# $CO_2$ emission by conifers at enhanced concentration of $O_3$ and $CO_2$

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The experimental results on $CO_2$ emission from cedar saplings at elevated concentration of $CO_2$ and $O_3$ are presented. An increase of intensity of both light and dark respiration of the saplings under $O_3$ fumigation was observed.

The forecast of plants state at increased concentration of atmospheric ozone and $CO_2$ is an urgent and very intricate problem of the environmental protection, attracting attention of scientists for many years. The ozone is a secondary pollutant generated as the result of complex atmospheric reactions with the participation of solar radiation. The ozone concentration in the ground atmospheric layer depends on the UV radiation intensity. Background concentration of the ozone equals 20–40 ppb (Ref. 1). An increase of $O_3$ concentration in the ground layer in various regions is caused by many various factors. In industrial areas, for example, with the enhanced amount of hydrocarbons and nitrogen dioxides, the $O_3$ concentration is 2–3 times higher than the background one (40–80 $\mu g/m^3$ for mid-latitudes). It increases by about 1–2% a year. In the forested regions the augmentation of $O_3$ concentration may be due to biogenic hydrocarbons (isoprene, terpene, and so on), emitted by arboreous plants. $CO_2$ is a usual component of air as a product of metabolism. It is released in the process of animals and plants respiration and organic matters degradation, and plays a significant role in evolution of the greenhouse effect (Ref. 1).

As a result of ozone action on plants, such phenomena are observed as a decrease in the photosynthesis rate, augmentation of respiration intensity, decrease of the plants growth in height and biomass, lowering of crop yield, and acceleration of the process of leaf aging and defoliation (both of herbaceous and coniferous plants).[2] On the exposure of plants to ozone fumigation, the necrosis and chlorosis develop in leaves, an activity of a series of ferments is depressed.[3] The present tendency toward cumulation of $O_3$ and $CO_2$ in the troposphere may affect the kinetics of the processes of gas exchange between the atmosphere and vegetative systems and this can result in additional emission of $CO_2$ under conditions of enhanced concentration of $O_3$ and $CO_2$, as it was proved in the laboratory experiments.[4]

This paper presents some experimental results on the studies of the $CO_2$ emission from cedar saplings exposed to action of $O_3$ and $CO_2$ at the enhanced concentrations.

## Experimental set-up

We used in the experiment a GIAM–15 gas-analyzer, an “OZON–5B ozone generator, and four exposure chambers (Fig. 1). The GIAM–15 gas-analyzer used is intended for control over various gaseous components in technological processes and environment, $CO_2$, for example. It is an automated stationary instrument operated in a continuous mode. The spectrophotometric method of gas analysis was used in its operation. Photoacoustic receiver was used to measure the power of radiation source. The range of measurable $CO_2$ concentration was 0–500 ppb. The limits of the acceptable error for $CO_2$ were no more than 10% (Ref. 5).

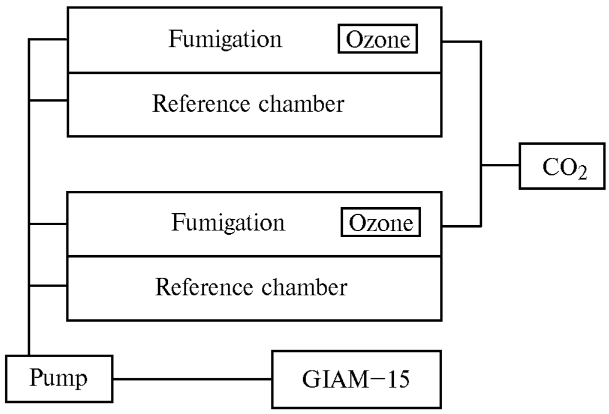


**Fig. 1.** Experimental set-up.

To study the influence of $O_3$ and $CO_2$ on the cedar saplings, they were placed inside four polyethylene chambers, each of 1 $m^3$ volume with closed bottom to prevent contribution of the $CO_2$ emitted from the soil.

The “OZON–5B ozone generator was used for fumigation with $O_3$. Its capacity was 5 g/hour. The

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$O_3$ dose was monitored by varying of the generator operation time.

