

Effect of Elevated Carbon Dioxide and Temperature on Growth, Yield and Quality Parameters of Mulberry

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ABSTRACT

Keywords

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Mulberry being a C₃ crop responsive to carbon, climate change in the form of elevated CO₂ coupled with increased temperature would be helpful for crop but it gets altered in presence of herbivore. The eCO₂ and temperature favoured growth and development of mulberry only in terms of quantity which was evidenced by accelerated growth of more plant height, leaves, leaf area index, leaf yield and plant biomass. Biochemical analysis of mulberry showed a lot of changes in it, wherein, the chlorophyll, carbon and carbon based compounds *viz.*, tannins, phenols, total sugars, carbohydrates significantly increased in eCO₂ as compared to aCO₂ treatments. On the contrary, nitrogen (N) and N- based compounds *viz.*, proteins decreased in eCO₂ compounds which in turn altered C: N ratio.

Introduction

Mulberry belongs to the family “Moraceae” under the genus “*Morus*” with several species. It thrives under varied climate ranging from temperate to tropical conditions and major mulberry growing areas of the globe is located north of the equator between 28 °N and 55 °N latitude. The ideal range of temperature is from 24 to 28 °C. Mulberry grows well in places with an annual rainfall ranging from 600 to 2500 mm. In areas with low rainfall, growth is limited through moisture stress, resulting in low yields. On an average, mulberry requires 340 m³ per ha of water every ten days in case of loamy soils and 15 days in clayey soils. Atmospheric

humidity range of 65-80 per cent is ideal for luxuriant mulberry growth. Sunshine is one of the important factors controlling growth and leaf quality. In the tropics, mulberry grows with a sunshine range of nine to 13 hours a day. Mulberry can be ideally cultivated up to an elevation of 1000 m above mean sea level. Mulberry leaves are highly palatable and digestible to mulberry silkworms and is the only satisfactory food plant. Protein content in the leaves and young stems, with a good essential amino acid profile, varying from 15 to 28 per cent depending on the variety. Mineral content is high with no anti-nutritional factors or toxic compounds have

been identified. India is the second largest producer of silk in the world. Production of raw silk in India during the year 2013-14 has been 26,480 MT. Now, as a result of growing realization, sericulture is gaining ground in non-traditional areas too. The existence and prosperity of sericulture industry depends upon the production of quality silk. For production of quality cocoon and silk, silkworm larva should be fed with quality mulberry leaves, which is the exclusive food plant of the *Bombyx mori* L.

Materials and Methods

An investigation was carried out to study the effect of elevated CO₂ and temperature on growth, yield and quality parameters of mulberry under Open Top Chamber (OTC's) conditions and subsequent effect on mulberry silkworm at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Raichur, Karnataka. The present study was carried out during *kharif* and *rabi* 2014-15 at MARS, Raichur, which is situated in the North Eastern Dry Zone (Zone-II) of Karnataka between 16° 15' N latitude and 77° 20' E longitude with an altitude of 389 m above the mean sea level. The cement pots (2½ feet height with 2 feet diameter) were procured and filled with loamy soil and added with farm yard manure (FYM). Mulberry saplings which have been grown for a period of four months were uprooted from mulberry nursery and planted two saplings per cement pots allowed for establishment with proper watering and care as per treatment in OTC as well as in open plot. Plant growth parameters *viz.*, time taken for sprouting, number of leaves per plant, number of shoots and plant height were recorded in one crop growth cycle. Also, leaf samples were collected on 65th days of pruning for biochemical analysis. Organic carbon, leaf nitrogen, C: N ratio, chlorophyll, flavonoids, tannins, phenols, morin were analyzed as per the standard

procedure. The leaves from each plant were collected from each treatment and weighed at 65 DAP and also shoot and root biomass was weighed by uprooting plants from the pot at last in order to know plant biomass. Leaf chlorophyll and flavonoids were measured using a Dualex Scientific sensor a hand tool leaf clip combining the use of fluorescence as well as light transmission of a leaf to determine its physiological status.

