Morpho-physiological responses of two Australian biotypes of parthenium weed (*Parthenium hysterophorus* L.) to soil moisture stress

Ali A. Bajwa[1,2], Bhagirath S. Chauhan[2] and Steve W. Adkins[1,2]
[1] School of Agriculture and Food Sciences, The University of Queensland, Gatton, Queensland 4343, Australia
[2] The Centre for Plant Science, Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Toowoomba, Queensland 4350, Australia
(a.bajwa@uq.edu.au)

Summary A pot study was conducted to evaluate the morpho-physiological responses of two Australian biotypes (Clermont and Toogoolawah) of parthenium weed (*Parthenium hysterophorus* L.) to 50, 75 and 100% of the soil water holding capacity (WHC). Moisture stress affected growth of both biotypes significantly ($P < 0.05$); however, the growth of Clermont was less affected than Toogoolawah across all soil moisture regimes. Significantly greater numbers of branches, leaves, longer shoots, higher fresh weight, and dry weight were observed for plants growing at 75% of WHC as compared with those growing at 100% of WHC. However, root length was increased in response to the 50% reduction in soil moisture. Physiological attributes including, net photosynthesis and stomatal conductance were also higher for Clermont than Toogoolawah and were at a maximum at 75% of WHC. Parthenium weed maintains good growth under sub-optimal soil moisture and therefore, is able to invade a wider range of environments than expected.

Keywords Biological invasion, parthenium weed, stress tolerance, weed biology.

INTRODUCTION

Parthenium weed is a Weed of National Significance (WoNS) in Australia with high invasive potential and severe impact on agriculture (Shabbir and Adkins 2014, Bajwa *et al.* 2016). It causes huge losses to grazing land productivity, livestock production, native biodiversity and crop production (Adkins and Navie 2006). Parthenium weed is more problematic due to its highly invasive nature. Two Australian biotypes of parthenium weed, Toogoolawah and Clermont (named after the places of their first introductions) differ significantly in their invasiveness. Clermont is highly invasive while Toogoolawah is non-invasive (Navie *et al.* 1996, Hanif *et al.* 2012). So, comparative study of their growth responses may provide better understanding of the invasion mechanism and will have implications for management.

Parthenium weed can tolerate abiotic stresses, which enables it to invade, establish, and even flourish under a wide range of stressful conditions (Kohli *et al.* 2006). Soil moisture is one of the most important factors determining the establishment and spread of an invasive weed species (Bajwa *et al.* 2016). Parthenium weed is known to invade areas with low moisture availability which might be due to its ability to tolerate soil moisture stress (Bajwa *et al.* 2016). Nguyen (2011) reported that under a low soil moisture condition, parthenium weed's life span was reduced by up to 43% while growth was enhanced by 20% due to modifications in the plant's vegetative and reproductive biology. Parthenium weed growth was improved under decreased soil moisture levels along with increased temperature and CO_2 levels (Belgeri 2013). The ability to tolerate the abiotic stresses through physiological regulation could be a strong tool for invasion.

Fifty percent of soil WHC is supposed to be a significant drought which affects growth of several crops and weed species (Nguyen 2011). Only a few studies have been conducted to evaluate the morpho-physiological responses of parthenium weed to soil moisture stress. The results of the present study may enable us to predict features of its invasion potential for different climatic and ecological zones.

