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The stimulating impact of elevated temperatures on growth and productivity of *Parthenium hysterophorus* L.

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Abstract

Invasive alien weeds pose a great threat to biodiversity by suppressing the native flora and causing negative impacts on crop yields. *Parthenium hysterophorus* is an exotic weed that causes nuisance and health hazard to mankind and animals, and is a danger to the environment. Experiments were conducted during summer and winter to understand the impact of different temperature conditions on the growth of *Parthenium*. Pot studies conducted at 22-30^{0}C temperature conditions were considered as control. During summer at 35-45^{0}C, various growth parameters significantly increased in comparison to the 7-15^{0}C temperature regime in winter. Different biochemical constituents were also higher in the leaves during summer than in winter season. The present investigation clearly indicates that growth and productivity of *Parthenium* was directly proportional to the increase in atmospheric temperature, indicating the possibility of the influence of rising temperature on its invasiveness.

Keywords: Climate change

Introduction

The process of economic development has resulted in large scale of environmental degradation across the world. Rapid industrialization, increases in greenhouse gases in the atmosphere, climate change, loss of biodiversity, deforestation and environmental pollution have all become matters of serious concern. Climate change is a global phenomenon, and increases in the global atmospheric concentration of carbon dioxide and other greenhouse gases beyond their natural level caused by anthropogenic activities are responsible for increases in the average temperature of the earth i.e. global warming. Global atmospheric carbon dioxide (CO_2) concentration is predicted to rise to 550 ppmv by the middle of the present century (Prentice et al.2001) and it has been predicted that there will be reduction in rainfall in future in comparison to the present rainfall pattern. Such climatic changes will adversely affect the entire agricultural production system through direct or indirect effects on crops, livestock and pests, and there is also predicted to be significant changes in the distribution and abundance of certain kinds of weeds (Houghton *et al*.1990). The Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report indicated that many developing countries are more vulnerable to climate change because they largely depend on climate-sensitive sectors.

Invasive alien weeds are aggressive invaders outside their natural range, adversely affecting the proper utilization of land, biodiversity and environment. Weeds have a greater genetic diversity than crop plants and show positive responses to elevated temperature and carbon dioxide level in comparison to crop plants. *Parthenium hysterophorus* L. (Asteraceae), popularly known as gajar grass, carrot weed, feverfew, star weed and whitetop, is one of the top ten worst weeds in the world. Itis native to north-east Mexico, and was probably introduced to India along with wheat grains under the PL 480 scheme from USA; it has spread alarmingly to almost all the states in India. Growing in wasteland, roadsides, railway tracks, vacant sites and construction sites, it can reduce crop yields up to 40% (Khosla & Sobti 1981). It begins to flower within a month of seedling emergence, and it can continue to flower profusely until senescence (Tamado *et al*. 2002). *P.hysterophorus* is considered a noxious weed because of its prolific seed production, plasticity in its physiological behaviour (Haseler1976), allelopathic

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effect on the neighbouring plants (Adkins &Sowerby 1996), strong competitiveness with crops(Tamado*et al*. 2002) and health hazard to humans (Pasricha 2010) as well as animals (Chippendale &Panetta 1994).Because of these effects, it contributes to social and economic instability by placing constraints on sustainable development, economic growth and food security (Kohli *et al*. 2006).

Biochemical and molecular responses in plants under elevated temperature conditions are not well documented in the literature. However, a critical perusal of the literature revealed few reports on changes in growth and physiological processes of various crop plants exposed to different temperature regimes (Mavi & Tupper 2004; Savicka&Skute 2010; Ribeiro *et al*. 2012). All the growth stages of *P.hysterophorus* can be seen throughout the year, but it has been observed to grow very quickly during the summer season. This study was designed to provide data on comparative growth under different temperature regimes due to seasonal variation.

Materials & Methods

The experiments were conducted at Amity University in Noida (28º57'N,77º32'E, elevation 200 m), located 20 km southeast of New Delhi in Gautam Budh Nagar district of Uttar Pradesh state, India. Noida experiences three seasonsper year:summer (Apr-June), rainy (July- Aug) and winter (Nov-Feb). With an annual mean temperature of 25-33°C, the mean maximum (42.5ºC) occurs in summer (May-June) and the mean minimum (4.5ºC) in winter (Dec- Jan).

