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Water use efficiency and phyto-remediation potential of water hyacinth under elevated CO_2

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ABSTRACT

A pot culture experiment was conducted in Open Top Chambers during 2007-08. The plantlets (ramets) of water hyacinth were grown in pots with four different media (M_1- tap water, M_2- distilled water, M_3- hoagland solution and M_4- hoagland solution with added heavy metals) in three replications and the pots were kept in open top chambers (OTCs), maintained at ambient (360±20ppm) and elevated CO_2 (550±30 ppm), and in open field conditions. Pots in three replications from each media-without plant-were kept under the above three conditions as control to measure the evaporation for WUE estimation. The growth of the plants grown in M_1 and M_2 was severely affected. The plants grown under elevated CO_2 and nutrient rich media (M_3 and M_4) maintained higher green-leaf area over the growth period and recorded higher net assimilation rate (NAR). CO_2 enrichment resulted into reduction of water loss (increased WUE) from plants grown in hoagland (M_3) and heavy metal (M_4) solutions. When the comparison was made in between M_3 and M_4 treatments, there was tremendous increase in WUE (reduced transpirational loss of water per gram of dry matter produced) in plants grown in M_4. the elevated CO_2 enhanced the uptake of heavy metals like Cu, Fe, Mn and Zn in both the media but it was higher in M_4 than in M_3 due to increased availability.

Key words: Water hyacinth, Elevated CO_2, Phytoremediation, Water use Efficiency

At present the need of recycling of waste water is very essential so as to compensate the decrease in water supply. Several methods have been practiced for treatment of waste water. However, there has been an increasing awareness about the potentiality of the vascular hydrophytes for the treatment of waste water and phytoremediation of contaminated soils. Water hyacinth (*Eichhornia crassipes* Mart. Solms) is considered to be one of the most damaging aquatic invasive weed in the world. It made its entry into India at Bengal about 1896 (Biswas and Calder 1954) and now occurs throughout the country in fresh water ponds, pools, tanks, lakes, reservoirs, streams, rivers, irrigation channels and paddy fields. It propagates by vegetative and sexual methods, adapts to changing climate and water quality and can even convert from an aquatic plant to a terrestrial one if its water way dries up. It reduces the volume of available fresh water by increasing the evapo-transpiration. However, the very ecological devastating properties of water hyacinth make it an ideal plant for water treatment and nutrient absorption from waste waters. Its appetite for nutrients and explosive growth rate has been put to use in cleaning up municipal and agricultural waste waters. It has been discovered that water hyacinth's quest for nutrients can be turned in a more useful direction. Its fantastic ability of absorbing nutrients, rapid growth, low economic maintenance and many other profits from the plant raised its value for reducing the pollution. It was recognized to be useful for waste water treatment for removing the heavy metals and other pollutants. The focus on water hyacinth as a key step in waste water recycling is due to the fact that it forms the central unit of recycling engine driven by photosynthesis and therefore the process is sustainable, energy efficient and cost effective under a wide variety of rural and urban conditions.

For many plants, especially those with C_3 photosynthesis, an increase in CO_2 produces an increase in net photosynthetic rate (Morgan *et al.* 2004, Leakey *et al.* 2006). Water hyacinth is most likely a C_3 plant. Unlike submerged macrophytes which are shade plants water hyacinth leaves growing in exposed locations can utilize full sunlight for photosynthesis. Ongoing combustion of fossil fuels leads to an increase in the atmospheric carbon dioxide (CO_2) concentration, which is contributing to global warming substantially (IPCC 2007). It is well known that the elevation of CO_2 in the atmosphere significantly affects global ecosystems (Woodward 2002). General concern about increasing global atmospheric CO_2 levels and given that atmospheric CO_2 levels are doubling in the next

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century it was of interest to determine the response of water hyacinth to elevated CO_2 in terms of water use efficiency and phytoremediation potential.

