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Effect of elevated CO_2 concentration on groundnut (*Arachis hypogaea*) (C_3) and pearl millet (*Pennisetum glaucum*) (C_4) crop plants and some implications on growth and photosynthetic activity

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ABSTRACT

Groundnut (*Arachis hypogaea* L.) (C_3) and pearl millet (*Pennisetum glaucum* L.R. Br. emend Stuntz) (C_4) crop plant species were grown in open top chambers (OTC) to find out performance at ambient CO_2 (380 ppm) and elevated CO_2(550±700 ppm) atmospheric CO_2 conditions.Compared with an elevated CO_2 atmosphere at ambient leaf water content increased in C_4 plants. But was the same or less for the C_3 plants. Groundnut (C_3) leaf mass per unit area was less for C_4 plants and greater for a C_3 species. At elevated study photosynthesis gas exchange (pn) values were the same for C_4 plants and were greater for C_3 plants. While stomatal conductances were reduced in all comparison compared to plants at ambient and elevated CO_2 levels. Short term photosynthetic value taken immediately after swiching treatments were not significantly different from long term values for the same treatments. In all tested species gas conduct values were lowered when measured directly after being transferred to the other treatments. Continual gas exchange measurements for up to 90 minutes after a transfer from long term elevated CO_2 enrichment to ambient and back indicated that the short term P*n* value for C_4 species. The chlorophyll a and b accumulation were also higher in the leaves of both C_3 and C_4 crop plants to increased elevated CO_2.As pointed out above in the switching experiments had not equilibrated to change in the treatment. Whereas C_4 plants had photosynthetic activity at elevated CO_2 continued at a rapid pace throughout the day for the C_3 plants. That for the same as at ambient levels. The decrease in P*n* at elevated CO_2 suggested non-stomatal control in the C_3 plants.

Key words: C_3 and C_4 crops plants, Chlorophyll, CO_2 enrichment, Photosynthesis, Stomatal conductance

The increasing level of CO_2 increases growth and photosynthesis in C_3 and C_4 plants, but in C_4 plants net leaf photosynthetic carbon dioxide exchange rate is nearly saturated by elevated CO_2 at current ambient CO_2 concentration. It has been assumed that increasing atmospheric elevated CO_2 concentration and associated global warming are expected to alter growth rates in pasture crops. The response of C_3 and C_4 crops to elevated CO_2 were reviewed by Wand *et al.* (1999) who reported that growth enhanced both in C_3 and C_4 plant from elevated CO_2 but greater responses were with C_3 crop plants. While photosynthesis in C_4 plants can respond directly to elevated CO_2 above the present atmospheric concentration (Le Cain and Morgan 1998), the response is considerably more compared to that of C_3 plants.

Recently Chen *et al.* reported changes in photosynthesis and gas exchange in pearl millet (*Pennisetum glaucum* L.R. Br. emend Stuntz) leaves acclimated to elevated CO_2 concentrations. The leaf photosynthesis performance at elevated CO_2 concentration is still limited and it is still useful to examine the photosynthetic behavior of both C_3 and C_4 crop plants at ambient and enriched elevated CO_2 conditions to understand the potential impact of increasing atmospheric CO_2 concentration. We also tried to examine mechanisms controlling photosynthesis acclimation to CO_2 enrichment for these species in order to test effects of long term CO_2 exposure on stomatal response.

MATERIALS AND METHODS

Groundnut (*Arachis hypogaea* L.) (C_3) and pearl millet (C_4) crops were grown in open top chambers (OTC), elevated CO_2 enrichment treatments were applied during the day time, using open top chambers as reported to at 30 days. The seeds were sown in pots. Three pots in one chamber which maintained 550 ppm and another three pots in other chamber it maintained CO_2 partial pressure of 550 ppm and 380 ppm. Each chamber was automatically monitored and controlled

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Table 1 Effect of elevated CO_2 on photosynthetic pigments (mg/g fresh weight) of C_3 and C_4 crops plants

