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Response of Bamboo seedlings to the elevated carbon dioxide concentration

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Abstract: *The response of bamboo seedlings belonging to four important species* viz. Bambusa tulda, B. nutans, B. balcooa *and* Dendrocalamus hamiltonii *to elevated carbon dioxide concentration were evaluated during 2012-13 inside open top chambers (OTC). The result revealed that the seedling height, seedling girth, number of shoot per seedling, phyllochron, leaf number per seedling, area of individual leaf, fresh and dry weight of a leaf, specific leaf weight (SLW), relative leaf water content (RLWC), leaf area per seedling, fresh and dry weight of leaf per seedling, fresh and dry weight of branch per seedling, fresh and dry weight of main stem per seedling, weight of above ground biomass per seedling, rhizome weight per seedling and total seedling weight were significantly increased with the increase in atmospheric* CO_2 *concentration from 380 ppm to 750 ppm in all four bamboo species studied. Again among the bamboo species* D. hamiltonii *maintained significant superiority over other species while* B. tulda *recorded the poorest performance. Moreover, the interaction effect of* CO_2 *concentration and bamboo species were also significant.*

CO_2 is an important long-lived trace gas of atmosphere and currently its concentration is about 400 ppm in the atmosphere on a molar basis. The recent phenomenon of global warming has been attributed primarily to increasing atmospheric CO_2 concentration in earth's atmosphere. The global concentration of CO_2 in the atmosphere has increased since the Industrial Revolution, from 280 ppm to 395 ppm in 2013 (Anonymous, 2013) and according to IPCC prediction it may reach 550-750 ppm in 2050 (Anonymous, 2007). Therefore, screening out a crop plant that performs better in such CO_2 enrichment and can traps more CO_2 from the atmosphere may provide useful information for an effective climate mitigation strategy. Bamboos as C_3 plants should have the potentiality to increase net primary productivity in response to CO_2 enriched atmosphere (Korner *et al*., 2007). Therefore, the present study was carried out to characterize the response of bamboo seedlings at elevated level to atmospheric carbon dioxide concentration.

MATERIALS AND METHODS

The experiment was carried out during 2012-13 in Open Top Chamber (OTC) in the Department of Crop Physiology, Assam Agricultural University, Jorhat, Assam. The design of experiment was FCRD having two factors *viz.* concentrations and bamboo species with three replications. Four concentrations of CO_2 were selected *viz.* C_1: Ambient CO_2 concentration, C_2: 380 ppm CO_2 concentration, C_3: 550 ppm CO_2 concentration and C_4: 750 ppm CO_2 concentration. The average atmospheric CO_2 concentration at the experimental site was estimated as 380 ppm, and according to IPCC prediction the global atmospheric CO_2 concentration may reach as high as 550 to 750 ppm by 2050. Therefore, the CO_2 concentrations were fixed at 380, 550 and 750 ppm during the study. Again to asses the effect of OTC if any the concentration of CO_2 at C_2 was fixed at 380 ppm which was same with ambient CO_2 concentration. Four bamboo species with socio-economic importance were selected *viz.* S_1: *Bambusa tulda,* S_2: *B. nutans,* S_3: *Bambusa balcooa* and S_4: *Dendrocalamus hamiltonii.* One year seedlings of uniform size were collected from the Rain Forest Research Institute, Jorhat, Assam and planted in pots, all total 48 earthen pots of equal size were prepared with equal proportion of garden soil, sand and dry cow dung. Seedlings were planted after removing