MATERIALS AND METHODS

The experiment was conducted during 2007-08 in open top chambers (OTCs), maintained at ambient (360±20 ppm) and elevated CO_2 (550±30 ppm), and in open field conditions. Plastic pots (1.5lit capacity) were filled with four different media (Tap water (M_1), Distilled water (M_2), Hoagland solution (M_3) and Hoagland solution with added heavy metals (M_4)) in three replications. Two uniform sized plantlets (ramets) of water hyacinth were placed in each pot and the pots were kept in open top chambers (OTCs), maintained at ambient (360±20 ppm) and elevated CO_2 (550±30 ppm), and in open field conditions. Pots in three replications from each media-without plant-were kept under the above three conditions as control to measure the evaporation for WUE estimation. The experiment was run for 50 days and on every fifth day the loss of water by evapo-transpiration (evaporation in case of control pots) was measured by gravimetric method. The water added (on every 5th day) was summated for the entire experimental period (50 days) to arrive at the cumulative water added (CWA) to pots with plant as well as without plant (control) separately. The cumulative water added to the pots without plants was noted as CWA* and used to correct the evaporation loss. This corrected cumulative water added for each pot (CWA-CWA*) was taken as the cumulative water transpired (CWT) during the experimental period. Water-use efficiency was determined as the ratio of the amount of biomass produced by a plant to the total amount of water transpired. For phyto-remediation studies the media used were Hoagland solution (Taiz and Zeiger 2002) and Hoagland solution with added heavy metals. Heavy metal solution was prepared by doubling the dose of micronutrient solution of Hoagland solution. The water samples were analyzed through Atomic Absorption Spectroscopy (AAS) before the start of the experiment and at the end of the experiment to find out the concentration of heavy metals (Fe, Cu, Mn and Zn).

RESULTS AND DISCUSSION

In water hyacinth leaf petiole and lamina constitute 70-90% of the total plant biomass. So the growth data on leaf and petiole reflect the overall plant growth (Naidu and Paroha 2007). The plant growth was severely affected in the plants grown in tap water and distilled water. This may be due to alkaline pH (8.03) of Tap water and dearth of nutrients in distilled water. The plants grown in M_3 and M_4 produced ten times higher number of leaves than the initial number and the leaf area increase was tremendous. The CO_2 enrichment enhanced the leaf area in both M_3 and M_4 grown plants and the M_4 recorded higher value (Fig. 1). The elevated CO_2 and nutrient rich media (M_3&M_4) maintained the higher green leaf area over the growth period (Fig. 2).

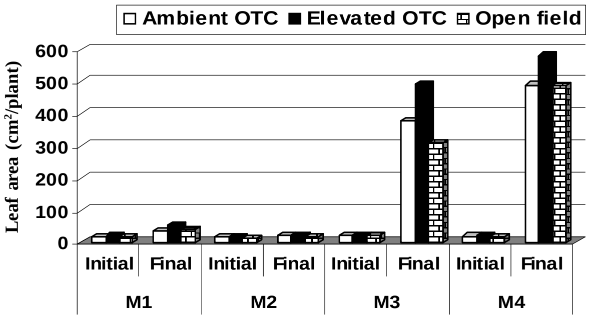

Fig.1. Leaf area in water hyacinth grown in different media under elevated CO_2

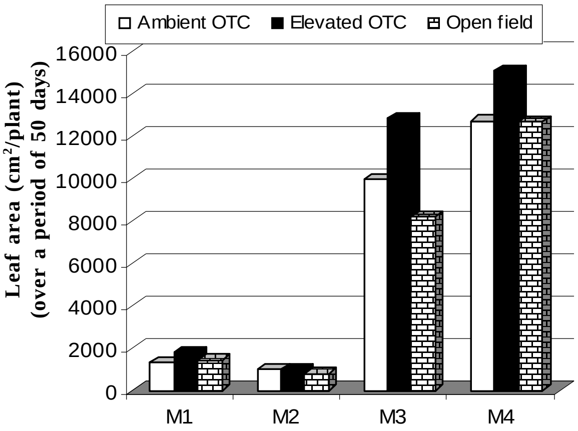

Fig. 2. Leaf Area Duration (LAD) in water hyacinth grown in different media under elevated CO_2

