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Invasive potential of C_3-C_4 intermediate *Parthenium hysterophorus* under elevated CO_2

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ABSTRACT

An experiment was conducted in open top chambers (OTCs) to study the growth, water-use efficiency and carbon isotope discrimination ($\Delta^{13}C$) in *Parthenium hysterophorus* in response to elevated CO_2. *Parthenium* plants were grown in OTCs maintained at ambient (370±20 ppm) and elevated (550±30) CO_2 levels as well as under open field conditions. Water-use efficiency (WUE) was determined by gravimetric method. The carbon isotope discrimination ($\Delta^{13}C$) was determined by Isotope Ratio Mass Spectrometry (IRMS). The CO_2 enrichment enhanced both the above and below ground biomass in *Parthenium*. Water-use efficiency (WUE) and Carbon isotope discrimination ($\Delta^{13}C$) were higher in plants grown under elevated CO_2 compared to plants under ambient CO_2 conditions. The growth stimulation and increased water-use efficiency in *Parthenium* indicates that this weed could become more aggressive in future if the atmospheric CO_2 continue to rise coupled with the rise in temperature.

Key words: Carbon isotope, Elevated CO_2, *Parthenium*

One aspect of the environment, which is of obvious interest is global climate change especially rising concentration of CO_2 in the atmosphere. Atmospheric CO_2 has already risen from 285 ppm to 380 ppm during the 20th century with most observed increase coming since late 1950s. More than 50% of the increase was witnessed during the second half of the 20th century (Houghton *et al*. 1996). *Parthenium hysterophorus*, a major invasive weed, occupied almost all parts of India and posing a threat to crop productivity, environment, human and animal health, and biodiversity. From the records, it is clear that parthenium has entered India before 1910 and lived unknown till 1956. It is also clear that since 1956, parthenium has spread like wild fire throughout India and has achieved the status of "worst weed". Based on several reports it is evident that the pace of increase in the invasion of *Parthenium* and the rate of increase in the atmospheric CO_2 are in the same trend during the last five decades indicating the possibility of the influence of the rising CO_2 on its invasiveness.

During the fixation of carbon by photosynthesis, the naturally occurring stable carbon isotope ^{13}C is discriminated against because of small differences in chemical and physical properties imparted by the difference in mass. Plants contain smaller ratio of ^{13}C to ^{12}C than does the CO_2 of the air that feeds them. Apparently, C_3 species had larger (more negative) discrimination effects than C_4 species. *Parthenium hysterophorus* is a C_3- C_4 intermediate plant with the presence of C_3 photosynthesis and with little or no photorespiration (Moore *et al*. 1987). As the type of photosynthetic pathway that a plant possesses has been found to influence its response to elevated CO_2 (Ziska and Runion 2006), it is hoped that this study would indicate the invasive potential of the *Parthenium* in future.

MATERIALS AND METHODS

The experiment was conducted at Directorate of Weed Science Research, Jabalpur during 2007–08. The *Parthenium* plants were grown in two sets of pots kept in OTCs, maintained at ambient (370±20 ppm) and elevated (550±30) CO_2 levels, as well as under open field conditions. One set of pots were used for estimation of water-use efficiency. Water-use efficiency was determined by gravimetric method involving weighing of pots daily to check the evapo-transpiration and water was added so as to maintain the field capacity. The gravimetric measurement was done daily for 35 days starting from 30 to 65 DAS and the plants were harvested at the end for estimation of biomass. Daily water added was summated for the entire experimental period (35 days) to arrive at the cumulative water added (CWA) to pots with plant. Though necessary care was taken by covering the soil surface with plastic pieces to reduce the direct surface

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evaporational losses, some amount of water would still be lost. To give correction to this, a set of empty pots without plants (with same amount of soil and plastic pieces as that of planted pots) were maintained and weighed daily to measure daily evaporation which were also brought back to 100% FC. The cumulative water added to these empty pots 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. The plants from the other set of pots were allowed to grow till maturity for recording growth characters.