Nitrogen content in the plant sample was determined by using Micro-Kjeldahl technique, discovered by McKenzie (1994) and the per cent nitrogen was calculated by using the formula,

$$\% \text{ Nitrogen} = \frac{\text{Titre value} \times \text{Normality of H}_2\text{SO}_4 \times 50}{\text{Weight of plant sample} \times 10}$$

Total organic carbon was estimated by dry combustion method / ash method using Muffle furnace.

$$\text{Ash \%} = \frac{(W_3 - W_1)}{(W_2 - W_1)} \times 100 \quad (1)$$

$$\text{Organic carbon \%} = (100 - \text{Ash \%}) \times 0.58 \quad (2)$$

Where, W₁ is weight of crucible, W₂ is weight of oven-dried sample along with crucibles, and W₃ is the weight of ash with crucibles and 0.58 is the conversion factor. Carbon to nitrogen ratio was analyzed by taking the ratio of carbon and nitrogen content readings previously obtained by estimation of the same. Tannins are polyphenolic compounds present in all types of plants. They were estimated by Folin –Dennis method (Malick and Singh, 1980) whereas, Phenols were estimated by Folin - Ciocalteu (FCR) method as suggested by Malick and Singh (1980). The method used for estimation of sugars was suggested by Nelson Somogyi

(Marais *et al.*, 1996) and for the estimation, alcohol was evaporated from the sample and was diluted appropriately. The aromatic amino acids present in a protein like tyrosine, tryptophan react with phosphomolybdo - phosphor tungstate (FCR) reagent to produce a blue coloured complex at 660 nm. The procedure for carbohydrates estimation was carried out as per AOAC (2005).

$$\text{Carbohydrates (\%)} = \frac{X}{0.1} \times 100$$

Where, X = Concentration of D-glucose from standard graph. The crude fibre content in mulberry leaves was determined by sequential acid and alkali hydrolysis method (AOAC, 2005) using Fibra-Plus apparatus.

$$\text{Crude fibre (\%)} = \frac{W_1 - W_2}{W} \times 100$$

Results and Discussion

Carbon dioxide is the most studied greenhouse gas in climate change research and the impact of elevated greenhouse gas concentrations on the performance of plants and herbivores has been well documented (Lindroth, 2010). The effect of elevated CO₂ and temperature on mulberry has direct effect on growth, development, nutritional status and yield of mulberry. The leaves and plant height showed significant increase in elevated CO₂ conditions over the cropping period. At 60 DAP, the CO₂ (550 ppm ± 25 ppm) alone treatment recorded maximum plant height (70.33 and 93.74 cm) and more number of leaves (247.33 and 350.00 leaves/ plant). The growth parameters of mulberry are well supported by earlier studies by Nereu (2005), Mirwais and David (2011) and Attipalli *et al.*, (2010) according to them plants/ crops exhibited increased growth rates in elevated

CO₂ treatment conditions. And also the leaf yield and total plant biomass were highest in elevated CO₂ (550ppm± 25 ppm) treatment 701.17g/plant and 1026.28g/plant, respectively. The results of the present study are in line with earlier findings of Thomas and Luit (1996) and they reported 56 per cent increased total shoot biomass in *Arabidopsis thaliana* L. Similarly the leaf area index, nitrogen biased index and chlorophyll was also found to be significantly highest in eCO₂ alone (2.09 μ/ cm², 28.51 μ/ cm² and 36.61 μ/ cm²) respectively.

The eCO₂ has positively influenced the growth indices *viz.*, leaf area index, nitrogen balanced index and the earlier studies of Nereu (2005) reported increased growth rates by C₃ plants under eCO₂ conditions and mulberry being C₃ plant in the present study responded positively to CO₂. Further, the direct effects of eCO₂ on individual plant species have been well documented (Curtis and Wang, 1998) wherein, eCO₂ generally resulted in increased leaf area index and increased growth rate and the rise in chlorophyll content in the elevated climate change treatments was because of that the plant chlorophyll content increased with increased CO₂ concentration exposure, especially in C₃ plants, (Hamid *et al.*, 2012). Whereas, the flavonoid content was significantly highest in reference plot compared to elevated conditions (1.53 μ/ cm²) (Table 1). Ambient CO₂ treatments recorded higher nitrogen percentage wherein, the leaves from reference plot recorded higher values (3.93 mg/ g) at 60 DAP. Further, carbon percentage recorded in the eCO₂ treatments was higher (25.67 mg/ g) over aCO₂ treatments at 60 DAP. Furthermore, with increased carbon and decreased nitrogen, the C: N ratio increased (8.89 mg/g) in the eCO₂ treatments as compared to aCO₂ treatments at 60 days after pruning.

