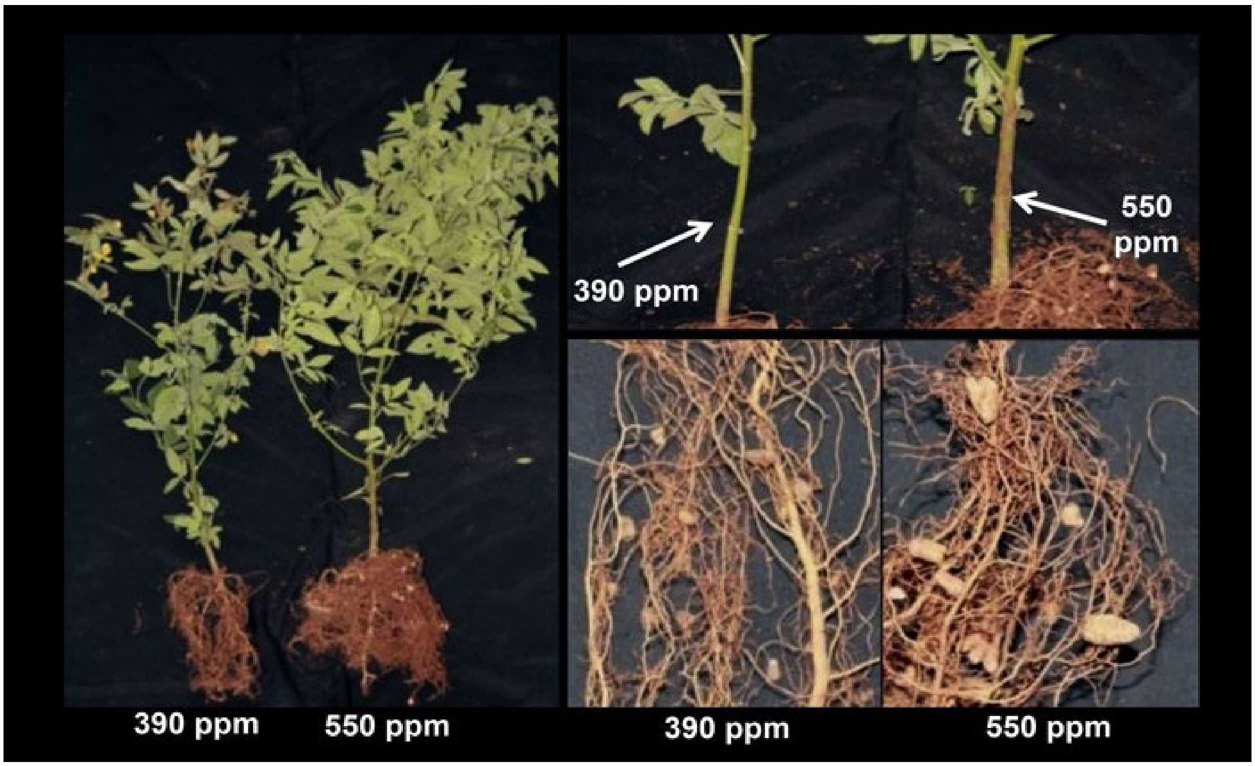
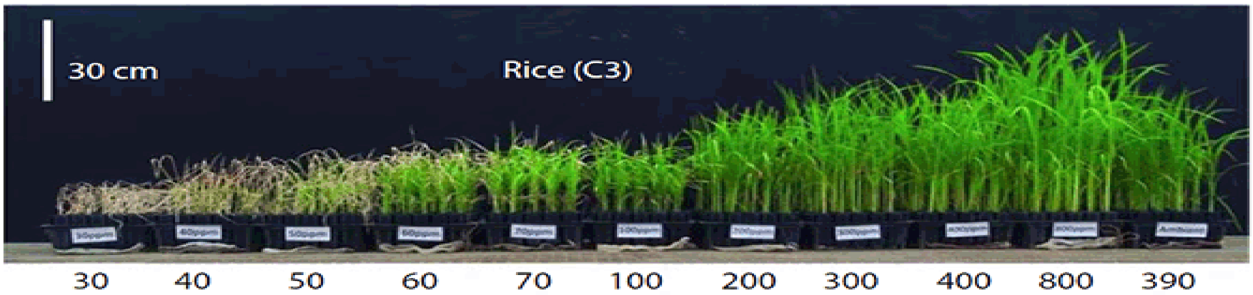


Plate 3: Increased plant growth under elevated carbon dioxide concentrations

Effect of this elevated carbon dioxide in plants are more prominent among C3 plants compared to C4 plants. The carboxylation reaction of RuBP is not saturated at the current atmospheric CO_2, therefore, as the availability of CO_2 increases under eCO_2 conditions so too will the rate of carboxylation where as in C4 plants such an effect is not seen.



