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Effect of CO2 elevation on Shisham growth at nursery stage

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ABSTRACT

The effects of elevated carbon dioxide concentration (CO_2) were evaluated on Shisham at nursery stage for height, diameter, number of branches and number of leaves by raising them for a year in open top chamber (OTC) with six levels of CO concentrations *viz.* Control, 400ppm, 600ppm, 800ppm, 1000ppm and 1200ppm. Morphological studies associated with it would be beneficial in understanding the overall mechanism underlying growth and development of Shisham in response to elevated CO_2. Stem height was observed to be maximum at 1000 ppm CO_2 Concentration (85.84±4.67) whereas diameter (10.21±0.22), number of leaves (56.82±4.74) and number of branches (6.53±0.50) were recorded maximum in control.

1. Introduction

Shisham (*Dalbergia sissoo* Roxb.) is an excellent timber species worldwide occurring naturally in many Asian countries like India, Afganistan, Pakistan, Bangladesh, Bhutan, Burma and Nepal. It is widely adapted to varied edaphic and climatic conditions, so it is one of the most preferred species for afforestation and reforestation programmes. Farmers of North India also plant this species in agroforestry systems for profitable economic returns and is well accepted for social forestry programmes.

Research has shown that plants respond positively at elevated CO_2 (Amthor 1995) which is the raw material of photosynthesis and has great influence on plant physiology, growth, structure and function of plant species. The current atmospheric CO_2 concentration is about 380 $\mu mol \cdot mol^{-1}$, which is far below the optimum concentration of plant photosynthesis. Generally, plants grown at elevated CO_2 relative to those grown at ambient CO_2 often exhibit increased growth, and photosynthesis with improved water use efficiency. The effects of elevated CO_2 are manifested by changes in photosynthesis. Studies of both deciduous and evergreen plants have shown that elevated CO_2 leads to increased photosynthesis (Ells worth *et al.* 2004) and decreased water conductance (Calfapietra *et al.* 2005). Although much is known regarding the effects of elevated CO_2 on agricultural crops but forest species including *Dalbergia sissoo* Roxb. an important industrial and agroforestry tree species, has received much less attention. Studies on effect of CO_2 elevation would be useful to understand the response of this economically important agroforestry tree species in purview of changing climate.

2. Material and Methods

The present study was conducted in the (OTC) Open Top Chamber facility at the campus of Forest Research Institute, Dehradun, India which is situated at Latitude 30°20'10.31" N, Longitude 77°59'55.32" E and altitude of 650 amsl. The study was conducted during the period March 2018 to February 2019. Clones of Shisham (Clone 14, 232 and 86) were raised *via* cuttings in OTCs. To maintain the homogeneity of the experiment the cuttings were raised in equal size pots. 18 plants per CO_2 concentration were taken in five chambers each.

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Commercial grade 100% CO_2 gas was supplied to the chambers through CO_2 gas cylinder and maintained at set levels (400 ppm, 600 ppm, 800 ppm, 1000 ppm and 1200 ppm) using gas regulators, pressure pipelines, solenoid valves, rotameters, sampler, pump, CO_2 analyzer, PC linked Program Logic Control (PLC) and Supervisory Control and Data Acquisition (SCADA). The uniformity of CO_2 gas was maintained by diluting CO_2 gas with air by a 120 liter capacity air compressor.

Growth attributes/ Biometric traits

Each plant's height (cm), collar diameter (mm), number of leaves, number of branches were recorded seasonally *viz.* spring, summer, rainy, and winter at interval of four months throughout the period of the entire experiment.

Height (in cm)

The height of emerged plants from root collar to tip of the shoot were recorded seasonally at interval of four months with the help of meter scale in centimeter (cm) seasonally.

Collar diameter (in mm)

The collar diameter (diameter at root collar) was recorded using digital caliper in millimeter seasonally at interval of four months.