Crops	Treatments	Chlorophyll a			Chlorophyll b			Chlorophyll a+b		
		Mean	SD	CV %	Mean	SD	CV %	Mean	SD	CV %
Groundnut	Elevated CO_2	4.95	0.65	0.46	1.93	0.12	0.09	6.88	0.770	0.550
	Ambient CO_2	3.97	0.34	0.24	1.36	0.27	0.19	5.33	0.610	0.430
Pearl millet	Elevated CO_2	5.31	0.37	0.26	1.78	0.24	0.17	7.09	0.610	0.430
	Ambient CO_2	4.34	0.33	0.24	1.87	0.1	0.07	6.21	0.430	0.310
Inference		HS			HS			HS		
CD (0.5%)		2.04			0.34			3.34		

SD, Standard deviation of mean; CV%, coefficient of variation in %; CD (5%), critical difference at 5% level risk; HS, highly significant

by CO_2 injection equipment and infrared gas analyzers. It mixed control air from air compressor before entering into the chamber. Throughout the experimental period continuous measurement of relative humidity and temperature of all the open top chambers were possible with the sensors fitted inside the chambers by C_3 crops while the lowest response by C_4 crops.

Leaf gas exchange rates and associated parameters were measured on new fully expanded leaves using Licor portable photosynthesis systems.Diurnel leaf gas exchange in measurements were made at both ambient and elevated CO_2 levels in C_3 and C_4 crop plants to examine photosynthetic performance.

The response of photosynthetic and gas exchanges in elevated CO_2 concentrations were studied to examine any differences in patterns of response to sudden changes in CO_2, plants exposed to a 550-700 ppm long term CO_2 environment levels were suddenly exposed to 350 ppm CO_2 in air, with frequent measurement of photosynthetic activity until a steady state gas exchange was achieved at which time the plants were exposed again to the 700 ppm treatment. Such changes in atmospheric CO_2 were imposed during morning hours under clear skies for C_3 and C_4 plant crop plants.

The rate of photosynthesis with leaf area, chlorophyll a,b and total chlorophyll content were determined by extraction by acetone method, following the techniques of Arnon *et al.* (1984).Leaf water content and specific leaf weight were measured after 30 days of CO_2 enrichment in C_3 and C_4 plants. Leaf at morphological age were collected leaf disc were made using a cork borer. Immediately after fresh weights were measured.C_3 and C_4 crop leaf disc were oven dried for 24 hours at 70°C to determine dry weight.

Table 2 Effect of elevated CO_2 levels on leaf water status

Plants	Leaf water content	Leaf dry mass per unit area
Groundnut (A)	69.6	0.033
Groundnut (E)	72.46	0.039
Pearl millet (A)	61.86	0.037
Pearl millet (E)	64.18	0.034

* A and E represent ambient (380 ppm) and elevated CO_2 levels. Each parameter indicates a significant difference at 0.05% level.

RESULTS AND DISCUSSION

The groundnut (C_3) and pearl millet (C_4) crop plants exhibited large differences in total biomass when grown at elevated CO_2 levels for 30 days. The C_4 plants had five times the total biomass of the C_3 plants when grown at the low temperature (22°C light/16°C dark) and almost 14 times the total mass of C_3 plants when grown at high temperature (30°C/24°C) for a total 30 days and therefore difference in final biomass mainly reflect differences in relative growth rate. The C_3 and C_4 plants exhibited relative differences in their response to temperature for total biomass and leaf area.