For the $\Delta^{13}C$ analysis, the leaf samples were immersed in liquid nitrogen, freeze-dried and then ground to a fine powder. Around 1 mg of dried leaf sample was combusted in the Flash Elemental Analyzer (NA 1112, Carlo Erba, Italy) interfaced to an Isotope Ratio Mass Spectrometer (IRMS; Delta-Plus, Thermo-Finnigan, Bremen, Germany) via a continuous flow device (Conflo-III), at Department of Crop Physiology, University of Agricultural Sciences, Bangalore, India. The stable carbon isotope composition ($\delta^{13}C$) was expressed relative to the Pee Dee belemnite standard. The carbon isotopic composition of plant samples ($\delta^{13}Cp$) was determined with an analytical precision of less than 0.1%. Carbon isotope discrimination ($\Delta^{13}C$) was calculated as given below according to Farquhar (1983, 1989), assuming the isotopic composition of atmospheric air ($\delta^{13}Ca$) to be –8% (Francey *et al*. 1995, Keeling *et al*. 1995).

$$\Delta^{13}C\ (‰) = [\delta^{13}Ca - \delta^{13}Cp] / [1 + \delta^{13}Cp / 1000]$$

RESULTS AND DISCUSSION

The CO_2 enrichment enhanced both the above and below ground biomass in *Parthenium* (Table 1). Visual differences in plant growth due to CO_2 enrichment was not evident till 45 DAS. However, the enhancement in the plant growth under elevated CO_2 was noticed from 45 DAS. The difference between open field and OTC-Ambient CO_2 was not significant. Under elevated CO_2 the plant height had shown more than 100% increase, with higher number of primary branches and leaves. The increase in number of leaves was 295% and 277%, however, the leaf area increase was just 69% and 55% over the open field and OTC-ambient CO_2 conditions respectively. This was because of the fact that under elevated CO_2 smaller sized leaves were produced at increased number especially on branches. The root biomass was increased by more than 200% due to profuse root proliferation on the upper portion as well as the increased thickness of the taproot. There was a tremendous increase in the capitula production under elevated CO_2. Under ambient CO_2 conditions (open field and OTC) about 80% of the biomass was allocated to stem (~45%) and leaves (~35%) and rest of the 20% was almost equally allocated to root and capitula (Fig.1). Whereas, under elevated CO_2 conditions ~70% of the biomass was accumulated in the stem and the rest has been to the leaves (~12%), flowers (~10%) and root (~8%). At the two CO_2 levels the greatest difference was in plant height and biomass (Navie *et al*. 2005). Water-use efficiency (WUE) was higher in plants grown under elevated CO_2 (Rogers *et al*. 2008) as it had produced 2.86 g of biomass per one litre of water consumed against 2.1 g and 1.43 g biomass per one litre of water under OTC-ambient CO_2 and open field conditions respectively (Fig 2). It can otherwise be inferred that plants under elevated CO_2 has used just 350 ml of water to produce one gram of dry matter against 477 ml and 698 ml per gram dry matter under OTC-ambient CO_2 and open field conditions respectively. The greater WUE is due to the greater carbon gain under elevated CO_2 (Mcalpine *et al*. 2008) as well as due to reduced carbon

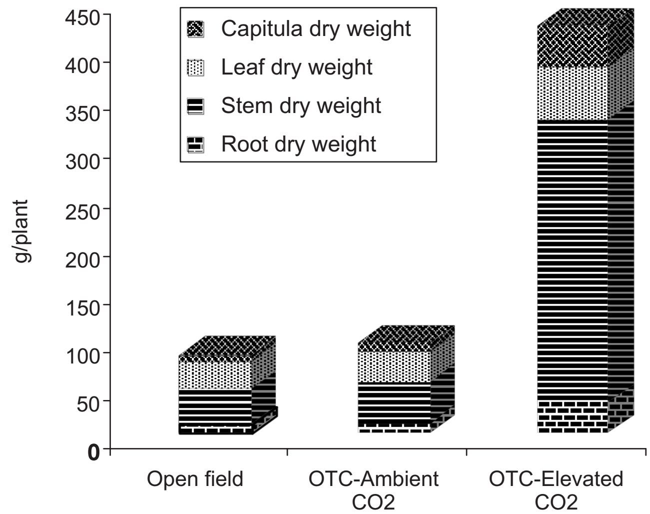

Fig 1 Biomass partitioning in *Parthenium hysterophorus* grown under ambient and elevated CO_2 (OTC) and open field conditions.

