Growth of Queensland *Jatropha gossypifolia* biotypes under varying water regimes

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Summary Bellyache bush (*Jatropha gossypifolia* L. (Euphorbiaceae)) is a serious weed of dry tropical regions of northern Australia, with the potential to spread over much of the tropical savannah. It is well adapted to the harsh conditions of the dry tropics, defoliating during the dry season and rapidly producing new leaves with the onset of the wet season. In this study we examined the growth and biomass allocation of the three Queensland biotypes (Queensland Green, Queensland Bronze and Queensland Purple) under three water regimes (water-stressed, weekly watering and constant water). Bellyache bush plants have a high capacity to adjust to water stress. The impact of water stress was consistent across the three biotypes. Water stressed plants produced significantly less biomass compared to plants with constant water, increased their biomass allocation to the roots and increased biomass allocation to leaf material. Queensland Purple plants allocated more resources to roots and less to shoots than Queensland Green (Queensland Bronze being intermediate). Queensland Green produced less root biomass than the other two biotypes.

Keywords Bellyache bush, water stress, biomass allocation.

INTRODUCTION

Jatropha gossypifolia L. (Euphorbiaceae), commonly known as bellyache bush, is a serious weed of dry tropical regions of northern Australia (Bebawi *et al*. 2007). There are infestations in Western Australia, Northern Territory and Queensland, and it has the potential to spread over much of the tropical savannah (Thorp and Lynch 2000). The weed forms dense thickets, reducing the usefulness of land for pastoral and grazing purposes. It also reduces biodiversity, affects fire regimes and increases erosion along creek and river banks (Csurhes 1999, Bebawi *et al*. 2007).

Bellyache bush is a genetically diverse species, and molecular genetic studies suggest that multiple introductions have occurred from throughout its native range (Prentis *et al*. 2009). This genetic diversity may contribute to the morphological, phenological and physiological diversity of bellyache bush in Australia, where five biotypes have been identified. The Queensland Bronze and Queensland Green biotypes grow in North Queensland; Queensland Purple in Far North Queensland; and Darwin Purple and Katherine Green occur in the Northern Territory (Bebawi *et al.* 2007). A sixth biotype may also exist; a green-leaved variety in Western Australia has been tentatively named Kununurra Green. Detailed taxonomic, genetic and ecological studies are required to verify and establish differences among these Australian biotypes. Any differences found may be important to weed control, particularly biological control.

Bellyache bush is xerophytic and is well adapted to the dry tropics of northern Australia (Csurhes 1999) which experiences hot wet summers and a pronounced dry season in winter. Plants lose their leaves during the dry season (unless occurring along watercourses), thereby minimising water loss. New leaves are rapidly produced with the onset of the wet season. The plant also has fleshy and tuberous roots.

In this study we examined the growth and biomass allocation of the three Queensland bellyache bush biotypes to three water regimes.

MATERIALS AND METHODS

The Queensland Bronze and Queensland Green plants used in this study were grown from seeds sourced from various sites around Charters Towers, and seeds of the Queensland Purple biotype were collected from sites along the Palmer River. Fifteen similar sized bellyache bush plants per biotype were potted in 140 mm diameter black plastic pots and all leaves were removed from the plants. The plants were randomly arranged on three benches in a heated glasshouse maintained at the Alan Fletcher Research Station, (Sherwood, Queensland) (approx. 20–27°C). The following three treatments were randomly assigned so that there were five replicates of each treatment for each biotype:

- Low water – 30 mL every four weeks.
- Moderate water – 60 mL twice a week.
- High water – constant water (20 mm deep saucers, refilled every couple of days).

At the beginning and end of the 31 week trial growth parameters (basal stem diameter, plant height, and number of leaves) were recorded for all replicates. At the end of the trial, plants were uprooted, separated into roots, stems and leaves, and dried in an oven at

50°C for two weeks. Root, leaf and stem weights were recorded and then divided by total weight to determine root, leaf and stem mass fractions.