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extra shoots keeping only one shoot per seedling. On 1st August, 2012 seedlings were grouped into four sets containing three randomly selected seedlings of each species to get twelve seedlings per set. One such set of seedlings was kept in an open place and considered as C_1 (ambient) seedlings. Likewise other three sets were kept inside three different OTCs and were considered as C_2, C_3 and C_4 seedlings and accordingly pots were labelled with zinc plates. The concentrations of CO_2 inside the OTCs were maintained accordingly through out the period of study (six months) with computerized control unit of OTC. The observations were recorded properly from each seedling and data were subjected to statistical analysis. The morpho-physiological parameters of bamboo seedlings were measured inside the OTCs at two stages, *viz.* at the onset of treatment (initial) and after six month of treatment exposure (final). The girth of bamboo seedlings was measured at the second internode from the base of seedlings. While, the Phyllochron was measured by counting the number of days taken for production of subsequent leaf from each bamboo seedling and average values of three seedlings were recorded for each treatment. The number of leaf per seedling was measured by counting all active leaf of each seedling and the average values were recorded. All green leaves were considered as active leaf. Ten representative leaves from each bamboo seedling were taken and their leaf area were measured with leaf area meter (ModelCI-203) and the average value was considered as the area of a single leaf. The leaf area per seedling was determined by multiplying the average leaf area of a single leaf with the number of leaf per seedling. On the other hand, the biomass related parameters of bamboo seedlings were measured after six month of treatment exposure. Ten representative third leaves from the tip of main stem or tip of branches from each bamboo seedling were taken, their weights were measured with electronic balance and the average value was considered as the fresh weight of a leaf. These leaves were then oven dried at 70°C for 72 hours (till the constant weight) and their weights were measured and the average value was considered as the dry weight of a leaf. The specific leaf weight was computed by dividing the dry weight of leaf with the volume of leaf. Relative leaf water content (RLWC) was computed following the standard equation provided by Weatherly and Barrs (1962).

RESULTS AND DISCUSSION

The result revealed that the bamboo seedlings of the same species were similar at initial stage in respect of seedling height, seedling girth and shoot number per seedling but they were significantly different in different species (Table 1). The S_1 (*Bambusa tulda*) maintained the tallest seedling followed by S_4 *(Dendrocalamus hamiltonii)* and S_2 (*Bambusa nutans*) and the shortest seedlings were found in S_3 (*Bambusa balcooa*). The seedling girth was highest in S_4 followed by S_3 and S_2 and it was lowest in S_1. All seedlings maintained single shoot per seedling at initial stage. But at the final stage, the seedling height, seedling girth and number of shoot per seedling were significantly increased with the increase in CO_2 concentration up to 750 ppm in all four bamboo species studied and the interaction effect were also significant. Among the bamboo species S_4 maintained significant superiority over other three species. The tallest seedling was produced at 750 ppm (194.24 cm) followed by 550 ppm (186.88 cm) and control (163.59 cm) while the shortest seedlings were found at 380 ppm CO_2 concentration (153.86 cm). Among the species S_4 produced the tallest seedlings followed by S_1, S_2 and S_3. This growth upliftment of bamboo seedlings in elevated CO_2 concentration might be due to increase in net primary productivity in response to CO_2 enrichment. Grombone-Guaratini *et al.*, (2013); Korner *et al*., (2007) and Zhihong *et al.,* (2011) reported that the leaf area, net photosynthetic rate and tillering of bamboo increased with increased atmospheric CO_2 concentration.

With the increase in CO_2 concentration, the phyllochron of bamboo seedling gradually but significantly decreased but the leaf number per seedling and the area of leaf significantly increased in all four bamboo species. The interaction effects of CO_2 concentration and species were also significant in respect of phyllochron, leaf number per seedling and leaf area. The lowest mean phyllochron was recorded at 750 ppm (6.49 days) which was at par with 550 ppm (6.53 days) but both were significantly lower than at 380 ppm (9.79 days) and control (9.52 days). Among the species, S_4 maintained the lowest phyllochron (7.23 days) followed by S_2 (8.85 days) and the highest phyllochron was found in S_3 (9.83 days) which was at par with S_1 (9.81 days) at 750 ppm CO_2 concentration but S_1 and S_3 differed significantly from S_4. The leaf number per seedling increased significantly with the increase in concentration of CO_2 and the lowest mean leaf number per seedling (60.08) was found at 380 ppm followed by 550 ppm (78.59) while the highest (84.14) mean leaf number per seedling was found at 750 ppm CO_2 concentration. Among the species, S_1 maintained the highest 90.33

Table 1
Seedling height, seedling girth, shoot number per seedling, phyllochron, leaf number per seedling and area of individual leaf of different bamboo seedlings at various CO_2 concentrations

