0BRIEF COMMUNICATION

Growth, biomass production, and assimilatory characters in *Cenchrus ciliaris* L. under elevated CO_2 condition

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Abstract

The effect of elevated carbon dioxide (600±50 cm^3 m^{-3}; C_{600}) on growth performance, biomass production, and photosynthesis of *Cenchrus ciliaris* L. cv. 3108 was studied. This crop responded significantly by plant height, leaf length and width, and biomass production under C_{600}. Leaf area index increased triple fold in the crops grown in the open top chamber with C_{600}. The biomass production in term of fresh and dry biomass accumulation increased by 134.35 (fresh) and 193.34 (dry) % over the control (C_{360}) condition where the crops were grown for 120 d. The rate of photosynthesis and stomatal conductance increased by 24.51 and 46.33 %, respectively, in C_{600} over C_{360} plants. In comparison with C_{360}, the rate of transpiration decreased by 6.8 % under C_{600}. Long-term exposure (120 d) to C_{600} enhanced photosynthetic water use efficiency by 34 %. Also the contents of chlorophylls *a* and *b* significantly increased in C_{600}. Thus *C. ciliaris* grown in C_{600} throughout the crop season may produce more fodder in terms of green biomass.

Additional key words: area leaf mass; leaf area index; net photosynthetic rate; specific leaf area; stomatal conductance; tiller; transpiration.

Since the mid 1800's, the human activities have contributed to an increase in atmospheric CO_2 concentration from roughly 250 to present day 350 cm^3 m^{-3} projecting a further doubling of the global CO_2 within the next century (Watson *et al.* 1990). Plant species are specific in physiological response to high CO_2 concentration (Zhang and Nobel 1996). The increased net photosynthetic rate (P_N) affects the growth of plants as indicated by increased growth and yield in many crop species grown under elevated CO_2 (Sasek and Strain 1991, Das *et al*. 2000). Pal *et al*. (2004) also reported the increase in plant growth and biomass production under elevated CO_2 concentration (EC).

Cenchrus ciliaris is the most important fodder grass species, grown in arid and semi-arid tropics (cf. Baig *et al*. 2005). This is perennial multi-cut, highly palatable, and nutritious grass species that can be utilized under cut and carry as well as under grazing system of production. The objective of the present study was to determine long term effect of high CO_2 concentration (600±50 cm^3 m^{-3}; C_{600}) on growth, biomass production, and photosynthesis of *C. ciliaris* L. cv. 3108.

30-d-old seedlings were transplanted inside the open top chambers (OTCs) and in open field as control at 50 cm row to row and plant to plant spacing. Nitrogen and phosphorus were applied as basal at the rate of 60 kg N and 40 kg P_2O_5 per hectar before transplanting seedlings at the onset of monsoon, *i.e*. in July. The plants were maintained using recommended agronomical practices. Pure CO_2 gas was used for enrichment of CO_2 inside the OTCs. The flow of CO_2 was adjusted with the help of a flow meter to get the target concentration of CO_2 inside the OTCs. The period of enrichment was from 08:00 to 17:00 h every day from transplantation of seedlings. Irrigation was given as and when required.

The morphological characters [plant height, tiller production, leaf area, fresh (FM) and dry (DM) biomass production] were recorded at stage of 50 % flowering. Leaf area of fresh leaves was measured before weighing by using leaf area meter (*LICOR-3000*, USA). The fresh

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biomass (FM) of whole plant was taken just after harvesting. For dry matter (DM) yield, plant samples were dried in an electric oven at 80 ºC for 48 h. The leaf area per unit land area (leaf area index = LAI) was calculated by dividing the leaf area per sample by the land area occupied by the sample. SLA (leaf area per leaf DM) was measured by harvesting randomly 10 fully expanded leaves from each replication. Area leaf mass (ALM) or leaf thickness was expressed as DM of leaf blade per unit leaf area.

P_N, transpiration rate (E), stomatal conductance (g_s), and intercellular CO_2 concentration (C_i) were recorded in the second fully expanded leaf from the top of the plant by using the portable photosynthesis system (*LI-6200*, *LICOR*, USA). The micro-environmental parameters [air temperature, photosynthetically active radiation (PAR), relative humidity (RH), and leaf temperature (LT)] were also recorded by the attached sensors of the photosynthesis system. All the measurements were made between 11:00 and 12:00 h on a clear sky day. The ratios P_N/E (photosynthetic water use efficiency, WUE) and P_N/C_i (carboxylation efficiency) were also calculated. Canopy photosynthesis was calculated by multiplying P_N with LAI. Chlorophyll (Chl) *a* and *b* contents were determined by using a non-maceration technique of Hiscox and Israelstam (1979) in which 25 mg leaf slices were kept overnight in 5 cm^3 dimethyl sulphoxide, the absorbances were recorded at 645 and 663 nm, and the Chl content was calculated using the equations of Arnon (1949).