The impact of biotype, treatment and time on variables were analysed using ANOVA and Fisher's Unprotected LSD with the statistical program GenStat (16th edition). Due to the small sample size and high level of variability, the significance level was set at $\alpha < 0.1$.

RESULTS

Growth and biomass allocations were all significantly affected by the water treatments (Table 1). All three biotypes produced the greatest amount of biomass in the high water treatment (Table 1). Plants in the low water treatment produced the lowest amount of root, stem and leaf biomass of the three treatments (Table 1). A greater amount of stem and root material was produced by plants in the high water treatment. However, plants subjected to the high water and moderate water treatments produced similar amounts of leaf biomass (Table 1). Biomass allocation was also affected by the water treatment. Plants subjected to the low water treatment allocated the greatest proportion of biomass to roots yet a similar portion to leaves as the high water treatment. Plants receiving a moderate amount of water allocated the greatest proportion of biomass to leaves and the least to stems.

Plant biotype was a significant factor for root mass fraction, stem mass fraction, the amount of root biomass produced and the amount of leaf biomass produced (Table 1). The Queensland Green biotype produced less root biomass than the other biotypes and less leaf biomass than the Queensland Purple biotype. Queensland Green also allocated less biomass to roots and more to stems than Queensland Purple.

DISCUSSION

Bellyache bush plants have a high capacity to adjust to water stress. The three Queensland biotypes performed similarly in the three water treatments. Biomass production was greatly reduced by water stress for all three biotypes. This was most evident in the stems where the biomass dropped from 60–70 g for plants with no water-stress (constant water) to 2–3 g for plants under water-stress (with monthly watering). Growth, while greatly reduced, still occurred under considerable water stress.

As is typical of plants experiencing water stress (to improve water absorption; Poorter and Nagel 2000), a greater proportion of resources were allocated to the roots of water stressed bellyache bush plants, increasing from around 10% for plants exposed to constant water to around 20% for highly stressed plants (monthly watering) and root/shoot ratio increasing from around 12% to 28%. These are relatively low fractions and demonstrate a strategy similar to succulent species, which opportunistically absorb moisture from soil surface layers and store it above ground (Smith *et al*. 1997). Bellyache bush plants also store moisture in their roots (Randall *et al*. 2009). During less stressful conditions, a small root allocation may provide bellyache bush with a competitive advantage over native species as more resources can be devoted to above ground growth, thus allowing for higher growth rates (Smith *et al.* 1997, Zheng *et al*. 2009).

Reduced leaf production is also typical of water stressed plants, reducing water loss via transpiration (Poorter and Nagel 2000, Wu *et al*. 2009). There was a significant decrease in leaf biomass in the low water treatment compared to the moderate water treatment and the leaf mass fraction dropped to around 5%. Plants in the moderate water and high water treatments produced similar amounts of leaf biomass. This suggests water was the limiting factor for growth rather than light. Due to the huge allocation of biomass to stem material (~85% – attributable in part to moisture storage) for plants in the high water treatment, their allocation to leaf materials was relatively small.

Of the three biotypes identified in Queensland, Queensland Bronze and Queensland Green occur predominately in north Queensland from Rockhampton north to Cairns and co-occur at some sites (Bebawi *et al*. 2007). Queensland Purple occurs from Cairns north to Cape York. Queensland Bronze is believed to be the most common biotype (Bebawi 2014). Queensland Green plants produced less root biomass than the other two biotypes and allocated less biomass to roots. Queensland Purple plants produced more leaf biomass than Queensland Green. Although, lower biomass allocations to roots are generally associated with higher growth rates we found no difference in total biomass between biotypes. Furthermore, the absence of any significant interactions between the biotypes and treatments suggests that no one biotype is better adapted to water stress.