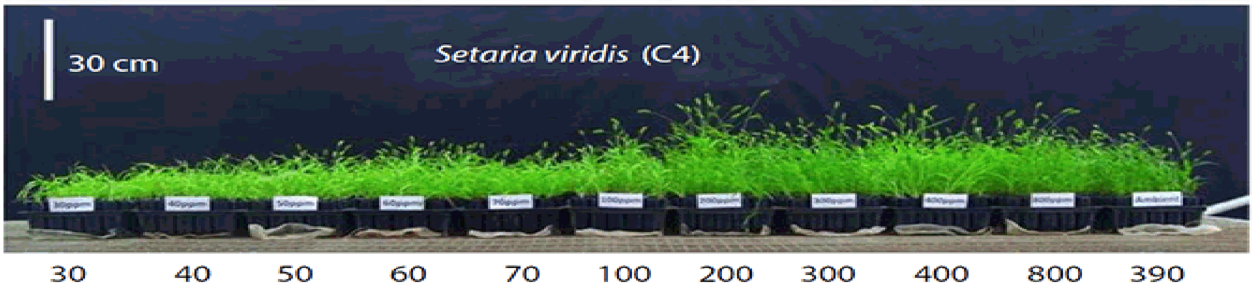


Plate 4: Response of C3 and C4 plants towards different CO_2 concentrations

3.2 Behaviour of stomata under elevated CO_2 condition

Under high CO_2 conditions, both stomatal conductance and its density decreases and water use efficiency increase (Jiang *et al*., 2016). Due to narrowing of the stomata, it has additional benefit that a lesser amount of pollutants in the air will enter through the narrower openings. When stomata closes water loss decreases and due to the influence of CO_2, photosynthetic rate increases. So dry matter produced per unit water increases. This might be the reason behind increased water productivity under elevated conditions (Allen, 1991).

3.3 Increased drought tolerance

Various studies suggests that drought tolerance is found to be increased under elevated CO_2 condition. One such study is described below. A pot culture experiment was conducted by Chatti *et al.*(2018) with three varieties of tomato *i.e*, Manulakshmi, Vellayani Vijay, Anagha with the objective to study the growth parameters contributing to increased drought tolerance responses in tomato (Solanum lycopersicum L.) under elevated Carbon dioxide using the Open Top Chambers (OTC) system. One month old potted tomato plants after shifting to OTC were subjected to water stress and then were allowed to recover. Various growth parameters like root weight, shoot weight, root shoot ratio, specific leaf area, total dry matter content were analysed both after stress and recovery. Elevated CO_2 was found to increase growth parameters like root weight, shoot weight, specific leaf area and total dry matter production. Significantly higher values were recorded for root weight (0.92 g), shoot weight (6.88 g), total dry matter production (5.74 g) under elevated CO_2 compared to open control(Fig. 10)

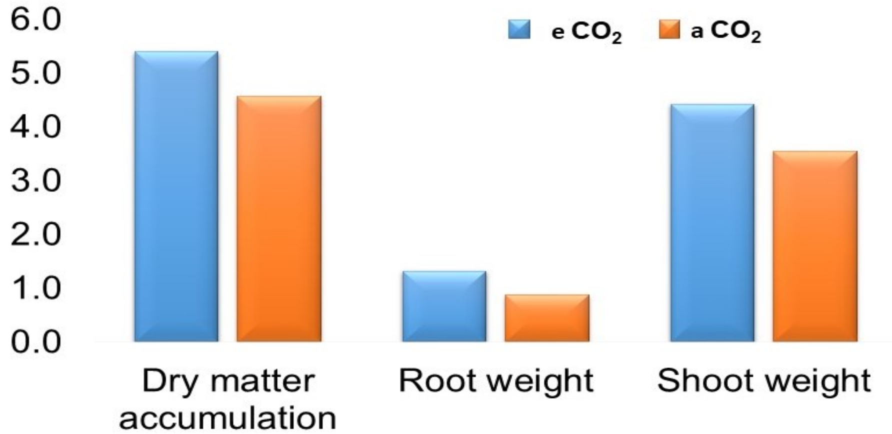


Fig. 10: Effect of elevated CO_2 on growth parameters during stress

Among the varieties, dry matter production was recorded significantly higher for Vellayani Vijay compared to both Manulakshmi and Anagha. After rewatering, highest recovery in dry matter production from stress was observed under elevated CO_2 for the variety vellayani vijay. Dry matter production was observed significantly higher under elevated CO_2 compared to treatment open control. Among the varieties, highest dry matter production was recorded for the variety Vellayani Vijay followed by Anagha and Manulakshmi which is depicted in Fig. 11