Number of leaves and branches

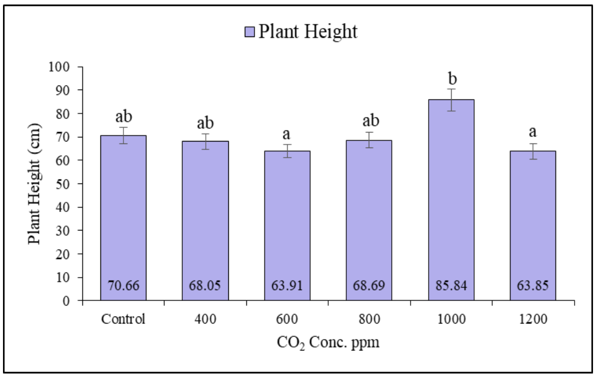
Leaf number and branches were counted seasonally at interval of four months. Being pinnately compound for counting each set of leaflets emerging from the branch was taken as a single leaf.

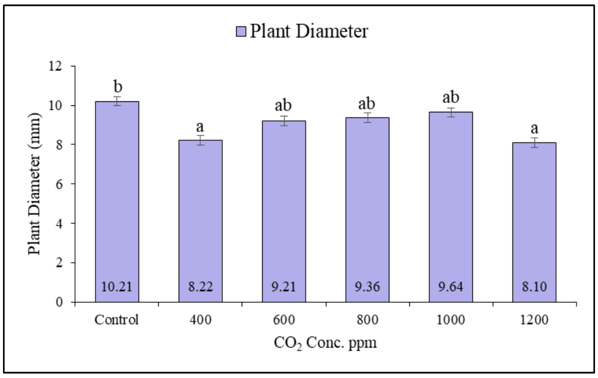
3. Results

Primary results indicated that altered CO_2 concentration had significant effects on growth parameters of Shisam at nursery stage. Maximum height was observed in Shisham growing at 1000 ppm of CO_2 (85.84±4.67cm**)** followed by Control (70.66±3.44 cm) and 800 ppm (68.69±3.32 cm) respectively. Among the different levels of CO_2 concentration maximum collar diameter was observed in Control (10.21±0.22 mm) followed by 1000 ppm (9.64±0.24 mm) and 800 ppm (9.36±0.25 mm). Maximum number of branches was seen in control (6.53±0.50) followed by 1000 ppm (4.58±0.45) and 800 ppm (4.18±0.40) respectively. Maximum number of leaves were recorded in Control (56.82±4.74) followed by 1000 ppm (43.15±4.28) and 1200 ppm (37.61±3.74) of CO_2 concentration respectively (Table 1).

Table 1. Effect of CO_2 elevation on growth parameters of *Dalbergia sissoo* at nursery stage

CO_2 Concentration	Height (cm)	Diameter (mm)	No. of Branches	No. of Leaves
Control	$70.66^{ab}\pm3.44$	$10.21^{b}\pm0.22$	$6.53^{b}\pm0.50$	$56.82^{b}\pm4.74$
400	$68.05^{ab}\pm3.43$	$8.22^{a}\pm0.25$	$2.81^{a}\pm0.25$	$28.76^{a}\pm2.09$
600	$63.91^{a}\pm2.87$	$9.21^{ab}\pm0.25$	$3.43^{a}\pm0.36$	$27.71^{a}\pm2.45$
800	$68.69^{ab}\pm3.32$	$9.36^{ab}\pm0.25$	$4.18^{a}\pm0.40$	$31.90^{a}\pm2.24$
1000	$85.84^{b}\pm4.67$	$9.64^{ab}\pm0.24$	$4.58^{ab}\pm0.45$	$43.15^{ab}\pm4.28$
1200	$63.85^{a}\pm3.34$	$8.10^{a}\pm0.23$	$3.85^{a}\pm0.45$	$37.61^{a}\pm3.74$
F value	3.314	4.373	6.278	7.749
p value	0.01	0.001	0	0
S/NS	S	S	S	S