MATERIALS AND METHODS

The experiment was carried out in a completely randomized design with four replications per biotype and 100% of WHC was considered as a control (which means total amount of water held by soil under field conditions). Soil moisture levels were maintained by calculating the actual water holding capacity of the soil and by adding the required amount of water at regular intervals. The weight of plants was also considered while maintaining the pot weight in each treatment. Parthenium weed seeds were germinated in Petri dishes in an incubator (25/15°C day/night temperature with 12h/12h photoperiod). The seedlings were transplanted to the soil (heavy clay loam) filled pots (300 mm diameter) kept in a glasshouse after 2 weeks growth. The experiment ran for 85 days till the plants matured and produced seed. Number of leaves and branches were counted at peak vegetative growth (40 days after transplanting). Gas exchange parameters were also measured 40 days after transplanting between 10:00 am and 12:00 pm, on the penultimate leaves (three leaves per plant) using a LI-6400 portable photosynthesis system (LI-COR Inc., Lincoln, NE, USA). Root and shoot lengths, and plant fresh and dry weights were recorded at harvest. The effects of treatments on the variables were statistically analyzed and tested by an analysis of variance (ANOVA). Comparisons among treatment means were made using the Tukey's HSD (honest significant difference) test calculated at $P < 0.05$.

RESULTS

Soil moisture stress affected growth of both Australian biotypes of parthenium weed significantly ($P < 0.05$) (Tables 1, 2). Morphological attributes including, number of leaves, number of branches, root length, shoot length, plant fresh weight, and plant dry weight were affected by different soil moisture levels (Table 2). Overall, the growth of Clermont biotype was more than Toogoolawah biotype at all moisture levels (Table 1). Maximum number of branches, number of leaves and shoot length were observed from plants growing at 75% moisture of soil WHC as compared with those growing at 100% WHC (Table 2). However, 50% WHC caused a significant decline in branching and leaf score of both biotypes as compared with 100%.

Root length was also more for Clermont as compared with Toogoolawah at all moisture levels (Table 1). Maximum root length for both biotypes was observed at severe moisture stress (50% WHC) followed by 75% WHC. Minimum root length was observed at 100% WHC. Whole plant fresh and dry weights were also more for Clermont than Toogoolawah (Table 1). Maximum fresh and dry weights were recorded from plants growing at 75% WHC followed by those at 100% WHC whereas, the minimum fresh and dry weights were observed at 50% WHC for both biotypes (Table 2).

Net photosynthesis and stomatal conductance were higher for Clermont than Toogoolawah across the moisture levels (Table 3). Maximum net photosynthesis and stomatal conductance were observed from plants growing at 75% WHC followed by those growing at 100% WHC while minimum values for these attributes were observed at 50% WHC (Table 3).

DISCUSSION

The ability of parthenium weed to grow at different levels of soil moisture indicates its successful biology to adapt a wide range of environmental conditions. Previously, variable responses of parthenium weed to soil type and quality have also been denoted to its invasiveness (Annapurna and Singh 2003). Vigorous growth of Clermont biotype at various moisture levels as compared with Toogoolawah biotype provides the

Table 1. Effect of biotypes on morphological attributes.

Attribute	Biotype	
	Clermont	Toogoolawah
No. of branches	21a[A]	18b
No. of leaves	63a	53b
Shoot length (cm)	60a	55b
Root length (cm)	23a	21b
Plant fresh weight (g)	122a	114b
Plant dry weight (g)	49a	36b

[A] Individual treatment means in each row followed by different letters are significantly different at $P < 0.05$.

Table 2. Effect of soil moisture on morphological attributes.

Attribute	Soil moisture level		
	WHC50	WHC75	WHC100
No. of branches	15a[A]	29a	19b
No. of leaves	43c	73a	59b
Shoot length (cm)	53c	63a	57b
Root length (cm)	24a	22ab	21b
Plant fresh weight (g)	102c	132a	120b
Plant dry weight (g)	32c	46a	39b

[A] Individual treatment means in each row followed by different letters are significantly different at $P < 0.05$.

Table 3. Effect of biotypes and soil moisture on photosynthesis and stomatal conductance.