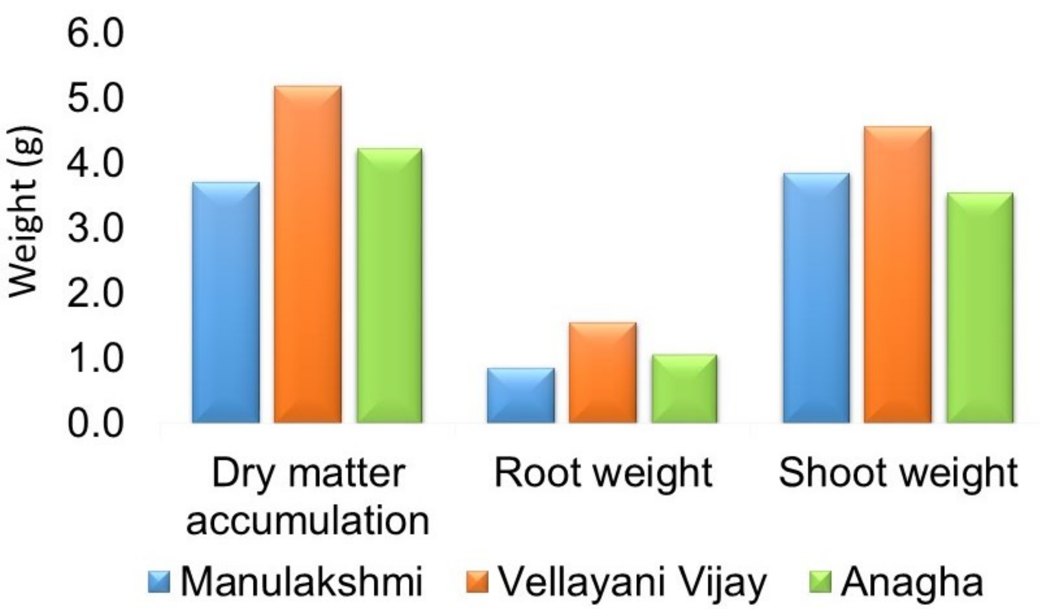


Fig 11: Effect of elevated CO_2 on growth parameters after stress and re-watering in tomato

3.4 Effect on nutritional quality

Higher concentrations of carbon dioxide is associated with increase in carbohydrate content and decrease in protein and mineral content, as suggested by most of the studies. A study was conducted using 18 common races of rice by Mercado *et al*.(2018) in University of Tokyo to study the impact of elevated carbon dioxide on nutritional quality of rice using FACE technology. Their results confirm previously reported declines in protein, iron and zinc in rice grown under elevated CO_2 concentrations that scientists expect by the end of the 21st century. In addition, the study reveals for the first time average declines in vitamins B1, B2, B5 and B9.(Table 2)

Table 2 : Decline in the nutrient content of rice under elevated carbon dioxide

Sl. No	Nutrient	Percentage decline
1	Protein	10
2	Iron	8
3	Zink	5
4	B1	17
5	B2	17
6	B5	13
7	B9	30

Under elevated CO_2 condition, the protein content is low because the concentration of nitrogen decreases due to increased carbohydrate accumulation *i.e.* increased C:N ratio. There is a decline in transpiration pull under elvated carbon dioxide condition . This might be the reason behind the reduced mineral uptake from the soil.

3.5 Increased pest incidence

Most of the studies suggest that pest incidence is found to be higher under elevated CO_2 condition because due to decline in nutritional content insect has to take more feed to satisfy their nutritional requirement and also increased carbohydrate will increase the vulnerability of plants to insect pests.