CO_2 enrichment resulted into reduction of water loss (increased WUE) (Naidu and Varshney 2011) from plants grown in Hoagland (M_3) and Heavy metal (M_4) solutions (Fig.3). There was about a 16.7% and 74.5% decrease in water loss under elevated CO_2 than under ambient CO_2 in M_3 and M_4 grown plants respectively. This might be because of enhanced biomass production due to nutrient rich medium and CO_2 enrichment and also because of reduced transpiration due to CO_2 induced stomatal closure (Idso *et al.* 1984). However, when the comparison was made in between M3 and M4 treatments, there was tremendous increase in WUE (reduced transpirational loss of water per gram of dry matter produced) in plants grown in M_4. Here the reason might be production of thick leaves with shiny surface which might have reflected the incident radia-

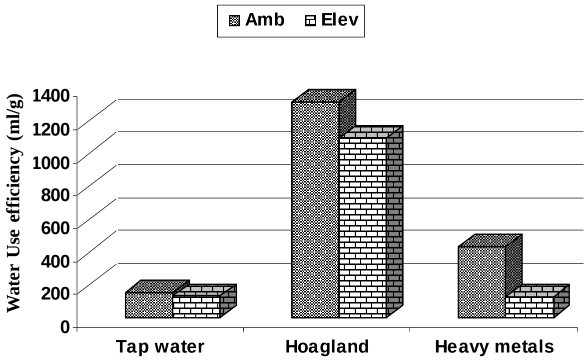

Fig. 3. Water Use efficiency (ml/g) in water hyacinth grown in different media under elevated CO_2

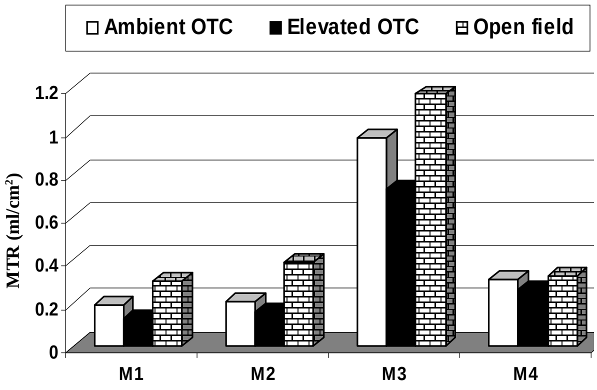

Fig. 4. Mean Transpiration Ratio (MTR) (ml/cm^2) in water hyacinth grown in different media under elevated CO_2

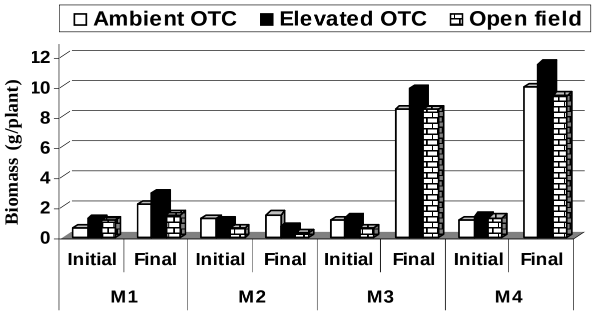

Fig. 5. Plant biomass (g/plant) in water hyacinth grown in different media under elevated CO_2

tion resulting into reduced heat and transpiration. The mean transpiration ratio (MTR), which gives the transpiration per unit leaf area over a period of time, shows (Fig.4) that the elevated CO2 reduced the transpiration and the reduction was high in heavy metal solution. The heavy metal uptake was higher in heavy metal solution than in Hoagland solution (Fig. 6-9). This is due to increased availability of these metals in heavy metal solution. The exposure of the plants to elevated CO_2 resulted into enhanced uptake of these metals in both the media (Fig. 6-9) and this might be due to enhanced growth and associated uptake under high

