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Research Article

Effect of Elevated CO2 and Low Temperature on Photosynthetic Potential of Indoor Plants

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Abstract

Several ornamental potted plant species have the ability to absorb pollutants and purify indoor air. The present study was aimed at to select best plant for pot transplantation in the cold areas of army installations. As diurnal variations in the temperature are high in these cold high altitude areas even in the indoor environment, plants were evaluated for their photosynthetic response under these conditions along with their oxygen releasing potential during light and dark conditions. Effect of temperature levels (10, 15, 20 and 25°C) and CO_2 levels (400, 420 and 450 ppm) were studied on net photosynthesis and transpiration rate in three indoor plants viz., spider plant (*Chlorophytum comosum*), dracaena (*Dracaena fragrans*) and snake plant (*Sansevieria trifasciata*). Decrease in photosynthetic as well as transpiration rate of these indoor plants was recorded with decrease in temperature from ambient (25°C) to 10°C. At 10°C, photosynthetic rate of Dracaena reduced to 1/7th of ambient whereas in case of snake and spider plants it was near to half only. Even though snake plant maintained the good photosynthetic rate (~5 umol/m^2/s). Small increase in CO_2 levels was not detrimental to photosynthetic efficiency of indoor plants even at temperatures lower than ambient. At 10°C, snake plant exhibited the maximum transpiration rate (0.163 mmol/m^2/s). Among the three tested plants, Snake plant exhibited better oxygen releasing potential during both light and dark period.

INTRODUCTION

In the present century, current CO_2 levels are rising much rapidly than the expected rate which has attracted the attention of global community. Many studies have predicted an increase in the enhancement of carbon gain associated with elevated CO_2 at higher temperatures [1-3] and in general predict better performance of crop in an environment having elevated CO_2 combined with higher temperature due to global warming. Although crop specific response have also been reported showing better yield at lower temperatures under influence of higher carbon dioxide concentration [4].

Photosynthesis has long been recognized as one of the most temperature-sensitive processes in plants [3]. Photosynthesis is the primary process by which carbon enters the biosphere and by which plants sense rising CO_2 [5]. Photosynthesis is particularly sensitive to thermal stress, with increased photo inhibition of PSII observed at temperature extremes [6]. Increases in atmospheric levels of CO_2 above current levels can increase photosynthesis [1] even when plants were grown at temperature extremes [2]. Elevated CO_2 has been reported to increase water-use efficiency through regulation of stomatal conductance and transpiration [7]. Since plants face environmental conditions simultaneously, interactive effect of temperature and CO_2 on photosynthesis is of paramount importance and has been review by Morison and Lawlor [2].

Indoor air quality has become a major issue in recent years. Volatile organic compounds (VOCs) in indoor air have received appreciable attention due to their adverse health effects on humans [8]. An alternative way to reduce the level of VOCs in indoor air is the use of plants. Several ornamental potted plant species have the ability to absorb VOCs [9] and purify indoor air [10,11]. Plants also offer the advantage of providing psychological and social benefits for humans [12]. The aim of the study was to select best plant for pot transplantation in the cold areas of army barracks to improve the indoor air quality because barracks are heated through keroheaters which is leading to poor indoor air quality. Since carbon dioxide levels are also generally high due to closed environment and poor air exchange rate during winter due to closed windows, effect of elevated carbon dioxide was also studied along with temperature. As diurnal variations in the temperature are high in these cold high altitude areas even in the indoor environment, plants were evaluated for their photosynthetic efficiency and oxygen releasing potential under light and dark conditions.

MATERIALS AND METHODS

Experimental materials and growing conditions

Fully grown potted-plants of three ornamental species were used in the present study. These were *Dracaena fragrans* (Dracaena), *Chlorophytum comosum* (Spider plant), *Sansevieria trifasciata* (Snake plant). All plants were exposed to four temperature regimes gradually from higher to lower (25˚C, 20˚C, 15˚C and 10˚C) and three CO_2 levels (400, 420 and 450 ppm) for 07 days in plant growth chamber LT-105 (Percival Scientific Inc., Perry, Lowa, USA) equipped with cold fluorescent light (25 K lux). Photoperiod of the growth chamber was adjusted to 12/12 h (day/night) and 70% humidity for all the treatments. Each treatment consisted of three pots of each species. Net photosynthesis was estimated by using a portable leaf chamber analyser (LCA-4, ADC Bio Scientific Ltd., UK). Data were collected from the all plants. Three samples were collected from each plant and average was worked out.