## The method and results of the experiment

The objects of the experiments were the cedar saplings of Tomsk and Altai populations. The Altai specimens were of two types: grown at the height of about 1500 m (type A) and 2000 m (type B). The experiment was divided into three stages:

1. Investigation of $CO_2$ emission from the cedar saplings under standard conditions (Fig. 2);
2. Control over $CO_2$ emission by the cedar saplings under stress conditions due to $CO_2$ at enhanced concentration (Fig. 3);
3. Control over $CO_2$ emission from the cedar saplings exposed to the $O_3$ fumigation (Figs. 4–6).

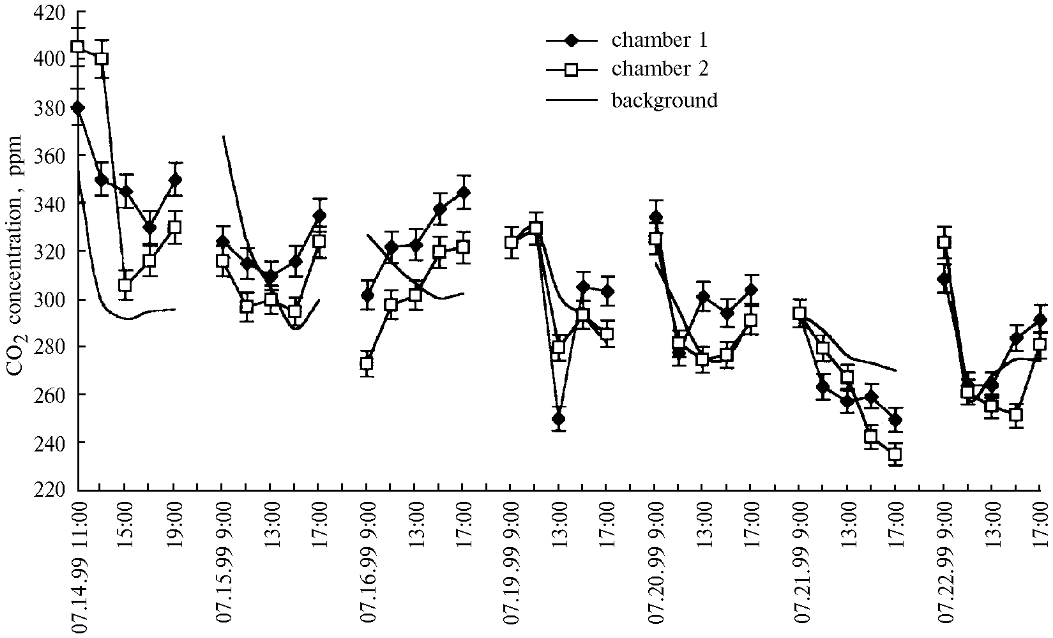


**Fig. 2.** Dynamics of $CO_2$ emission, ppm, from cedar saplings of Tomsk population (v. Kurlek) under standard conditions.