Table.1 Effect of eCO₂ and temperature on growth and yield parameters of mulberry

Treatment	Plant height (cm)	No. of leaves (No.)	Leaf yield (g)	Plant biomass (g)	LAI (μ/ cm ²)	NBI (μ/ cm ²)	Chlorophyll (μ/ cm ²)	Flavonoid (μ/ cm ²)
eCO ₂ (550ppm)	93.74	350.00	701.17	1026.28	2.09	26.21	36.61	1.24
eCO ₂ + eTemp. (550ppm+2 ⁰ C)	95.11	331.66	657.83	935.50	1.98	28.51	35.38	1.07
aCO ₂ + eTemp. (390ppm+2 ⁰ C)	91.02	312.00	663.00	900.77	1.62	25.23	35.60	1.05
aCO ₂ (390 ppm)	92.98	324.94	630.00	947.614	1.90	22.65	35.13	1.46
Reference Plot	91.55	319.00	627.33	947.38	1.81	20.65	34.70	1.53
CV (%)	0.85	0.93	4.12	2.18	3.30	1.54	0.58	1.35
S.Em ±	0.39	1.50	13.52	10.40	0.03	0.19	0.10	0.01
CD @ 0.01	1.21	6.60	58.4	44.95	0.13	0.82	0.44	0.04

Table.2 Effect of elevated CO₂ and temperature on phytochemistry of mulberry

Treatment	Leaf nitrogen (mg/g)	Leaf carbon (mg/g)	C:N (mg/g)	Tannin (mg/g)	Phenol (mg/g)	Total sugars (mg/g)	CHO (mg/g)	Proteins (mg/g)	Crude fibre (mg/g)
eCO ₂ (550ppm)	3.08	23.54	7.66	1.91	4.19	13.08	5.26	5.39	7.87
eCO ₂ + eTemp. (550ppm+2 ⁰ C)	2.94	25.67	8.89	1.52	4.09	12.9	5.18	4.82	7.5
aCO ₂ + eTemp. (390ppm+2 ⁰ C)	3.27	22.7	6.96	1.17	3.09	12.13	4.84	5.44	6.9
aCO ₂ (390 ppm)	3.83	22.5	5.91	1.07	3.26	12	4.91	6.12	6.33
Reference Plot	3.93	21.25	5.45	0.98	3.39	11.89	5.15	6.24	6.18
CV (%)	1.01	0.32	1.27	2.73	0.92	2.52	0.58	2.07	2.47
S.Em ±	0.02	0.04	0.04	0.02	0.02	0.16	0.02	0.06	0.09
CD @ 0.01	0.07	0.16	0.19	0.08	0.07	0.68	0.08	0.25	0.37

It is well known that the direct effect of enriched atmospheric CO₂ on plant growth, physiology and community structure is depicted by increased plant growth by accelerating rates of photosynthesis, which reduced tissue quality and increased the carbon to nitrogen (C:N) ratio (Robinson *et al.*, 2010). Elevated CO₂ conditions has promoted increased biomass production with reduced foliar nitrogen and increased C: N ratio for most plants, especially C₃ crops

(Chen *et al.*, 2005). Tannins and phenols content were significantly higher in eCO₂ treatments over aCO₂ treatments. Highest tannins (1.91 mg/ g) and phenols (4.19 mg/ g) were recorded in eCO₂ (550 ppm ± 25 ppm). The present findings with respect to tannins and phenols revealed that elevated conditions favoured plant defensive chemicals wherein, highest values of tannins and phenols were found in the elevated treatments as compared to ambient levels. Since, tannins and phenols

are carbon based compounds, along with increased carbon; these compounds have also increased in the elevated climate change treatments. The current findings are in line with earlier studies of Xiaowei *et al.*, (2008) who reported that some kinds of defensive secondary compounds such as phenolics tend to increase in the eCO₂ conditions. The total sugars were significantly highest in eCO₂ (550 ppm) treatment (13.08 mg/ g) at 60 DAP. The present findings are in line with earlier studies by Xin *et al.*, (2013) who reported that eCO₂ conditions favoured increased carbohydrates accumulation in tomato plants. Further, the leaf carbohydrate determinations showed that the starch, total sugars and sucrose concentration increased significantly in plants exposed to eCO₂ conditions. Elevated CO₂ treatments recorded lower protein levels (4.82 mg/ g) at 60 DAP whereas, the carbohydrate content was significantly maximum in eCO₂ (550 ± 25 ppm) treatment (5.26 mg/ g) at 60 DAP. The carbohydrate content was lower in aCO₂ treatments in comparison with eCO₂ treatment (Table 2). Contrary to this, protein production in mulberry was higher in aCO₂ treatment is in line with the reports of Yin *et al.*, (2010) according to them atmospheric CO₂ enrichment induced changes in phytochemistry of maize plant with decreased protein. Further, the present investigations showed that soluble proteins and carbohydrates had a significant negative effect of eCO₂ and temperature.