The pot studies were conducted in the Botanical Garden of Amity University in Noida. *Parthenium hysterophorus* plants were grown under three different temperature regimes (seasons) (35-45,7-15and 22-30ºC) representing typical warm, cool and intermediate conditions respectively. Photoperiod was 10 hours and relative humidity was 65% . Earthen pots 25 cm deep and 25 cm in diameter had their drainage holes plugged with cotton and these were filled with equal weights of a homogeneous mixture of 10 kg sandy loam soil and 80 gm of diammonium phosphate. Ten viable seeds of *Parthenium hysterophorus* were sown per pot equidistantly on the surface and covered with a thin layer of soil. After 10 days, seedlings were thinned to five plants per pot in those pots which had more than five plants. The soil of each pot was thoroughly watered and then uniform watering was continued for upto 60 days.

Plant growth was recorded after 30 and 60 days by recording the number of seedlings per pot, number of leaves per plant, leaf length, plant height, number of branches per plant, number of capitula per plant and number of seeds per five capitula.

Different biochemical constituents present in the leaves were analyzed as follows. The amount of chlorophyll was determined by the method of Arnon (1949). 0.5 grams of fresh leaves were ground with 10 ml 80% acetone and centrifuged at 3000g for 10 mins. The volume of supernatant was recorded. The optical density was measured at 645 and 663 nm, and the concentrations (mg g^{-1}) of chlorophyll a, chlorophyll b and total chlorophyll calculated by using coefficients multiplied by the OD_{645} and OD_{663} readings (total chlorophyll [20.2, 8.02], chlorophyll a [12.7, -2.69], chlorophyll b [22.9, -4.68]) in the formula:

$$\text{concentration} = [a(OD_{645}) + b(OD_{663})].(V/1000W)$$

where V is the volume of the supernatant in ml, W is the fresh weight of the sample in grams, and OD is the optical density reading.

To estimate total soluble sugars, *Parthenium* leaves were harvested after 60 DAS and placed in an electric oven with forced air circulation at 70ºC for 96 hr. The leaf dry matter was lyophilized and the leaf powder kept in glass containers in the dark at 15ºC until biochemical analysis. Carbohydrate content was determined with 50 mg of dry leaf powder incubated with

5 ml of distilled water at 100ºC for 30 min. Subsequently the homogenized solution was centrifuged at 2000 g for 5 min at 20ºC and the supernatant removed. Quantification of total soluble sugars was carried out at 490 nm according to the method of Dubois *et al*. (1956) using glucose as a standard.

Quantitative estimation of protein content was analyzed by the method of Lowry *et al*. (1951). Stock solution of the following reagents was prepared: alkaline sodium carbonate solution (0.2 % Na_2CO_3 in 0.1 N NaOH); copper sulphate - sodium potassium tartarate solution (0.5% $CuSO_4 . 5H_2O$ in 1% sodium potassium tartarate); alkaline copper reagent (mixed 50 ml of reagent A and 1 ml of reagent B); Folin-Ciocalteu reagent diluted with an equal volume of water just before use; 1 N NaOH.0.5 grams fresh leaf material of *Parthenium* were homogenized with 1 ml of 1 N NaOH for 5 minutes at 100 ºC. 5 ml of alkaline copper reagent were added to it and the mixture allowed to stand at room temperature for 10 min. Then 0.5 ml of Folin-Ciocalteu reagent were added immediately and mixed in the test tube. The absorbance of the solution was measured at 650 nm after 30 min. The amount of protein was calculated with reference to a standard curve for lysozyme.

All the experiments were laid out in a complete randomized block design with three replicates (Snedecor 1957).

Results

In summer, seeds begin to germinate after five days, but in intermediate and winter seasons seed germination was delayed with fewer seedlings. Ten days after sowing, there were more seedlings in pots sowed in summer; numbers were reduced by almost a quarter in winter (Table 1). After 30 days, there were substantial differences in the various growth parameters, with every measurement greater for seeds sown in summer (Table 1).

The same patterns were evident for the various biochemical constituents (Table 1), with values in summer very different from those of winter.

Days after sowing	**Variable**	**Season (a proxy for temperature)**		
		Winter	**Intermediate**	**Summer**
10	Seedlings per pot	5.62 ± 0.45	7.23 ± 0.63	9.16 ± 0.94
30	Leaves per plant	5.95 ± 0.57	7.36 ± 0.74	9.52 ± 0.87
30	Leaf length (cm)	4.82 ± 0.32	6.84 ± 0.63	8.14 ± 0.72
30	Plant height (cm)	9.71 ± 0.82	10.72 ± 0.88	12.56 ± 0.98
60	Leaves per plant	19.64 ±0.73	23.95 ± 0.93	29.36 ± 0.85
60	Leaf length (cm)	10.45 ± 0.09	13.92 ± 0.12	15.12 ± 0.23
60	Plant height (cm)	31.73 ± 0.25	45.30 ± 0.59	54.95 ± 0.46
60	Number of branches per plant	5.84 ± 0.03	7.31 ± 0.08	8.26 ± 0.09
60	Number of capitula per plant	239 ± 0.86	275 ± 0.96	288 ± 0.64
60	Number of seeds per five capitula	16 ± 0.05	23 ± 0.07	25 ± 0.19
60	Total chlorophyll content (mg/g)	1.92 ± 0.21	2.73 ± 0.38	3.84 ± 0.96
60	Total soluble sugar (mg/g)	1.93 ± 0.16	2.52 ± 0.31	3.46 ± 0.87
60	Protein content (µg/ml)	71 ± 0.52	98 ± 0.35	123 ± 0.94