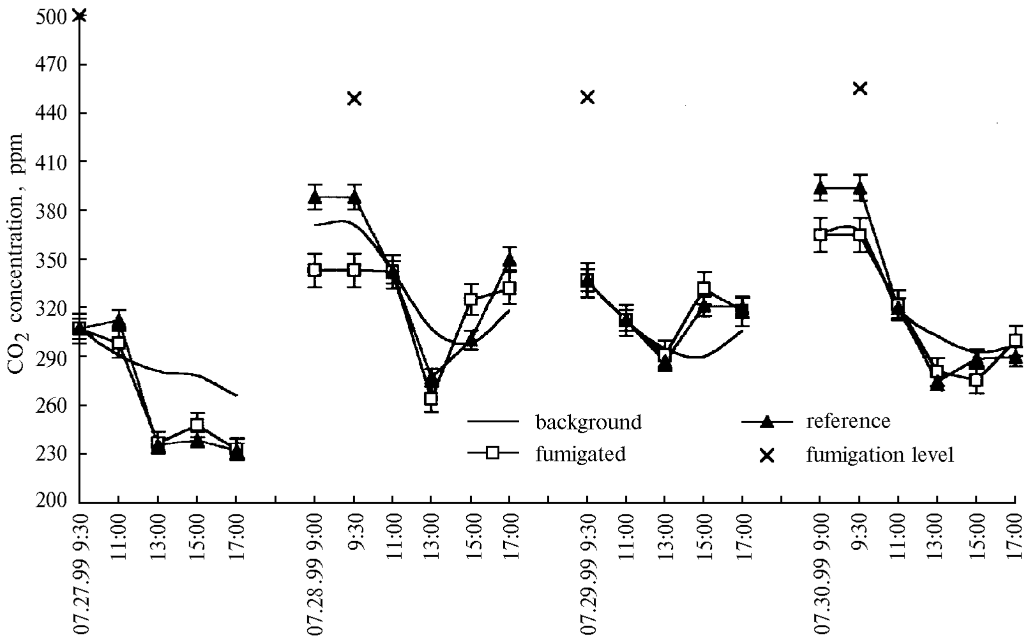


**Fig. 3.** Dynamics of $CO_2$ emission, ppm, from cedar saplings of Tomsk population (v. Kurlek) under conditions of enhanced $CO_2$ concentration.

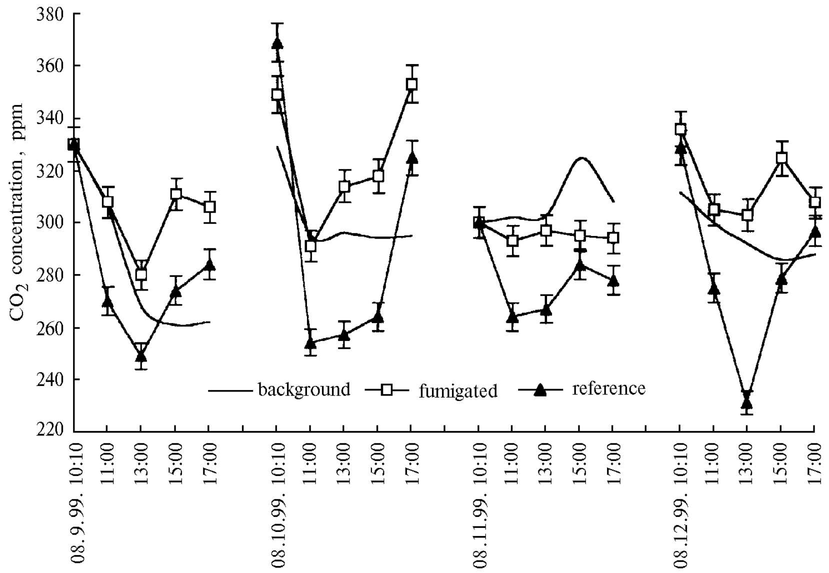


**Fig. 4.** Dynamics of $CO_2$ emission, ppm, from cedar saplings of Tomsk population (v. Kurlek) exposed to $O_3$ fumigation.

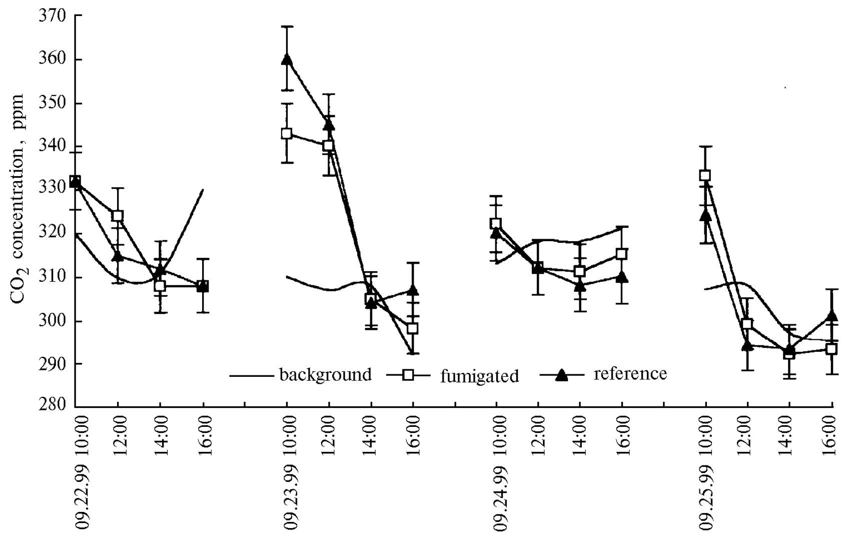


**Fig. 5.** Dynamics of $CO_2$ emission, ppm, from cedar saplings of Altai population (Alpine morphotype (A)) exposed to $O_3$ fumigation.