References

- AOAC, Association of Official Analytical Chemists, 2005, *J. Association of Official Agri. Chemists.*, 80: 725.
- Attipalli, R. R., Girish, K. R. and Agepati, S. R., 2010. The impact of global elevated CO₂ concentration on photosynthesis and plant productivity. Department of Plant Sciences, *Curr. Sci.*, 98: 1305-1319.
- Curtis, P. S., and Wang, X., 1998, A meta-analysis of elevated CO₂ effects on woody plant mass, form and physiology, *Oecol.*, 113: 299-313.
- David, N. K., and Christopher, G., 2011, Elevated CO₂ increases constitutive phenolics and trichomes, but decreases inducibility of phenolics in *Brassica rapa* (Brassicaceae). *J. Chem. Ecol.*, 37: 1332-1340.
- Hamid. R. M., Ahmad, R. and Bagheri, A. R., 2012. The impact of elevated CO₂ on growth and competitiveness of C₃ and C₄ crops and weeds. *Eur. J. Exp. Biol.*, 2(4): 1144-1150.
- Lindroth, R. L., 2010, Impacts of elevated atmospheric CO₂ and O₃ on forests: phytochemistry, trophic interactions and ecosystem dynamics. *J. Chem. Ecol.*, 36: 2-21.
- Malick, E. P., and Singh, M. B., 1980, Plant enzymology and hittoenzymology. Kalyani Publishers, New Delhi, p. 286.
- Marais, J.P., Wilt, J. L and Quicke, G. V., 1986. A critical examination of the Nelson Somogyi method for the determination of reducing sugars. *Anal. Biochem*, 15(3): 373-381.
- Mckenzie, H. A., 1994, The Kjeldhal determination of nitrogen: retrospect and prospect. *Anal. Chem.*, 13(14): 138.
- Mirwais, M. Q., and David, M. R., 2009, Crop responses to elevated carbon dioxide and temperature. Department of biological sciences, *Climate Change and Crops, Environ Sci and Eng.*, 3: 540-88.
- Nereu, A. S., 2005, Climate change and agroecosystems: the effect of elevated atmospheric CO₂ and temperature on crop growth, development, and yield. *Ciencias. Rurais*, 35: 730-740.
- Phoungchandang, S., Tochip, L. and Srijesdaruk, V., 2008, White mulberry leaf drying by tray and heat pump

- dehumidified dryers, *World. J. Agric. Sci*, 4: 844-851.
- Robinson, E. A., Ryon, G. D. and Newman, J. A., 2012. A meta-analytical review of the effects of elevated CO₂ on plant-arthropod interactions highlights the importance of interacting environmental and biological variables, *New Phytol.*, 194: 321-336.
- Thomas, A. W. V., and Luit, J. D. K., 1996, Impact of elevated CO₂ on growth and development of *Arabidopsis thaliana* L., Department of Genetics, University of Groningen, download under www.biologiezentrum.at
- Xiaowei, W., Lanzhu, J. I., Guiqing, W. and Yan, L., 2008, Potential effects of elevated CO₂ on leaf-feeding forest insects. *Chinese. J. Appl. Ecol.*, 3(1): 68-77.
- Xin, L., Zhang, G., Sun, B., Zhang, S., Zhang, Y., Liao, Y., Zhou, Y., Xia, X., Shi, K. and Jinqaun, Y., 2013, Stimulated leaf dark respiration in tomato in an elevated carbon dioxide atmosphere. *Sci. Rep.*, pp. 3433.
- Yin, J., Cheng, S., Gang, W. and Feng, G., 2010, Effects of elevated CO₂ associated with maize on multiple generations of the cotton bollworm, *Helicoverpa armigera*. *Entomol. Exp. Appl.*, 136(1): 12-20.

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