A study was done in Soybean using FACE technology at University of Illinois. Soybeans in the test plot exhibited more signs of insect damage than those in control plots plots. A closer inspection showed that soybeans grown at elevated CO_2 levels attracted many more adult Japanese beetles, Western corn rootworms and, during outbreaks of Asian soybean aphids, more of these than soybeans in other plots. Caterpillars and other insect larvae need nitrogen to grow and build new tissues, but adult insects can survive and reproduce on a high carbohydrate diet. So it made sense that more adults would migrate to the high CO_2 plots. Study was also done to know wheather the effect is due to increased sugar level. For this beetles are grown on a high CO2 plant, on a low CO2 plant outside the Soy FACE plot, and on a low CO2 plant grown outside the test plot but which had its sugar content artificially boosted. The beetles on the high CO2 soybean plants lived longer, and as a result produced more offspring, than those living outside the Soy FACE plot. Even those fed a supplemental diet of sugars did not see their life span extended. Similarly elevated CO_2 reduced jasmonic acid production which inturn reduced the plant defense mechanism against insect pest (Evan *et al.,* 2008).

4. Conclusion

Being a majour constituent in photosynthesis, atmospheric carbon dioxide plays a crucial role in crop production. There is an urgent need to understand the likely effect of elevated carbon dioxide in plants and to develop cultivars which are suitable under elevated CO_2 conditions. Various studies conducted using carbon dioxide enrichment technologies revealed that elevated CO_2 have significant effect on crops like increased growth and development due to increased photosynthesis, decreased nutrient content and stomatal conductance, increased drought tolerance and increased pest and disease attack. With the aid of carbon dioxide enrichment technologies, crops or cultivars which are performing better under elevated carbon dioxide concentration can be selected for developing climate resilient crops.

5. Discussion

1. Due to decrease in transpiration pull there is a reduction in mineral content. Will it affect the photosynthate translocation ?

Reduction in transpiration will influence the movement through xylem. Photosynthate translocation takes place through phloem. So it wont be affected.

2. Compared to FACE, OTC which one is more cost effective?

Cost of both FACE and OTC depends on the location where the experiment is conducted, duration of crops and cultivar used. Compared to open top chamber FACE will be having more cost due to more carbon dioxide consumption. The FACE experiments conducted in CRIDA will have an average expenditure of 15 lakhs per experiment and OTC will have an expenditure of 3-5 lakhs per experiment.

3.Is it possible to use these technologies for plantation crops ?

Open top chambers are used in Central Plantation Crops Research Institute, Kasargode. Plantation crops can be grown under these structures having appropriate heights. Experiments are conducted in crops like coconut.

4. The carbon dioxide measurements are made at *Mauna loa*. How much reliable it is as a representative of global carbon dioxide concentration ?

Carbon dioxide measurements at *Mauna loa* is a representative of global carbon dioxide concentration. Carbon dioxide concentration at selected costal regeions were measured and average values were calculated. This average value was on par with the carbon dioxide measurement done at *Mauna loa.*

6. References

Allen, L. H. 1991. Effects of increasing carbon dioxide level and climate change on plant growth, evapotranspiration and water resources. In: Managing water resources in the west under conditions of climate uncertainity. *Proceedings of a Colloquium*, 14-16 November 1990, Scottsdale, AZ, Acad. Press. pp. 101-104.

Chakrabarti, B., Singh, S. D., Kumar, N. S., Aggarwal, P. K., Pathak, H., and Nagarajan, S. 2012. Low cost facility for assessing impact of carbon dioxide on crops. *Curr. Sci.* 102(7): 1035-1040

Rao, M., S., Vanaja, M., Srinivas, I., Rao, C., V., K., Srinivas, K., Maheswari, M., Prabhakar, M., Sreelakshmi, P., Bhaskar, S., and K., Reddy S. 2018. CTGC: A facility to study the interactive effects of CO_2 and Temperature. ICAR- CRIDA, Hyderabad. 2018. 43p.

ESRL [Earth System Research Laboratory]. 2019. ESRL home page. Available: http://www.esrl.noaa.gov [30 Oct. 2019].

Leadley, P., W., Niklaus, P., Stocker, R., and Korner. 1997. Screen-aided CO 2 control (SACC): a middle ground between FACE and open-top chambers. *Acta Ecologic*. 18 (3): 207-219

Lee, S. J., Usami, T., and Oikawa, T. 2001. High performance of carbon dioxide temperature gradient chamber newly built for studying the global warming effect on a plant population. *Ecol. Res.* 16: 347-358

Machacova, K. 2010. Open top chamber and free air carbon dioxide enrichment approaches to investigate tree responses to elevated carbon dioxide. *iFor. Biogeosci. For.* [Online] 3(4): 102. Available: https://doi.org/10.3832/ifor. 0544-003 [30 Oct. 2019].