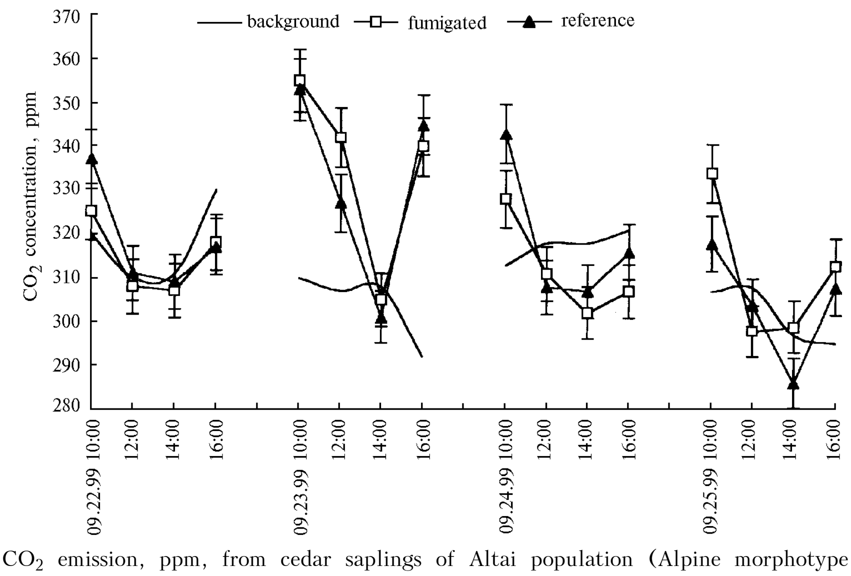


**Fig. 6.** Dynamics of $CO_2$ emission, ppm, from cedar saplings of Altai population (Alpine morphotype (B)) exposed to $O_3$ fumigation.

At the first two stages of the experiment we used one and the same saplings of Tomsk reproduction for studying kinetics of light and dark respiration. At the third stage, both Tomsk (August measurements) and Altai (September measurements) specimens were used.

The specimens were planted in four chambers: two reference and two fumigation ones.

At the second stage, the fumigation chambers were filled with $CO_2$ up to its concentration of 450–500 ppm. The specimens were kept under these conditions for 60 min. Then, after ventilation, the chambers were closed. After that, the $CO_2$ measurements were conducted inside each chamber during some time (up to 2 hours).

At the third stage, the $O_3$ fumigation was performed with the use of the ozone generator. The ozone generator was put inside a chamber and switched on for 60 s (the case of Tomsk specimens) and for 10 s (the case of Altai specimens). We estimated the $O_3$ concentration therewith to be about 30 and 5 times higher than the standard background level.

On processing the measurement results, we have calculated the following characteristics (Ref. 6):

1. Average value

$$\overline{X} = \frac{1}{n} \sum_{i=1}^{n} X_i ,$$

where $X_i$ is the result of one measurement; $n$ is the sampling volume;

2. Root-mean-square deviation

$$S = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (X_i - \overline{X})};$$

3. Sample coefficient of variation (%)

$$V = S/X \cdot 100;$$

4. Halfwidth of the confidence interval

$$\delta = t\, S/\sqrt{n},$$

where $t$ is the Student coefficient.

The plots present the sample means of the $CO_2$ concentrations and their confidence intervals.

## Discussion and conclusion

The measurements have shown that $CO_2$ emission from the cedar saplings increases at enhanced concentrations of $CO_2$ and $O_3$. Maximum intensity of light and dark respiration was observed under 60 s exposure of the saplings to $O_3$ fumigation. The difference between kinetics of the $CO_2$ emission from the test saplings and fumigated ones in this case was ~20%, which exceeded the instrumental error of determining the $CO_2$ concentration with a gas-analyzer (10%). Lowering of chloroplasts level in needles (chlorosis) was also noticeable. This can be explained as follows. Ozone breaks down the membranes and their penetrability, what changes the passive penetrability, selective inhibition of active transportation, and change of membrane potential. All this results in the disturbance of transportation of organic compounds and free ions (Ref. 7). Nevertheless, even at moderate (up to 5 times) excess of the ozone concentration over the background level, the difference in the kinetics of $CO_2$ emission from test saplings and those exposed to short-term ozone fumigation, is 7%.

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