Brazilian Coffee Free-Air Carbon Dioxide Enrichment (FACE) Facility: Predicting the Impact of Climate Change

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SUMMARY

The atmospheric CO_2 concentration has been increasing significantly in the last decades, despite the international efforts for the reduction of emissions. The Climapest FACE facility was established at Embrapa Environment (Jaguariúna, São Paulo State, Brazil), on August 25th, 2011, in order to generate field response data in broad-acre coffee to elevated CO_2 air concentration and water supply. Diseases, pests and weeds, as well as plant physiology of two coffee cultivars (Catuaí Vermelho IAC 144 and Obatã IAC 1669-20), multitrophic interactions and soil attributes have been monitored in twelve 10-m-diameter octagonal rings (plots) located within a 7-ha coffee field. Six rings, representing the control treatment, were left under untreated conditions (current atmosphere), whereas other six rings have been treated with pure CO_2 to achieve the concentration of 200 µmol mol^{-1} above ambient concentration, supplied by a bulk CO_2 container with the capacity of 20 t. The system instrumentation is based on wireless sensor network technology. Each octagon segment has individual gas valves to compensate the wind direction and a flow control device to compensate wind speed changes. The objective of this paper is to describe the first coffee FACE facility in the world.

INTRODUCTION

The average atmospheric concentration of carbon dioxide (CO2) reached 397 µmol mol-1 in 2012, exceeding the concentrations of the last 800,000 years (180 to 300 µmol mol-1).Projections indicate that CO2 concentration could reach 730 to 1020 µmol mol-1 by 2100 under the A2 scenario.

Despite the evidence of beneficial effects of CO2 on plants, it is not well known whether these effects will still take place in the presence of pathogens, pests and weeds or other limiting factors, particularly in tropical countries. Studies conducted under controlled conditions might not reflect plant responses in the field, where there are variations and interactions among temperature, precipitation, and other factors. The search for more realistic conditions has led to the use of Free Air Carbon-dioxide Enrichment (FACE) experiments.

FACE experiments are characterized by large-scale and long-term exposure of plants to elevated CO2 concentrations under field conditions without enclosure, allowing interdisciplinary evaluations. This paper discribes the first FACE facility stablished in order to generate field response data in broad-acre coffee to elevated CO2 air concentration and water supply.

MATERIALS AND METHODS

The Climapest FACE facility (Fig. 1) is located at Embrapa Environment, in Jaguariúna, São Paulo State, Brazil (latitude 22°41'S, longitude 47°W, altitude of 570 m a.s.l.) and became operational on August 25th, 2011.

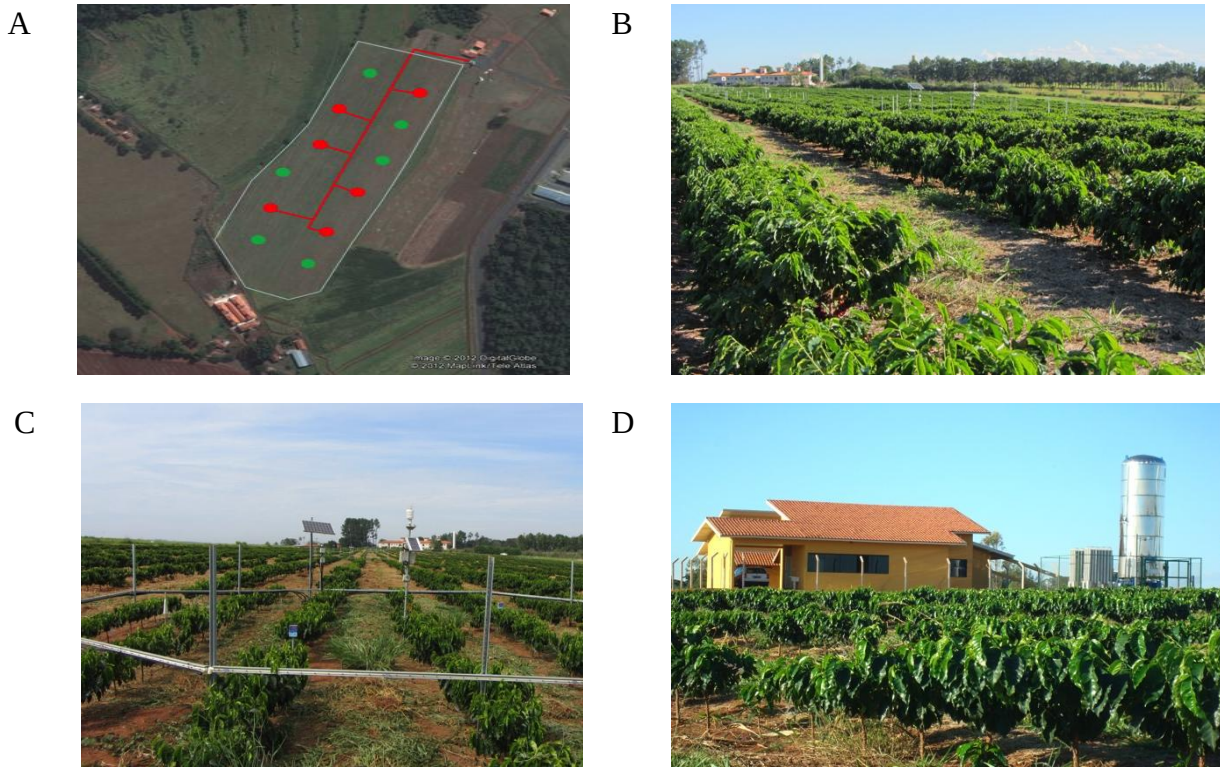

Figure 1. Climapest FACE facility: (A) Google aerial view of the total area (red rings are plots with elevated [CO_2] and green rings are plots with ambient [CO_2], (B) rings in the coffee field, (C) a octogonal ring and (D) bulk CO_2 container and laboratory.