Leaf water status

A number of reports have shown that plant response to elevated CO_2 varies among different plants. In this study long term CO_2 exposure resulted in increase in leaf water content in groundnut (C_3) plant while it decreased in pearl millet (C_4) plants compared to ambient grown plants. The leaf dry mass per unit area was higher in pearl millet and lower in groundnut compared to ambient CO_2 grown plants. As reported earlier non-structural carbohydrates increased with CO_2 enrichment in pearl millet contributing to the increase in leaf mass per unit area and the decrease in relative water content. Leaf area expansion might have been stimulated in plants growing at the higher CO_2 level. The increase in leaf water content might have been due to reduced gas and leaf transpiration rate (E). Leaf mass per unit area responded to elevated CO_2 enrichment differently the C_4 plants tested. Anatomic and metabolic differences these plants may contribute to leaf water content and leaf mass per unit area response to elevated CO_2 in different ways and these may be key factors causing diversity in the way plants acclimate to elevated CO_2 concentrations.

Photosynthesis measurements

The reports have shown that long term elevated CO_2 enrichment results in photosynthetic and stomatal acclimation.

Table 3 Photosynthetic gas exchange of C_3 and C_4 crop leaves at ambient and elevated CO_2 concentrations

Plants	Growing measuring condition	P*n* [µmol (CO_2)/ m^2/s)	gs [mol (H_2O)/ M^2/S]	E mmol (H_2O)/ M^2/S)
Groundnut	A / A	31.92	1.73	0.014
	E /E	47.69	1.47	0.014
	E / A	35.19	1.27	0.012
	A / E	48.7	0.9	0.013
Pearl millet	A / A	30.89	0.54	0.012
	E /E	32.85	0.37	0.009
	E / A	31.94	0.32	0.008
	A / E	29.92	0.011	0.006

* A and E represent ambient (380 ppm) and elevated CO_2 levels. Each parameter indicates a significant difference 0.05% level.

Although several hypotheses have been proposed for mechanisms involved in different species, shows photosynthetic gas exchange of C_3 and C_4 plant leaves grown at ambient and elevated CO_2 concentration in open top chambers (OTC) for 30 days.

Photosynthetic activity of both treatments were measured to compare short term effects. Photosynthetic activity of C_4 was not affected by CO_2 concentration. Although differed greatly especially for ambient grown leaves suddenly exposed to elevated CO_2 concentrations. Where it was only 0.9 of the value measured at ambient CO_2 levels. C_4 plants had lower photosynthetic activity in leaves measured at the new concentration for both C_3 species tested. Photosynthetic activity did not respond statistically to a change in measured CO_2 concentration gas in C_3 leaves was much less immediately after exposure to elevated CO_2 concentration. It has been reported that gas in C_3 plants become less sensitive to elevated CO_2 after long term CO_2 enrichments. The accumulation of chlorophyll a and b in these crop species increased under elevated CO_2 as compared to the open top chambers. The higher accumulation of chlorophyll a and b under elevated CO_2 in both C_3 and C_4 crop species probably indicates the adaptation of these crops at higher level of atmospheric CO_2. Total chlorophyll was estimated in C_3 crop plants were higher by 0.550(CV%) under elevated CO_2 than lower by 0.430 (CV%) in C_4 crop plants. The increase in total accumulation predicts that there could be higher photosynthesis under elevated CO_2 lead to higher CO_2 assimilation resulting in increased growth and biomass production. It is similar to the Thomas and Sean (2005) who reported increase in leaf chlorophyll content under elevated CO_2.

Gas exchange behaviors

Gas exchange due to leaf photosynthetic responses to elevated CO_2 have been reported. In C_4 plant gas exchange dropped quickly after the change from high to low CO_2 and did not recover for 20 minutes. In C_3 species photosynthetic activity changed rapidly after swiching plants from 700-550 ppm or from 350 ppm back to 700 ppm with photosynthesis increasing after exposure to 350 ppm as gas increased over a 25-30 minutes period.

CONCLUSION

C_3 plant behaves generally like C_4 plant to ambient and elevated CO_2 treatments. While photosynthesis in C_4 plants is the same at 350 ppm and 700 ppm to sudden changes in photosynthesis and gas that sometimes revert slowly to the original level.gs is often slow to reach a new equilibrium value after a change in Ca, and sometimes may limit P*n* while doing so. Such results are valuable for analysis of plants grown under more carefully controlled condition.

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