Estimation of oxygen releasing potential

To estimate the oxygen releasing potential, three selected potted plants viz., *Dracaena fragrans* (Dracaena), *Chlorophytum comosum* (Spider plant), *Sansevieria trifasciata* (Snake plant) were kept inside the leak proof air tight polythene bags of 150 gsm (Himedia) at ambient temperature. Mouth of the polythene was tide tightly with a provision of tubing to monitor the gas exchange with the help of multigas analyzer (GasAlertMicro5, BW Technologies by Honeywell, USA) as per schedule. Tubing was plugged suitably to avoid any leakage of gas. Plants were kept inside the polybags for 05 hrs with and without light to estimate the effect of light/dark conditions on oxygen releasing potential of these indoor plants. Dark conditions were created by covering the polythene bags with dark cotton cloth. Gas composition for oxygen content was checked on hourly basis. Plants selected were of uniform height and growth of one year age.

RESULTS

Effect on photosynthesis and transpiration rate

In the present experiment, results revealed that photosynthetic rates in all three plants decreased significantly as they were exposed to low temperature from ambient (Figure 1). This drop in photosynthetic rate was more pronounced for initial drop in temperature from 25 to 20˚C and ranged from 50-58%. Whereas further decrease in temperature from 20 to 10˚C resulted in to gradual decrease in photosynthetic rate except snake plant which exhibited higher photosynthetic rates compared to other two plants. Effect of higher CO_2 concentrations (>400 ppm) followed the same trend as of 400 ppm. The results also revealed that photosynthetic rate was marginally better at the highest CO_2 concentration (450 ppm) at ambient temperature but as the temperature dropped to 10˚C from ambient, photosynthetic rates more or less dropped slightly at this CO_2 level. Corresponding decrease in photosynthetic rate of these indoor plants with decrease in temperature from ambient to 10˚C exhibited the litmus paper test on the endurance of these plants. At 10˚C, photosynthetic rate of Dracaena reduced to 1/7th of ambient whereas in case of snake and spider plants it was near to half only. Even though snake plant maintained the good photosynthetic rate (~5 umol/m^2/s).

Transpiration rate also decreased significantly with the decrease in temperature from ambient to 10˚C (Figure 2) in all three plants. Average transpiration rate over all three CO_2 concentrations was comparatively higher in dracaena (0.564 mmol/m^2/s) than rest two plants at ambient temperature whereas at 10˚C, it was recorded maximum in snake plant (0.163 mmol/m^2/s). Similarly to the photosynthetic rate, transpiration rate also exhibited steady decline during initial phase of temperature reduction and then decreased gradually except in snake plant which exhibited slightly increase in transpiration at 10˚C at 400ppm CO_2 concentration. Variations in the transpiration rate due to change in CO_2 concentration were also non-significant at all temperature levels.