CO_2 concentration	*Bamboo species*	*Seedling height (cm)*		*Seedling girth (cm)*		*Shoot number per seedling*		*Phyllochron (days)*	*Leaf number per Seedling*	*Area per leaf (cm^2)*
		Initial	*Final*	*Initial*	*Final*	*Initial*	*Final*			
Control	S_1	130.67	174.53	3.02	5.39	1.00	2.67	10.33	76.33	42.72
	S_2	95.37	158.23	3.22	5.53	1.00	2.33	9.56	65.67	46.26
	S_3	56.42	106.85	4.51	6.25	1.00	2.00	10.65	55.67	56.18
	S_4	126.87	214.76	5.27	6.74	1.00	2.33	7.53	68.67	121.98
	Mean	**102.33**	**163.59**	**4.01**	**5.98**	**1.00**	**2.33**	**9.52**	**66.59**	**66.79**
380 ppm	S_1	131.24	165.98	3.01	5.27	1.00	2.67	10.58	71.67	40.28
	S_2	94.73	150.16	3.20	5.50	1.00	2.00	9.93	59.33	43.56
	S_3	56.32	102.92	4.50	6.20	1.00	2.00	10.78	51.33	52.74
	S_4	127.87	196.37	5.25	6.38	1.00	2.33	7.87	58.00	120.07
	Mean	**102.54**	**153.86**	**3.99**	**5.84**	**1.00**	**2.25**	**9.79**	**60.08**	**64.16**
550 ppm	S_1	129.73	200.89	3.04	6.11	1.00	3.00	9.85	87.67	45.69
	S_2	96.86	187.29	3.29	6.38	1.00	2.67	8.92	79.67	49.53
	S_3	54.73	127.66	4.60	7.75	1.00	2.33	9. 96	67.33	61.27
	S_4	126.96	231.68	5.14	8.89	1.00	2.67	7.36	79.67	131.86
	Mean	**102.07**	**186.88**	**4.02**	**7.28**	**1.00**	**2.67**	**6.53**	**78.59**	**72.09**
750 ppm	S_1	130.52	205.43	3.05	6.37	1.00	3.33	9.81	90.33	46.88
	S_2	95.89	190.47	3.32	6.85	1.00	2.67	8.85	81.33	51.69
	S_3	57.35	135.82	4.54	8.17	1.00	2.67	9.83	76.33	64.35
	S_4	127.89	245.24	5.26	9.86	1.00	3.00	7.29	88.67	135.32
	Mean	**102.91**	**194.24**	**4.04**	**7.81**	**1.00**	**2.92**	**6.49**	**84.17**	**74.56**
CD 0.05	Conc.	NS	2.99	NS	0.37	–	0.13	0.12	3.14	2.22
	Species	0.88	2.99	0.19	0.37	–	0.13	0.12	3.14	2.22
	Interaction	NS	5.99	NS	0.48	–	0.27	0.23	6.27	4.43
CD 0.01	Conc.	1.16	3.94	NS	0.73	–	0.18	0.15	4.12	2.91
	Species	NS	3.94	0.25	0.73	–	0.18	0.15	4.12	2.91
	Interaction	NS	7.87	NS	0.96	–	NS	0.30	8.24	5.82

leaf number per seedling followed by S_4 (88.67), S_2 (81.33) and the lowest was recorded in S_3 (76.33). Table 1 demonstrated that the area of a leaf increased significantly with the increase in CO_2 concentration and the lowest mean leaf area was found at 380 ppm (64.16 cm^2) followed by 550 ppm (72.09 cm^2) while the highest mean leaf area was found at 750 ppm CO_2 concentration (74.56 cm^2). Among the species S_1 maintained the lowest leaf area (46.88 cm^2) followed by S_2 (51.69 cm^2), S_3 (64.35 cm^2) and the highest was recorded in S_4 (135.32 cm^2) at 750 ppm CO_2 concentration. These lower phyllochron and higher leaf number and leaf area of bamboo seedlings at enriched CO_2 concentration might be due to the necessity of production of more leaf at a faster rate to cope up with the demand to carry out more photosynthesis at that modified environment. This result confirms the findings of earlier worker Grombone-Guaratini *et al.,* (2013) who had quoted that the bamboos grown under elevated CO_2 concentration showed an increase in tillering, leaf area, height and total biomass production.