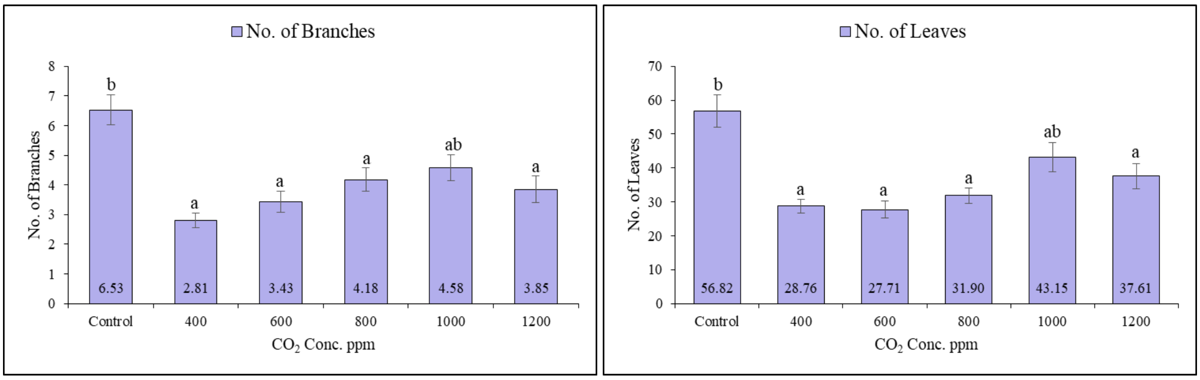


Fig 1. Efffect of CO_2 elevation on growth parameters of *Dalbergia sissoo* at nursery stage

Fig 2. *Dalbergia sissoo* plants in Open top chambers (OTC) at different CO_2 level concentrations; a. Control, b. 400ppm, c. 600ppm, d. 800ppm, e. 1000ppm and f. 1200ppm.

4. Discussion

CO_2 enrichment has shown varying effect on agricultural and horticultural crops. Usui *et al.* (2014) found that heat tolerant cultivars of rice showed higher grain percentage along with maintaining grain quality in Free Air CO_2 Enrichment (FACE) experiment studies. Kimball *et al.* (2007) showed that enrichment at +300 ppm CO_2 above ambient (ambient was about 350 ppm in 2007) resulted in an overall growth (fruit + wood) stimulation of 70% (± 12%) after 17 years in sour orange (*Citrus aurantium* L.) trees. Madan *et al.* (2012) concluded that elevated CO_2 increase yield in rice varieties but high temperature reduces grain quality. Chakraborty *et al.* (2015) showed that CO_2 enrichment resulted in significant increase in growth, leaf area and dry matter production in *Brassica* cultivars. Tomato grown under enhanced CO_2 concentrations were found to flower earlier and produce 30% more marketable fruit than ambient air by Hickleton and Jolliffe (1978).

Increased CO_2 levels have also been observed to stimulate growth in forest species. In an assessment, modern oaks growing at an average CO_2 of 330 ppm, growth sensitivity to temperature was found about twice than that of paleo oaks growing at an average CO_2 of 230 ppm by Voelker *et al.* (2017). In their studies Purohit and Habibi (2010) found that among certain tree species; *Acharus sapota*, *Wrightia tomentosa*, *Feronia limonia*, *Terminalia bellerica* and *Celastrus paniculatus* cultural growth, survival percentage, overall growth parameters showed significant enhancement over the control under elevated CO_2. Large synergistic gains from higher CO_2 and nutrients was detected with nutrients added in forest experiments on maturing pine by Oren *et al.* (2001). Smith *et al.* (2013) found that the mean effect of CO_2 enrichment on aboveground woody biomass was +29, +22 and +16% for *A. glutinosa*, *F. sylvatica* and *B. pendula*, respectively in monoculture. Dawes *et al.* (2011) depicted larger growth in *Larix* growing under elevated CO_2 but not in *Pinus*. Density of algae (*Trebouxia* sp.) was found significantly higher after 380 days exposure to the CO_2-enriched environment by Ismail *et al.* (2017). In another important observation Mohan *et al.* (2007) noticed that shade tolerant species showed increment whereas shade intolerant species didn't survive better with CO_2 enrichment.

5. Conclusion

Previous research has shown a positive response of plants to elevated CO_2 (Amthor 1995) in our primary results it has been clearly depicted that CO_2 elevation had significant increase in height of Shisham, collar diameter, number of branches and number of leaves when compared to ambient (Fig. 1). Shisham was found to outperform in terms of growth at ambient levels (400ppm) of CO_2 in controlled environment, optimum growth was seen at 1000ppm which declined steeply thereafter at 1200ppm which might be the toler threshold for the species.

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