Table 1: Effects of seasonal variation in temperature on growth parameters and biochemical constituents of *Parthenium hysterophorus.*

Discussion

Climate change directly affects the population dynamics, invasive capacity and decline and extinction of plant species and it can provide opportunity for weeds to invade into new ecosystems. Temperature and atmospheric CO_2 are considered as climatic variables that can alter plant invasiveness (Bradley *et al*. 2010). *Parthenium hysterophorus* L. is reported to be physiologically adaptable and thereby tolerant to wide range of temperature regimes, lower rainfall and elevated CO_2 level (Hegde & Patil 1980), as observed in the present investigation. Rising atmospheric temperature may give competitive advantage to C_4 plants over C_3 plants; the majority of weeds are C_4 plants (Singh *et al*. 2011). Moore *et al*.(1987) and Tirumala Devi & Raghavendra (1993) reported that *Parthenium* is a C_3 - C_4 intermediate plant because the upper leaves seem to use the C_3 photosynthetic pathway, while middle and basal leaves have the typical Kranz leaf anatomy associated with C_4 photosynthesis. *Parthenium* is therefore likely to increase its growth in elevated temperature and CO_2 concentrations.

A higher percentage of *Parthenium* seed germination was observed during summer. Ahlawat *et al*. (1979) reported that *Parthenium* seeds treated at 40ºC for 24 h prior to germination brought down germination success to 40%, whereas treatment at 90ºC showed only 8% germination. Nguyen *et al*. (2010) have reported that the highest number of *Parthenium* seeds were produced under warm conditions, with a maximum number (60%) of unfilled seeds under cool condition. Warm dry conditions allow reproduction after only 50 days of growth, while cool and wet conditions delay this to after 75 days. Warm conditions may therefore promote the reproductive ability of *Parthenium* by increasing seed production and the seed-fill percentage, producing seeds with the capacity to live longer in the soil seed bank. Higher temperature during seed development increases seed germinability in many species (Llorens *et al*. 2008). According to Long *et al*. (2008), warm temperature at the time of *Parthenium* seed production enables the seed once shed to persist in the soil for more than three years, whereas cool temperature permit survival for only 1 - 3 years.

Toh *et al*. (2011) reported that increased temperature enhances growth of *Parthenium*, enlarges canopy size and structure and accelerates population growth rate because of the shortened life cycle, supported by Entz &Fowler (1991) in wheat and Pandey *et al*. (2003) in *Parthenium*. Singh & Singh (2010) reported the extensive coverage of vacant cultivated land during summer by *Parthenium*. The growth-enhancing effects of CO_2 enrichment will increase with increasing temperature,increasing water-utilization efficiency because of the large biomass (Idso 1990).

The findings of the present paper clearly indicate the inhibition of photosynthesis due to low light intensity and short photoperiod in winter, decreasing photosynthates probably because of decreased biosynthesis of chlorophyll - resulting in less biomass production in winter. Naidu &Swamy (2009) reported that *Eugenia jambolana, Terminalia arjuna* and *Chukrasia tabularis* plants grown under high light intensity showed higher level of biochemical constituents such as carbohydrates, protein and lipids in all plant parts as compared to plants grown in low light intensity. Goodchild *et al*. (1972) also reported that shaded plants show lower protein content than plants grown in the sun; the low protein content in shade-grown plants is associated with lower activity of RUBPcarboxylase (Bjorkman 1968) and nitrate reductase (Naidu &Swamy 1993). Similar results were observed in *Erythrina variegate* by Muthuchelian *et al*. (1989) and in *Pongamia pinnata* by Naidu &Swamy (1993).

Hence the present study clearly indicates that *Parthenium hysterophorus* is likely to accelerate its growth under changing climatic conditions and it will become a more aggressive weed due to the warmer climatic conditions in future. The data of the present paper can help in development of predictive models of weed emergence in the agricultural lands and may generate significant information that can be useful for the development of integrated management strategies for the control of *Parthenium*.

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