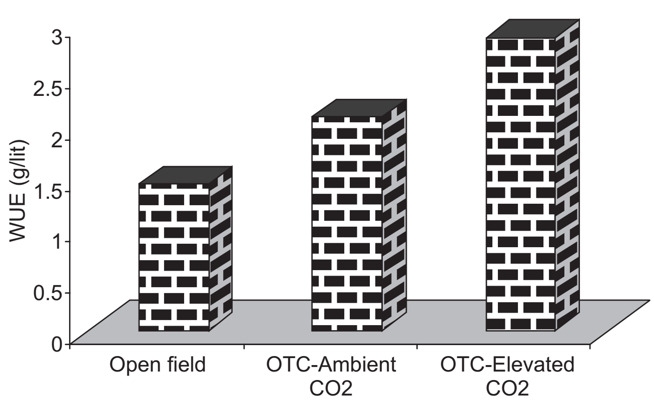

Fig 2 Water-use effieciency (WUE) in *Parthenium hysterophorus* grown under ambient and elevated CO_2 (OTC) and open field conditions.

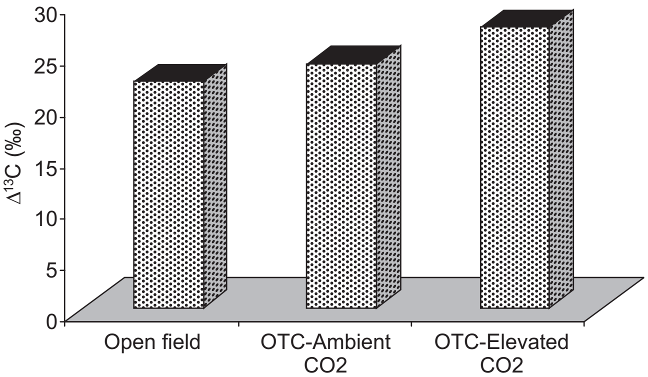

Fig 3 Carbon isotope discrimination ($\Delta^{13}C$) in *Parthenium hysterophorus* grown under ambient and elevated CO_2 (OTC) and open field conditions.

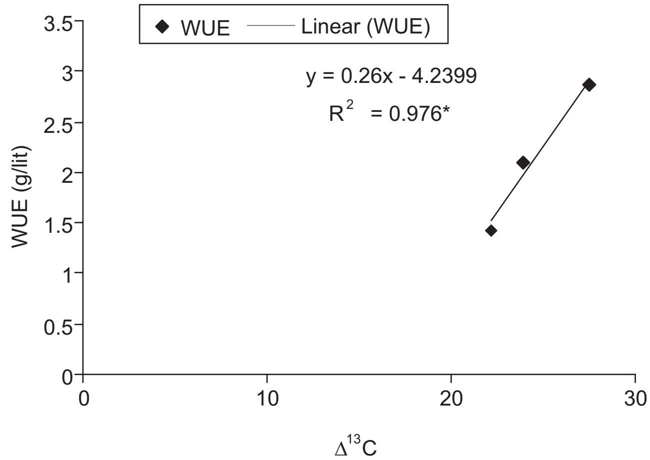

Fig 4 Relationship between Carbon isotope discrimination (($\Delta^{13}C$) and water-use effieciency (WUE) (*P = <0.01)

loss as the photorespiration is repotedly negligible (Brandon *et al*. 1987). The carbon isotope discrimination ($\Delta^{13}C$) inversely represents the incorporation of the heavier fraction of the stable carbon isotope, ie ^{13}C in the plant biomass and the accumulation of ^{13}C fraction of the carbon was influenced by the CO_2 enrichment. Carbon isotope discrimination ($\Delta^{13}C$) was higher (27.5‰) in plants grown at elevated levels of CO_2 than of those grown at OTC-ambient CO_2 (23.9‰) (Fig 3). Plants grown in OTCs have higher $\Delta^{13}C$ than of those grown in open field conditions (22.13‰) indicating the higher temperature favouring the photosynthetic response and growth. The plants displaying higher $\Delta^{13}C$ have shown higher water use efficiency and biomass production. This was evident from the strong positive correlation between $\Delta^{13}C$ and WUE (Fig 4) and biomass (Fig 5). High values of $\Delta^{13}C$ would be associated with an enhanced ability to exploit the resources and reflect a better adaptation to the environment. Biomass allocation to roots (table 1) indicate that the below-ground sinks contributed to the large growth