Uprety, D. C. and Reddy, V. R. 2008. *Rising Carbon dioxide and Crops*. Indian Council of Agricultural Research, New Delhi, 195p.

KERALA AGRICULTURAL UNIVERSITY

COLLEGE OF HORTICULTURE, VELLANIKKARA

Department of Agricultural Meteorology

AGM 591: Masters Seminar

Name : Harithalekshmi V. Venue : Seminar Hall

Admission no. : 2018-11-067 Date : 21-11-2019

Major advisor : Dr. B. Ajithkumar Time : 9. 15 am

Microclimate modification using Carbon dioxide Enrichment Technologies (CET) and crop responses

Abstract

Atmospheric carbon dioxide is increasing at an accelerating rate. Its concentration has reached a peak of 418.7 ppm on 15 May 2019, which was the highest recorded value ever since the history of mankind (ESRL, 2019). The impact of rising atmospheric carbon dioxide on crop production has emerged as a major research area during the past decades. The possible impacts of elevated carbon dioxide can be understood by conducting experiments that modify crop microclimate by means of carbon dioxide enrichment technology.

Carbon dioxide Enrichment Technologies (CET) are controlled environments and field based facilities to study the crop responses to elevated carbon dioxide concentration. Soil Plant Atmosphere Research (SPAR), Carbon dioxide and Temperature Gradient Chamber (CTGC), Open Top Chamber (OTC), Free Air Carbon dioxide Enrichment (FACE) and Screen Aided Carbon dioxide Control (SACC) are most popular and efficient carbon dioxide enrichment technologies. SPAR chambers are enclosed structures where plants can be grown under the controlled conditions of carbon dioxide, temperature and humidity. OTC are extensively used as plant exposure units in both carbon dioxide response studies and air pollution studies (Uprety and Reddy, 2008). FACE experiments allow us to study the effects of elevated atmospheric CO_2 on plants grown under natural conditions (Chakrabarti *et al*., 2012). SACC is developed by eliminating disadvantages and combining advantages of both OTC and FACE (Machacova, 2010). CTGC was developed to study the interactive effect of temperature and elevated carbon dioxide

on plant growth under field like condition (Lee *et al.,* 2001). Carbon dioxide is essential for photosynthesis and atmospheric carbon dioxide serves as the primary carbon source for green plants. . Various studies conducted using carbon dioxide enrichment technologies revealed that elevated CO_2 have significant effect on crops like increased growth and development due to increased photosynthesis, decreased nutrient content and stomatal conductance, increased drought tolerance and increased pest and disease attack (Allen, 1991).

Increased carbon dioxide concentration have a significant impact on crop production. With the help of different CET, the cultivars which are performing better under elevated carbon dioxide concentration can be identified and can be used for developing climate resilient crops.

References

Allen, L. H. 1991. Effects of increasing carbon dioxide level and climate change on plant growth, evapotranspiration and water resources. In: Managing water resources in the west under conditions of climate uncertainity. *Proceedings of a Colloquium*, 14-16 November 1990, Scottsdale, AZ, Acad. Press. pp. 101-104.

Chakrabarti, B., Singh, S. D., Kumar, N. S., Aggarwal, P. K., Pathak, H., and Nagarajan, S. 2012. Low cost facility for assessing impact of carbon dioxide on crops. *Curr. Sci.* 102(7): 1035-1040

ESRL [Earth System Research Laboratory]. 2019. ESRL home page. Available: http://www.esrl.noaa.gov [30 Oct. 2019].

Lee, S. J., Usami, T., and Oikawa, T. 2001. High performance of carbon dioxide temperature gradient chamber newly built for studying the global warming effect on a plant population. *Ecol. Res.* 16: 347-358

Machacova, K. 2010. Open top chamber and free air carbon dioxide enrichment approaches to investigate tree responses to elevated carbon dioxide. *iFor. Biogeosci. For.* [Online] 3(4): 102. Available: https://doi.org/10.3832/ifor. 0544-003 [30 Oct. 2019].

Uprety, D. C. and Reddy, V. R. 2008. *sRising Carbon dioxide and Crops*. Indian Council of Agricultural Research, New Delhi, 195p.