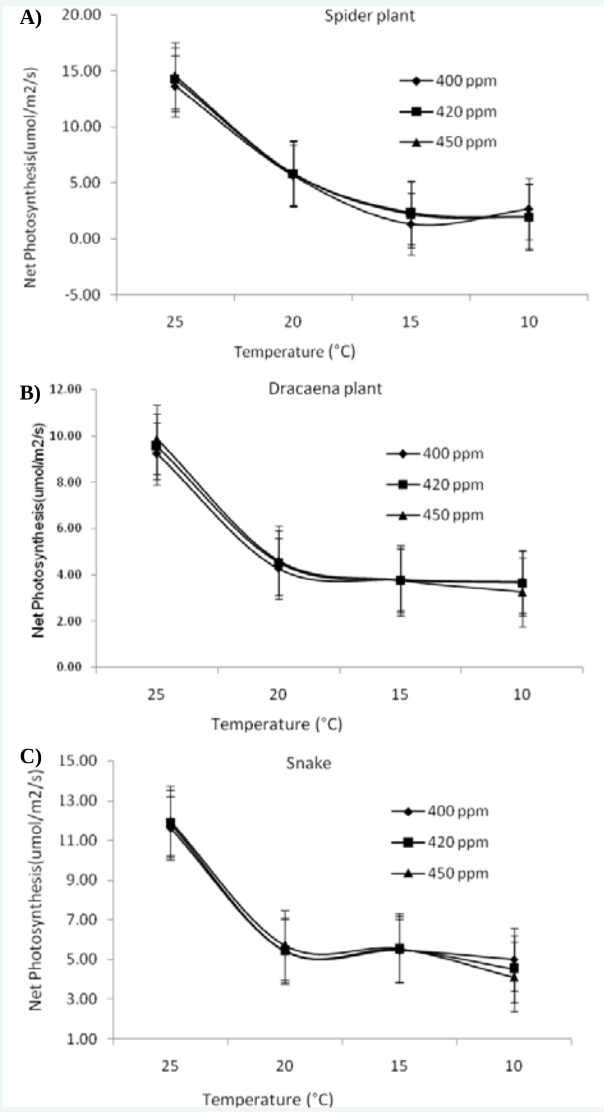

Figure 1 Effect of temperature (10, 15, 20 and 25°C) and CO2 levels (400, 420 and 450 ppm) on net photosynthesis in three indoor plants; a) spider plant (Chlorophytum comosum), b) Dracaena (Dracaena fragrans) and c) Snake plant (Sansevieria trifasciata). Bar shown means (n = 3) ± SE are statistically significant (P<0.05) according to LSD test..

Effect on oxygen releasing potential

To estimate the oxygen releasing potential of these indoor plants, they were kept in air tight transparent polythene sheet. Gaseous oxygen composition of air inside the polythene bag was checked to measure the oxygen releasing potential of the indoor plants. Results revealed that all three plants behaved differently in their behavior of oxygen releasing potential [Figure 4, 5]. During the light sufficient conditions as presented in [Figure 4] decrease in gaseous oxygen content was rapid in dracaena during first hour whereas spider plant exhibited almost static oxygen content during first two hours and then gradual decrease in inside oxygen content in spider plant showing its better oxygen releasing potential. Snake plant exhibited a slight decrease in polythene gaseous content the first two hours but then it exhibited positive trend in maintaining the oxygen content of gaseous content of polythene up to 5 hrs. During the dark conditions, oxygen releasing potential was also checked and results revealed that dracaena plant was poor in maintaining oxygen content inside the polythene during dark [Figure 5] whereas snake plant exhibited its potential in maintaining oxygen levels above 20.4% inside the polythene assembly even during dark conditions. Spider plants also exhibited its ability to cope with the dark and revealed its oxygen releasing potential even in dark conditions.