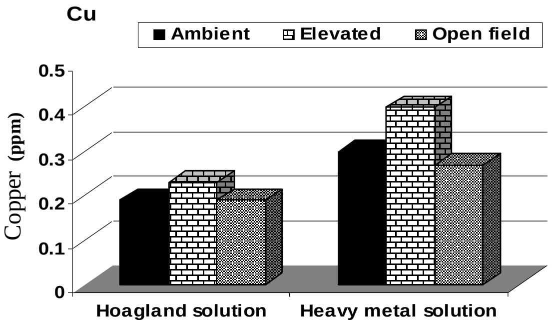

Fig. 6. Copper concentration (ppm) in water hyacinth grown in different media under elevated CO_2

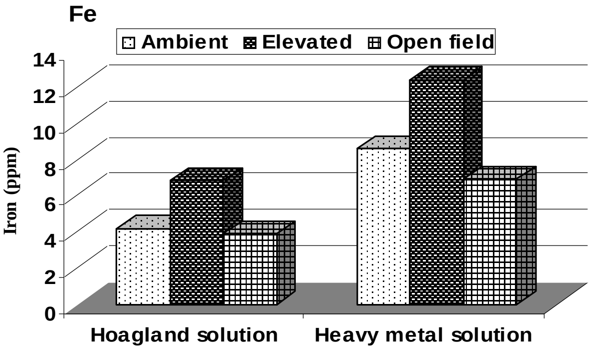

Fig. 7. Iron concentration (ppm) in water hyacinth grown in different media under elevated CO_2

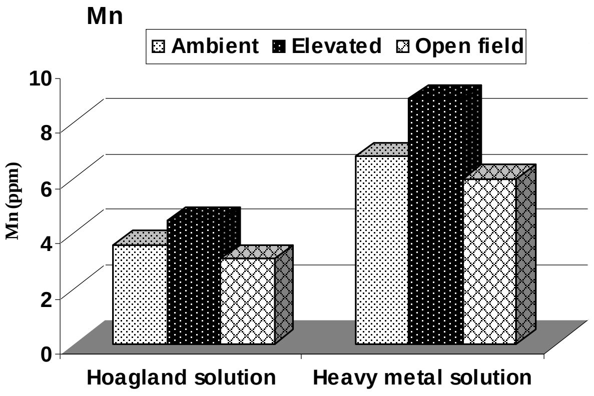

Fig. 8. Manganese concentration (ppm) in water hyacinth grown in different media under elevated CO_2

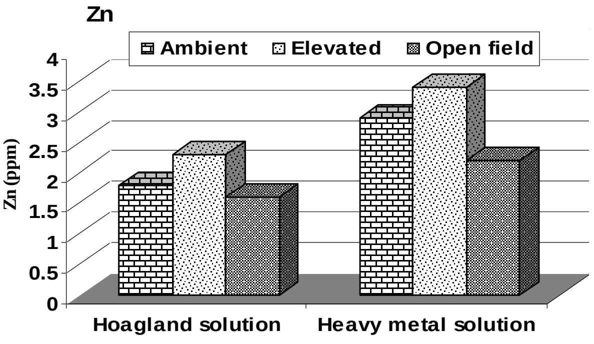

Fig. 9. Zinc concentration (ppm) in water hyacinth grown in different media under elevated CO_2

CO_2 (Idso *et al.* 1985, Zheng *et al.* 2008, Li *et al.* 2012, Song *et al.* 2012). Since the increase of plant biomass resulting from CO2 enhancement (Fig. 5) could suggest that more metal be taken up from the contaminated sites (Tang *et al.* 2003). The results indicate that the ever-increasing atmospheric CO_2 may enhance the phytoremediation efficiency of water hyacinth (Sunghyun Kim and Hojeong Kang 2011). However, this work was limited to a growth chamber, and further investigation is needed in field conditions.

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