The fresh and dry weight of leaf of bamboo seedlings gradually increased with the increase in CO_2 concentration in all four bamboo species tested (Table 2). The highest average fresh leaf weight (0.6026g) and dry leaf weight (0.2458g) were found at 750 ppm followed by 550 ppm (0.5799g and 0.2372g respectively) while the same were lowest at 380 ppm CO_2 concentration (0.4834g and 0.1926g, respectively). Among the bamboo species, S_4 produced the heaviest leaf with 1.0203g fresh weight and 0.3958g dry weight followed by S_3 (0.5723g and 0.2498g), S_2 (0.4356 and 0.1783g) while S_1 produced the lightest leaf with 0.3823g and 0.1594g fresh and dry weight respectively. Significant differences in leaf moisture content were observed amongst the bamboo species, the highest being 59.48% at 380 ppm CO_2 concentration and the lowest being the 58.39% moisture content found in control which was at par with 750 ppm (58.73%) and 550 ppm (58.71%) CO_2 concentration. The S_4 maintained the highest 62.18% moisture content followed by S_2 (60.41%), S_1 (58.14%) while S_3 maintained the lowest 57.19% moisture content. The interaction effects of CO_2 concentration and bamboo species were also found to be significant for fresh and dry leaf weight and moisture content of leaf. This positive impact of enriched CO_2

Table 2
Fresh and dry weight of a leaf, leaf moisture content, specific leaf weight (SLW), relative leaf water content (RLWC), leaf area per seedling and fresh and dry weight of leaf per seedling of different bamboo seedlings at various CO_2 concentrations

CO_2 concentration	*Bamboo species*	*Weight of a leaf (g)*		*Moisturecontent (%)*	*SLW (gcm^{-3})*	*RLWC (%)*	*Leaf area per seedling(cm^2)*	*Leaf weight per seedling (g)*	
		Fresh	*Dry*					*Fresh*	*Dry*
Control	S_1	0.2598	0.1108	57.35	0.0031	73.16	3260.82	19.83	8.46
	S_2	0.3312	0.1367	58.73	0.0029	74.52	3037.89	21.75	8.98
	S_3	0.5124	0.2235	56.38	0.0039	70.67	3127.54	28.53	12.44
	S_4	0.8916	0.3468	61.10	0.0026	77.38	8376.37	61.23	23.81
	Mean	**0.5988**	**0.2045**	**58.39**	**0.0031**	**73.93**	**4450.66**	**32.84**	**13.42**
380 ppm	S_1	0.2401	0.1005	58.14	0.0030	73.39	2886.87	17.21	7.20
	S_2	0.3135	0.1241	60.41	0.0028	74.56	2584.41	18.60	7.36
	S_3	0.4754	0.2035	57.19	0.0039	71.18	2707.14	24.40	10.45
	S_4	0.9045	0.3421	62.18	0.0026	77.46	6964.06	52.46	19.84
	Mean	**0.4834**	**0.1926**	**59.48**	**0.0031**	**74.15**	**3785.62**	**28.17**	**11.21**
550 ppm	S_1	0.3580	0.1536	57.09	0.0039	73.85	4005.64	31.39	13.47
	S_2	0.4303	0.1692	60.68	0.0035	74.75	3946.06	34.28	13.48
	S_3	0.5623	0.2456	56.32	0.0044	71.09	4125.31	37.86	16.54
	S_4	0.9691	0.3805	60.74	0.0042	77.53	10505.30	77.21	30.31
	Mean	**0.5799**	**0.2372**	**58.71**	**0.0040**	**74.31**	**5645.58**	**45.19**	**18.45**
750 ppm	S_1	0.3823	0.1594	58.30	0.0041	74.08	4234.67	34.53	14.39
	S_2	0.4356	0.1783	59.07	0.0038	74.89	4203.95	35.43	14.50
	S_3	0.5723	0.2498	56.35	0.0047	71.25	4911.84	43.68	19.07
	S_4	1.0203	0.3958	61.21	0.0043	77.81	11998.82	100.67	39.05
	Mean	**0.6026**	**0.2458**	**58.73**	**0.0042**	**74.51**	**6337.32**	**53.58**	**21.75**
CD 0.05	Conc.	0.0236	0.0042	0.45	0.0002	0.26	749.54	5.01	1.82
	Species	0.0236	0.0042	0.45	0.0002	0.26	749.54	5.01	1.82
	Interaction	0.0472	0.0083	0.90	0.0004	0.52	1499.08	10.02	3.64
CD 0.01	Conc.	0.0310	0.0055	0.59	0.0003	0.34	985.11	6.58	2.39
	Species	0.0310	0.0055	0.59	0.0003	0.34	985.11	6.58	2.39
	Interaction	0.0620	0.0110	1.19	0.0006	0.68	1970.22	13.16	4.78