Net photosynthesis (mol m^{-2} s^{-1})		
	Clermont	Toogoolawah
WHC50	21.8e[A]	17.3f
WHC75	35.2a	30.8b
WHC100	27.2c	25.0d
Stomatal conductance (m mol m^{-2} s^{-1})		
	Clermont	Toogoolawah
WHC50	0.7cd	0.3d
WHC75	3.4a	1.6b
WHC100	1.2bc	0.9c

[A] Interaction means followed by different letters are significantly different at $P < 0.05$.

reason for profound invasiveness of Clermont (Bajwa *et al.* 2016). Sustaining its growth through morphological adaptations and physiological regulation even at low moisture availability provides parthenium weed an excellent mechanism to reproduce and spread effectively (Nguyen 2011). Maximum growth and photosynthetic activity at 75% of soil WHC is unique and shows that parthenium weed thrives best under slightly less moist conditions. Usually, plants thrive best at optimum moisture which exist at soil WHC but the ability of parthenium weed to grow best at 25% less moisture of soil WHC is an important feature towards moisture stress tolerance. More branching, leaf score and tall stature ensures vigorous growth and physiological activity. Increase in root length at 50% less soil moisture would have helped plants to absorb water efficiently. In addition, higher photosynthetic activity of Clermont biotype might have significant role in its invasiveness.

In conclusion, the Clermont biotype of parthenium weed grew best at the 75% of WHC. Vigorous growth and higher photosynthetic efficiency of the Clermont biotype may explain why it is highly invasive compared to Toogoolawah which is a non-invasive biotype. Although growth and photosynthesis of parthenium weed was reduced at the 50% of WHC, plants still completed their life cycle. The ability to grow vigorously and moderately at 75 and 50% of WHC, respectively, may help parthenium weed to establish in a wide range of edaphic environments. There are certainly many other factors involved in invasion mechanism of these parthenium weed biotypes. Further research to evaluate the individual and interactive effects of other environmental factors including, temperature and CO_2 may unravel the mechanism of parthenium weed invasion. It will not only help to predict future invasions under climate change scenario but also will have pragmatic implications for management of this problematic weed.

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REFERENCES

Adkins, S. and Shabbir, A. (2014). Biology, ecology and management of the invasive parthenium weed (*Parthenium hysterophorus* L.). *Pest Management Science* 70, 1023-9.

Adkins, S.W. and Navie, S.C. (2006). Parthenium weed: a potential major weed for agro-ecosystems in Pakistan. *Pakistan Journal of Weed Science Research* 12, 19-36.

Annapurna, C. and Singh, J.S. (2003). Variation of *Parthenium hysterophorus* in response to soil quality: implications for invasiveness. *Weed Research* 43, 190-98.

Bajwa, A.A., Chauhan, B.S., Farooq, M., Shabbir, A. and Adkins, S.W. (2016). What do we really know about alien plant invasion? A review of the invasion mechanism of one of the world's worst weeds. *Planta* 244, 39-57.

Belgeri, A. (2013). Assessing the impact of parthenium weed (*Parthenium hysterophorus* L.) invasion and its management upon grassland community composition. PhD Thesis, The School of Agriculture and Food Sciences, The University of Queensland, Australia.

Hanif, Z., Adkins, S.W., Prentis, P.J., Navie, S.C. and O'Donnell, C. (2012). Characterization of the reproductive behaviour and invasive potential of parthenium weed in Australia. *Pakistan Journal of Weed Science Research* 18, 767-74.

Kohli, R.K., Batish, D.R., Singh, H.P. and Dogra, K.S. (2006). Status, invasiveness and environmental threats of three tropical American invasive weeds (*Parthenium hysterophorus* L., *Ageratum conyzoides* L., *Lantana camara* L.) in India. *Biological Invasions* 8, 1501-10.

Navie, S.C., McFadyen, R.E., Panetta, F.D. and Adkins, S.W. (1996). The biology of Australian weeds. 27. *Parthenium hysterophorus* L. *Plant Protection Quarterly* 11, 76-88.

Nguyen, T.L.T. (2011). The invasive potential of parthenium weed (*Parthenium hysterophorus* L.) in Australia. PhD Thesis, The School of Agriculture and Food Sciences, The University of Queensland, Australia.