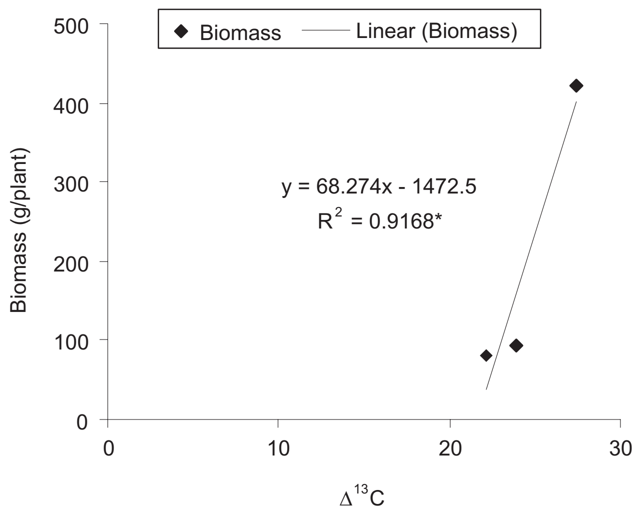

Fig 5 Relationship between Carbon isotope discrimination (($\Delta^{13}C$) and plant biomass (*P = <0.01)

Table 1 Growth parameters of *Parthenium hysterophorus* grown under ambient and elevated CO_2 (OTC) and open field conditions

Character	Treatment			% increase due to elevated CO_2 over		F_{2df}	P
	Open field	OTC-ambient CO_2	OTC-Elevated CO_2	Open field	OTC-ambient CO_2		
Plant height	87	93	176	102.3	89.2	74.29	0.0001
No. of primary branches	12	10	16	33.3	60	5.385	0.021*
No of leaves	376	394	1 487	295.5	277.4	879.096	0.0001
Leaf area	3 176	3 463	5 387	69.6	55.5	1 303.455	0.0001
Number of flowers (capitula)	1 582	1 794	8 600	443	379	16 027.305	0.0001
Root length (Cm)	36	39	58	61	48.7	224.737	0.0001
Stem base girth (Cm)	3.4	3.6	6.8	100	88.9	280.00	0.0001
Leaf dry weight	28.2	31.4	53.6	90.1	70.1	172.772	0.0001
Stem dry weight	36.8	42.6	294	699	590	3 432.210	0.0001
Root dry weight	9.2	10.8	32.4	252	200	556.552	0.0001
Capitula dry weight	6.9	8.4	42.8	520	409	325.582	0.0001

*Significant at 5% probability and non significant at 1%

stimulation under CO_2 enriched environment providing a link between CO_2 responsiveness and invasiveness (Weltzin *et al*. 2003, Ziska 2003). Previous studies (Ziska and George 2004) had also reported that invasive species may show a stronger response to both recent and projected changes in atmospheric carbon dioxide than other plant species. There was a clear coincidence between exponential increase in the atmospheric CO_2 / increase in temperature and spread of the *Parthenium* in India especially since middle of the 20^{th} century indicating the elevated CO_2 and associated temperature increases were the factors responsible for its spread and further *Parthenium* may become aggressive and problematic under changing climate. As the large increases in atmospheric CO_2 concentration have been shown to alter both plant biomass and chemistry in many plant species (Ainsworth and Long 2005, Taub *et al*. 2008) it may possibly stimulate the production and concentration of phytochemicals (Ziska 2005, Wang *et al*. 2010) and production of allergenic pollen (LaDeau and Clark 2006, Rogers *et al*. 2006, Ziska *et al*. 2003) in *Parthenium* that are reportedly responsible for human and animal health hazards. The potential for further invasion under both current and predicted climates, especially increasing CO_2, emphasizes the concerns that *Parthenium* is a weed of national significance.

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