concentration on biomass of leaf of bamboo seedlings might be either due to increase in net photosynthetic rate and dry matter accumulation or due to poor translocation of the dry matter to other sink part from leaf. During the present investigation higher relative leaf water content were recorded with the increase in CO_2 concentration from 380 ppm to 750 ppm (Table 2) which might help to produce higher fresh and dry weight of leaf. Grombone-Guaratini *et al.*, (2013); Korner *et al*., (2007) and Zhihong *et al.*, (2011) also reported higher net photosynthetic rate and total biomass production of bamboo with CO_2 enrichment.

The SLW and RLWC increased significantly with the increase in CO_2 concentration from 380 ppm to 750 ppm. The table 2 revealed that the highest SLW (0.0042gcm^{-3}) and RLWC (74.51%) were found at 750 ppm while the lowest SLW (0.0031gcm^{-3}) and RLWC (73.93%) were observed at control. Among the species S_3 maintained the highest SLW (0.0047gcm^{-3}) while S_2 maintained the lowest SLW (0.0038gcm^{-3}) at 750 ppm CO_2 concentration. On the other hand, the lowest RLWC (73.93%) was noted at control. The S_4 maintained superiority over other species in term of RLWC at all CO_2 concentrations tested while S_1 was significantly inferior compared with other species in term of RLWC at all CO_2 concentrations tested. The increase in SLW and RLWC at elevated CO_2 concentration might indicate more dry matter accumulation and less moisture loss from the leaf at that modified microenvironment. During the study higher photosynthetic rates were observed with the increase in CO_2 concentration which might help to retain more sugars in leaf and thereby could maintain higher SLW and RLWC with better osmotic adjustment at higher CO_2 concentrations. At higher CO_2 concentration, the stomata may be partially closed leading to lower stomatal conductance resulting in higher RLWC. In such situation lower stomatal conductance and increased water use efficiency of bamboo were also observed (Grombone-Guaratini *et al.,* 2013 and Li *et al*, 2013). The leaf area and leaf weight per seedling of all four bamboo species significantly increased with the increase in CO_2 concentration (Table 2). The highest average leaf area (6337.32 cm^2), fresh weight of leaf (53.58g) and dry weight of leaf (21.75g) per seedling were recorded

Table 3
Fresh and dry weight of branch, main stem, above ground biomass, rhizome weight and total seedling weight of different bamboo seedlings at various CO_2 concentrations