The experiment was designed to study the effects of: CO_2 concentrations (current ~395 µmol mol^{-1} and 200 µmol mol^{-1} above current concentration) and water supply (with and without irrigation) on two coffee cultivars (Catuaí Vermelho IAC 144 and Obatã IAC 1669-20). Twelve 10-m-diameter octagonal rings (plots) were established within a 7-ha-coffee field; six of which with elevated [CO_2] and six with ambient [CO_2], separated at least 70 m from each other to minimize cross-plot contamination. Plots were built with eight chlorinated polyvinyl chloride (PVC) tubes (internal diameter of 18 mm).

The system instrumentation is based on wireless sensor network technology. Environmental sensors (infra-red gas analyzers – IRGA - to measure the CO_2 concentration, anemometers, sensors of air and soil temperature and humidity, solar radiation and precipitation) have been adapted to ZigBee modules. The wireless sensor network based instrumentation facilitated the system installation and maintenance, and increased its portability. Each octagon segment has individual gas valves to compensate the wind direction and a flow control device to compensate wind speed changes. The system has been adjusted to allow injection only for wind speeds within the range of 0.5 to 4.0 m s^{-1} and the CO_2 injection is run only during daylight hours.

The FACE facility is part of the project entitled "Impacts of climate change on plant diseases, pests and weeds - Climapest" (http://www.macroprograma1.cnptia.embrapa.br/climapest), which has been supported by Embrapa (Brazilian Agricultural Research Corporation).

RESULTS AND DISCUSSION

Since August 25th, 2011, plants of the two coffee cultivars have been treated with CO_2. Average CO_2 concentrations in the elevated [CO_2] were significatively higher than in ambient plots. Data from April 2012 are shown in Figure 2.

Understanding how coffee plants, pathogens, pests, weeds and related organisms respond to future increase in CO_2 concentration and their interaction with water supply will allow the development of adaptation strategies. The results can help minimize the negative impacts of climate change or provide new opportunities from the positive impacts.

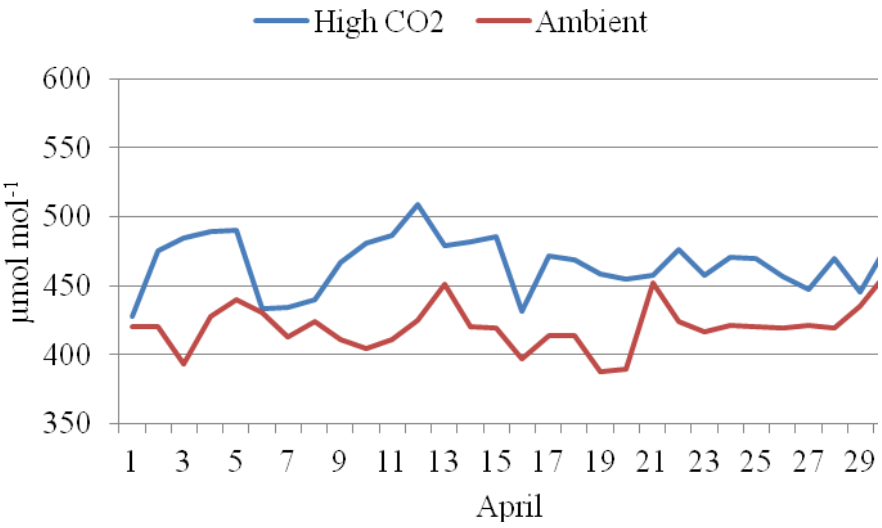

Figure 2. Average CO_2 concentrations in the elevated [CO_2] plots (High CO2) and in ambient plots in April 2012.

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REFERENCES

Lüthi, D., Floch M. L., Bereiter, B., Blunier, T., Barnola, J-M., Siegenthaler, U., Raynaud, D., Jouzel, J., Fischer, H., Kawamura, K., Stocker, T. F. High-resolution carbon dioxide concentration record 650,000–800,000 years before present. *Nature.* 2008. 453, 379-382.

IPCC. Climate Change 2007: The Physical Science Basis. *Contribution of Working Group I for the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, United Kingdom, 2007.

Ghini, R., Bettiol, W., Hamada, E. Diseases in tropical and plantation crops as affected by climate changes: current knowledge and perspectives. *Plant Pathology*. 2011. 60, 122-132.

Hendrey, G. R., Ellsworth, D. S., Lewin, K. F., Nagy, J. A free-air enrichment system for exposing tall forest vegetation to elevated atmospheric CO_2. *Global Change Biology*. 1999. 5, 293-309.

Ainsworth, E. A., Long, S. P. What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO_2. *New Phytologist*. 2005. 165, 351-372.