Long term exposure to C_{600} in open top chambers increased the growth of *C. ciliaris*: plant height increased by 43.72 %, also the tiller production per square meter increased significantly and LAI increased 3.34-fold. The ALM decreased under C_{600} whereas SLA increased. The increase in SLA at C_{600} indicated greater expansion of the leaf area per unit of DM accumulation. *C. ciliaris* also showed significant increase in biomass production in terms of both FM and DM (Table 1). The FM increased by 134.35 % in the crop grown under C_{600} over C_{360}. Similarly, the DM accumulation was three fold in the C_{600} crop over the C_{360} one. Booker *et al*. (2004) reported that biomass, leaf area, WUE, and yield were increased significantly by EC.

The leaf temperature increased by 0.96 ºC in the C_{600} leaves over the C_{360} ones. P_N of the C_{600} plants was higher by 24.80 % over that of the C_{360} ones. The canopy photosynthesis which is calculated by multiplying P_N with LAI increased significantly under C_{600}. Also C_i was significantly higher under C_{600} that under C_{360}. The g_s increased at C_{600} which is in contrast to the data of Rogers *et al*. (2004) who reported decreased g_s at EC in soybean. In our experiment E was decreased slightly at C_{600}. The P_N/C_i ratio which indicates the carboxylation efficiency (Farquhar and Sharkey 1982) also decreased at C_{600} which may be due to higher C_i. The P_N/E ratio which indicates the photosynthetic WUE increased by 33.93 % at C_{600} over C_{360} indicating an improvement in WUE under EC. Similar to our findings, Baker and Allen (2005) indicated that EC significantly increased canopy P_N and WUE while reducing evapo-transpiration. The accumulation of Chl *a* and *b* was also increased by 168.25 and 100.00 %, respectively, in the crops grown at C_{600} over C_{360}. In agreement with this, the Chl *a/b* ratio also significantly increased. Moreover, Wang *et al*. (2004) reported that EC increased chloroplast number per unit cell area.

Table 1. Effect of elevated CO_2 (C_{600}) and ambient CO_2 (C_{360}) on growth, leaf area index (LAI), area leaf mass (ALM), specific leaf area (SLA), biomass production (FM – fresh mass, DM – dry mass), net photosynthetic rate (P_N), intercellular CO_2 concentration (C_i), stomatal conductance (g_s), transpiration rate (E), and chlorophyll (Chl) accumulation of *C. ciliaris*.

Parameter	C_{360}	C_{600}	CD at 5 %
Plant height [cm]	107.50	154.50	18.65
Tiller per m^2	116.25	154.50	9.35
Leaf length [cm]	36.47	44.78	6.29
Leaf width [cm]	0.63	0.95	0.12
LAI	2.115	7.054	0.828
ALM [g m^{-2}]	53.0	40.2	NS
SLA [m^2 kg^{-1}]	1907.9	2586.2	218.9
FM [g m^{-2}]	1754.70	4112.20	219.02
DM [g m^{-2}]	223.90	656.80	53.53
P_N [µmol m^{-2} s^{-1}]	34.02	42.46	3.07
C_i [cm^3 m^{-3}]	250.26	457.06	7.66
g_s [cm s^{-1}]	1.226	1.794	0.214
E [mmol m^{-2} s^{-1}]	10.214	9.519	NS
P_N × LAI	71.95	299.51	13.47
P_N/C_i	0.136	0.093	0.026
P_N/E	3.33	4.46	0.25
Chl (*a*+*b*)	0.77	1.97	0.11
Chl *a/b*	4.50	6.03	NS

Long term exposure of *C. ciliaris* crop to C_{600} in open top chambers resulted in a significant enhancement in the growth and biomass production. This increase in growth was due to the production of more photosynthates and their partitioning to different plant parts which ultimately increased the total biomass production. Sharma and Sengupta (1990) also observed that the extra carbon fixed by the plants due to CO_2 enrichment was translocated to the growing axis. Increased fodder production of white clover and increased yield in rice grown under EC has been reported by Saebo and Mortensen (1995) and Uprety *et al*. (2002), respectively. The increase in P_N and LAI under EC might have resulted in greater accumulation of assimilates which resulted in the production of more biomass.

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