CO_2 concentration	*Bamboo species*	*Branch weight (g)*		*Main stem weight (kg)*		*Above ground biomass (kg)*		*Rhizome weight (g)*		*Total seedling weight (kg)*	
		Fresh	*Dry*	*Fresh*	*Dry*	*Fresh*	*Dry*	*Fresh*	*Dry*	*Fresh*	*Dry*
Control	S_1	5.93	3.11	0.3586	0.2273	0.3844	0.2389	21.04	13.73	0.4054	0.2526
	S_2	6.19	3.40	0.3319	0.2184	0.3598	0.2308	21.56	14.27	0.3814	0.2451
	S_3	9.25	5.64	0.6061	0.4079	0.6439	0.4260	22.76	16.84	0.6666	0.4428
	S_4	10.32	5.02	0.7086	0.4163	0.7802	0.4451	26.07	17.02	0.8062	0.4622
	Mean	**7.92**	**4.29**	**0.5013**	**0.3175**	**0.5421**	**0.3352**	**22.86**	**15.47**	**0.5649**	**0.3507**
380 ppm	S_1	5.39	2.98	0.3207	0.2017	0.3433	0.2119	20.64	13.48	0.3639	0.2254
	S_2	5.13	3.25	0.2954	0.1835	0.3191	0.1941	21.32	14.24	0.3405	0.2084
	S_3	7.89	4.68	0.5118	0.3434	0.5441	0.3585	22.47	16.63	0.5666	0.3752
	S_4	8.15	4.29	0.6034	0.3651	0.6644	0.3892	26.09	16.68	0.6901	0.4059
	Mean	**6.64**	**3.80**	**0.4328**	**0.2734**	**0.4677**	**0.2884**	**22.63**	**15.26**	**0.4903**	**0.3038**
550 ppm	S_1	10.66	5.30	0.7815	0.4154	0.8236	0.4342	23.52	15.52	0.8471	0.4497
	S_2	10.97	5.64	0.7023	0.4001	0.7476	0.4192	24.61	16.32	0.7722	0.4355
	S_3	15.84	8.03	0.9581	0.6935	1.0118	0.7181	26.08	19.36	1.0379	0.7374
	S_4	15.90	8.31	1.0265	0.6975	1.1196	0.7361	29.24	19.68	1.1489	0.7558
	Mean	**13.34**	**6.82**	**0.8671**	**0.5516**	**0.9257**	**0.5769**	**25.86**	**17.72**	**0.9515**	**0.5946**
750 ppm	S_1	11.18	5.89	0.7659	0.4439	0.8116	0.4642	24.18	15.79	0.8358	0.4800
	S_2	11.71	6.16	0.7352	0.4324	0.7823	0.4531	24.89	16.51	0.8072	0.4696
	S_3	15.69	8.76	1.0527	0.7038	1.1121	0.7331	26.72	19.53	1.1388	0.7527
	S_4	15.87	8.92	1.2093	0.7056	1.3258	0.7518	29.73	19.87	1.3556	0.7716
	Mean	**13.61**	**7.43**	**0.9408**	**0.5714**	**1.0080**	**0.6006**	**26.38**	**17.93**	**1.0344**	**0.6185**
CD 0.05	Conc.	0.75	0.36	0.0299	0.0257	0.0337	0.0271	0.16	0.18	0.0402	0.0274
	Species	0.75	0.36	0.0299	0.0257	0.0337	0.0271	0.16	0.18	0.0420	0.0274
	Interaction	1.49	0.73	0.0599	0.0515	0.0674	0.0543	0.32	0.36	0.0804	0.0547
CD 0.01	Conc.	0.98	0.48	0.0394	0.0338	0.0443	0.0357	0.21	0.24	0.0528	0.0360
	Species	0.98	0.48	0.0394	0.0338	0.0443	0.0357	0.21	0.24	0.0528	0.0360
	Interaction	1.96	0.96	0.0787	0.0677	0.0886	0.0713	0.43	0.48	0.1057	0.0719

at 750 ppm CO_2 concentration followed by at 550 ppm (5645.58 cm², 45.19g and 18.45g respectively) while lowest were found at 380 ppm CO_2, with leaf area (3785.62 cm²), fresh weight of leaf (28.17g) and dry weight of leaf (11.21g) per seedling. Again, among the species S_4 produced the highest leaf area (11998.82 cm²), fresh weight of leaf (100.67g) and dry weight of leaf (39.05g) followed by S_3 (4911.84 cm², 43.68g and 39.05g respectively) while S_1 produced the lowest values (4234.67 cm², 34.53g and 14.39g respectively) at 750 ppm CO_2 concentration. The higher leaf number per seedling and area of a single leaf at CO_2 enriched environment led to higher leaf area and leaf weight per seedling. This result was in close agreement with the findings of Grombone-Guaratini *et al.,* (2013); Korner *et al*., (2007) and Zhihong *et al*., (2011).