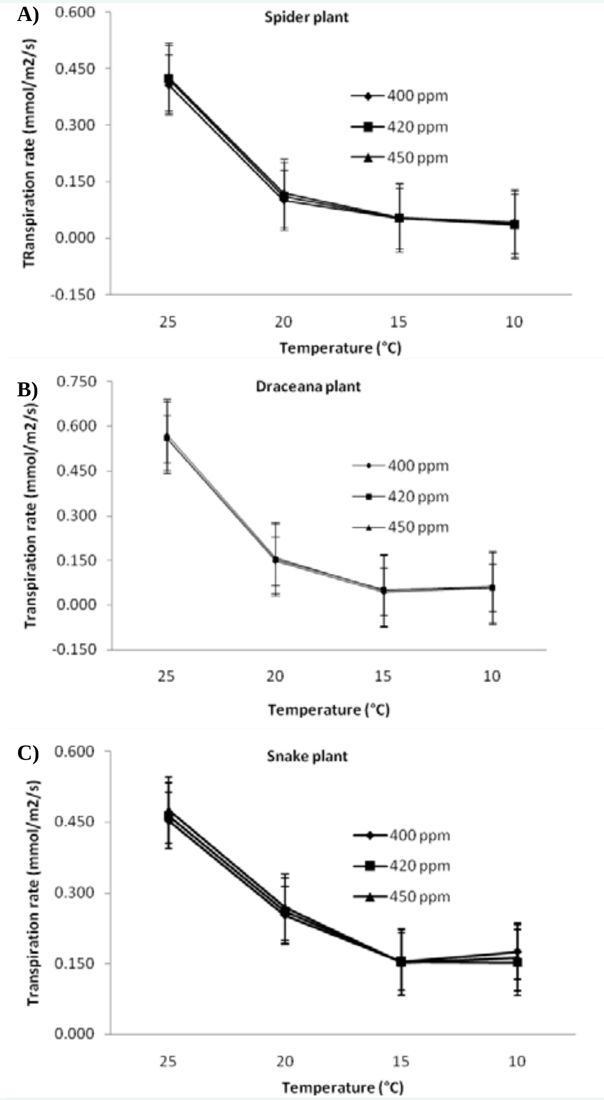

Figure 2 Effect of temperature (10, 15, 20 and 25°C) and CO_2 levels (400, 420 and 450 ppm) on transpiration rate in three indoor plants; a) spider plant (*Chlorophytum comosum*), b) Dracaena (*Dracaena fragrans*) and c) Snake plant (*Sansevieria trifasciata*). Bar shown means (n = 3) ± SE are statistically significant (P<0.05) according to LSD test.

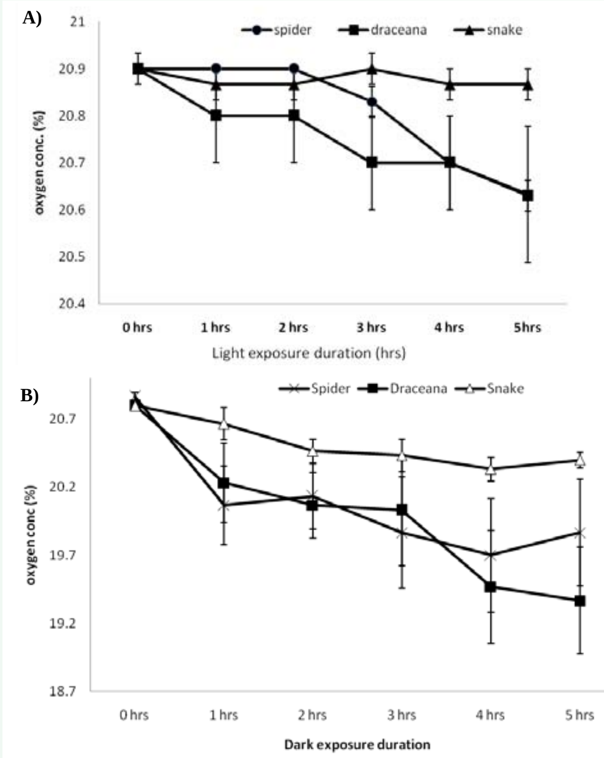

Figure 3 Concentration of Oxygen recorded inside the closed chamber to quantify the oxygen releasing potential of three indoor plants under a) light conditions, b) dark conditions. Bar shown means (n = 3) ± SE are statistically significant (P<0.05) according to LSD test.