The weight of branch, main stem and total aboveground biomass (AGB) of bamboo seedlings increased significantly with the increase in CO_2 concentration in all four bamboo species tested (Table 3). The highest average fresh weight (13.61g) and dry weight (7.43g) of branch, fresh weight (0.9408 kg) and dry weight (0.5714 kg) of main stem and average fresh weight (1.0080 kg) and dry weight (0.6006 kg) of AGB were found at 750 ppm CO_2 concentration which was followed by 550 ppm and same were the lowest at 380 ppm CO_2 concentration (6.64g and 3.80g, 0.4328 kg and 0.2734 kg and 0.4677 kg and 0.2884 kg, respectively). Likewise the S_4 produced the heavier branch, main stem and AGB (15.87g and 8.92g, 1.2093kg and 0.7056 kg and 1.3258 kg and 0.7518 kg fresh and dry weight respectively) and the lowest main stem and AGB weight were noticed with S_2 (0.7352 kg and 0.4324 kg and 0.7823 kg and 0.4531 kg fresh and dry weight respectively) at 750 ppm CO_2 concentration. The heavier branch, main stem and AGB of bamboo seedlings achieved at elevated CO_2 concentration might be because of the higher leaf number and leaf area per seedling as well as being a raw material for photosynthesis the CO_2 itself could increase the net photosynthetic rate and total biomass production and that finally led to higher biomass accumulation. Higher CO_2 concentration also increased the Rubisco activity of bamboo seedlings and being the key enzyme of the C_3 photosynthetic pathway Rubisco efficiently could convert the CO_2 in to biomass of bamboo seedlings. The findings of earlier workers Grombone-Guaratini *et al.,* (2013);

Korner *et al*., (2007) and Zhihong *et al.,* (2011) also revealed higher biomass accumulation of bamboo at elevated CO_2 concentration.

The weight of rhizome and total weight of bamboo seedling increased significantly with the increase in CO_2 concentration from 380 ppm to 750 ppm (Table 3). The highest average fresh and dry weight of rhizome (36.38g and 17.93g respectively) and average fresh and dry weight of total seedling (1.0344 kg and 0.6185 kg, respectively) were found at 750 ppm CO_2 concentration which was followed by 550 ppm (25.86g & 17.72g fresh and dry weight of rhizome and 0.9515 kg & 0.5946 kg fresh and dry weight of total seedling respectively). While the lowest fresh and dry weight of rhizome (22.63g and 15.26g respectively) and fresh and dry weight of total seedling (0.4903 kg and 0.3038 kg respectively) were found at 380 ppm CO_2 concentration. Among the species S_4 produced the heaviest bamboo rhizome (29.73g and 19.87g fresh and dry weight respectively) at 750 ppm CO_2 concentration which was followed by S_3 (26.72g and 19.53g), S_2 (24.89g and 16.51g) and the lowest 24.18g and 15.79g fresh and dry weight of rhizome respectively were found at S_1 at 750 ppm CO_2 concentration and these differences were significant. S_4 also produced the heaviest weight of total seedlings (1.3556 kg and 0.7716 kg fresh and dry weight respectively) and S_2 produced the lightest weight of total seedlings (0.8072 kg and 0.4696 kg fresh and dry weight respectively) at 750 ppm CO_2 concentration and these differences were significant. Moreover, a significant interaction effect was also noticed in respect of fresh and dry weight of rhizome. Since at higher CO_2 concentration the weight of leaf, branch, main stem and total aboveground biomass of bamboo seedlings increased significantly so the total weight of seedling was also increased. However, the heavier rhizome at enriched CO_2 concentration revealed an efficient partitioning of dry matter produced to the different parts of bamboo seedlings. Before shedding of old leaves of bamboo a large amount of nutrients was remobilized and translocated to other parts (Li *et al.,* 1998). Therefore, with higher net photosynthetic rate, efficient partitioning and accumulation of dry matter to the different parts of bamboo finally led to heavier seedling with CO_2 enrichment. Earlier study revealed that net photosynthetic rate and partitioning of dry matter to different parts increased in bamboo with increased atmospheric CO_2 concentrations. Our study therefore, confirms a positive respond of bamboo seedlings to the CO_2 enrichment which might be due to the fact that being C_3 plant, the bamboo seedlings increases the rate of photosynthesis at elevated CO_2 concentration and thereby increases in dry matter production and accumulation and enhances other growth parameters. The *Dendrocalamus hamiltonii* is found to be the prominent one while *Bambusa tulda* shows poorest performance in respect to above mentioned traits in CO_2 enriched environment.

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