DISCUSSION AND CONCLUSIONS

Effect on photosynthesis and transpiration rate

The present study was basically aimed to study the response of indoor plants to low temperature ambience of cold region with elevated levels of CO_2 with study on interaction effect of elevated CO_2 and low temperature on plant response to photosynthetic and transpiration rate. The results in the present study revealed that photosynthetic rates in all three plants decreased significantly as they were exposed to low temperature from ambient. This drop in photosynthetic rate was more pronounced (50-58%) for initial drop in temperature from 25 to 20°C. Reduction in photosynthetic capacity, photochemical efficiency of PSII and apparent quantum yield has been reported under cold temperature conditions in potted plants compared to optimum temperature [13]. Slightly better net photosynthesis at 10°C temperature in snake plant compared to 15°C may be attributed to plant inherent capacity to adjust temperature change. Most plants show considerable capacity to adjust their photosynthesis characteristics to their growing temperature by shifting temperature optimum required for photosynthesis and to counter the seasonal temperature shift [3] but ability of temperature acclimation of photosynthesis differ between plant species [14,15]. Snake plant has shown better cold tolerance potential in relation to photosynthetic ability [16]. The results also revealed that photosynthetic rate was marginally better at the highest CO_2 concentration (450 ppm) at ambient temperature but as the temperature dropped to 10°C from ambient, photosynthetic rates more or less dropped slightly at this CO_2 level. Although effect of CO_2 levels on net photosynthesis was somewhat similar at all temperatures, snake plant exhibited better performance. Higher photosynthesis under elevated CO_2 conditions in plants is largely due to lower rates of respiration and photorespiration [17]. When respiration is curtailed, carbon fixed during photosynthesis is available for anabolic process which may also result in increased photosynthetic capacity of plants [18, 19]. Increased levels of CO_2 result in closure of stomata in C_3 and C_4 plants which in turn increase water use efficiency and a consequence exhibit better photosynthetic efficiency [20, 21] as well as lower electron transport in C_3 and C_4 and CAM plants with decreased stomatal conductance [1]. At higher CO_2 concentration, water use efficiency increased in all temperatures due to increased canopy photosynthesis and decreased canopy respiration along with higher carbon assimilation [22] in cotton. Idso and Kimball [23] reported that doubling of CO_2 from 360 to 720 µl/l concentration doubled the net photosynthesis and decreased respiration by half in two tree species. A good correlation has been reported between the elevated CO_2 and increased level of chloroplast solutes [24,25] which may also have contributed to the phenomenon of higher photosynthesis.

Stomata opening are the common path for gas exchange and therefore transpiration is well correlated with photosynthesis. Transpiration regulates the water balance in plants and is influenced indirectly by environmental factors which affect stomatal opening [26]. In present study, transpiration rate also decreased significantly with the decrease in temperature from ambient to 10°C in all three plants. Average transpiration rate over all three CO_2 concentrations was comparatively higher in dracaena at ambient temperature whereas at low temperature (10°C), it was recorded maximum in snake plant, which in turn can be related to the better photosynthetic ability of snake plant at lower temperature. Transpiration was found to be temperature dependent and at sub optimal temperature for metabolic activity of *Vigna sinensis* transpiration was also low compared to optimal temperature [27]. Transpiration rates of plants have been found to decrease at higher CO_2 concentration despite increased leaf area index [28] which indicates greater canopy resistance to water vapour flux in high CO_2 environment but biomass increase in temperature dependent till achievement of maximum photosynthetic capacity [22].

Effect on oxygen releasing potential

Gaseous oxygen composition of air inside the polythene bag decreased with time in dracaena and spider plant but it remained somewhat static in snake plant in light as well dark conditions which indicated the good oxygen releasing potential of snake plant compared to other two. Srivatsan [29] also noted that common house plants have a very unique pattern of O_2 production during the course of a day. All tested plants including snake plant attained peak of O_2 production during early morning hours much before sunlight reaches its maximum intensity. He also found that snake plant maintains good O_2 concentration even at the lower light intensities. Difference in diurnal gas exchange (O_2 and CO_2) has been observed between C_3 and C_4 plants species when photosynthetic photon flux density and water potential were moderate with better performance of C_4 [30]. Snake plant exhibited its potential in maintaining oxygen levels above 20.4% inside the polythene assembly in the present study. Snake plant, a CAM family plant, has exhibited better photosynthetic potential at low temperature compared to other indoor plants as well as tolerance to low temperature in our previous study [16]. Temperature dependent CO_2 fixation rate at day and night differ in CAM species plant Kalanchoe [3] although principal limiting step for CO_2 fixation at night was not stomatal conductance but malate formation by enzyme. Since photosynthesis and respiratory process are related, O_2 evolution depend on the balance of these two and positive relationship between these two indicates that higher amount of O_2 is released compared to its consumption at temperatures suitable for crop growth compared to lower or higher temperatures [31].

In conclusion, it can be said that small increase in CO_2 levels are not detrimental to photosynthetic efficiency of indoor plants even at temperatures lower than ambient but photosynthetic and transpiration rates of indoor plants decreases sharply at lower temperature. Although snake plant maintained almost double photosynthetic potential than dracaena including better oxygen releasing potential in light and dark conditions therefore could be a better candidate indoor plant for pot transplantation in cold locations to improve the indoor air quality as also have seen in our previous study [32].

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