The results obtained in this study showed wide variation between plants within biotypes. This combined with the low sample size made it difficult to identify biotype specific trends and the presence of biotype × treatment interactions. The results from this study suggest that growth parameters are unlikely to be a significant factor contributing to the relative distribution of the biotypes in Queensland. However, further studies on the ecophysiology of the various bellyache bush varieties may help to explain current distribution patterns of bellyache bush populations in Australia.

Table 1. Mean growth and biomass values for *Jatropha gossypifolia* plants subjected to three different water treatments.

		Growth per week			Dry Weight (g)					Biomass allocation		
Treatment	Biotype	BSD (mm)	Height (cm)	Leaves (no.)	Shoots	Leaves	Roots	Root/shoot	Total	RMF	SMF	LMF
High water (H)	Bronze	0.40 ± 0.02	0.74 ± 0.08	0.61 ± 0.07	65.0 ± 6.5	3.8 ± 0.4	9.6 ± 0.8	0.15 ± 0.02	78.3 ± 5.9	0.13 ± 0.02	0.82 ± 0.02	0.05 ± 0.01
	Green	0.37 ± 0.01	0.64 ± 0.08	0.60 ± 0.04	54.7 ± 4.8	3.5 ± 0.5	5.4 ± 1.7	0.09 ± 0.02	63.5 ± 6.4	0.08 ± 0.02	0.86 ± 0.02	0.06 ± 0.01
	Purple	0.35 ± 0.01	0.51 ± 0.05	0.68 ±0.03	59.1 ± 4.2	4.2 ± 0.6	8.9 ± 2.2	0.14 ± 0.03	72.2 ± 5.8	0.12 ± 0.02	0.82 ± 0.0	0.06 ± 0.01
Moderate water (M)	Bronze	0.14 ± 0.02	0.52 ± 0.07	0.41 ± 0.07	10.1 ± 0.6	4.5 ± 0.5	2.5 ± 0.1	0.18 ± 0.01	17.2 ± 0.8	0.15 ± 0.01	0.59 ± 0.02	0.26 ± 0.02
	Green	0.11 ± 0.01	0.44 ± 0.04	0.55 ± 0.04	9.1 ± 0.8	3.4 ± 0.2	1.8 ± 0.4	0.14 ± 0.02	14.3 ± 1.2	0.12 ± 0.01	0.64 ± 0.02	0.24 ± 0.02
	Purple	0.11 ± 0.02	0.56 ± 0.02	0.60 ± 0.03	9.1 ± 0.4	4.9 ± 0.4	3.0 ± 0.1	0.22 ± 0.01	17.0 ± 0.7	0.18 ± 0.01	0.54 ± 0.01	0.29 ± 0.02
Low water (L)	Bronze	-0.03 ± 0.01	0.03 ± 0.01	0.17 ± 0.04	2.0 ± 0.2	0.1 ± 0.1	0.5 ± 0.1	0.26 ± 0.01	2.60 ± 0.2	0.21 ± 0.01	0.77 ± 0.01	0.03 ± 0.01
	Green	-0.02 ± 0.01	0.01 ± 0.01	0.08 ± 0.02	2.0 ± 0.4	0.1 ± 0.1	0.6 ± 0.1	0.30 ± 0.04	2.7 ± 0.5	0.23 ± 0.02	0.73 ± 0.03	0.04 ± 0.01
	Purple	-0.02 ± 0.01	0.01 ± 0.01	0.15 ± 0.03	1.9 ± 0.3	0.1 ± 0.1	0.6 ± 0.1	0.29 ± 0.04	2.6 ± 0.4	0.22 ± 0.02	0.73 ± 0.02	0.05 ± 0.03
ANOVA												
Biotype		NS	NS	* (QP>QB, QG)	NS	* (QP>QG)	* (QP, QB>QG)	NS	NS	* (QP>QG)	** (QG, QB>QP)	NS
Treatment		**** (H>M>L)	**** (H>M>L)	**** (H>M>L)	**** (H>M>L)	**** (H, M>L)	**** (H>M>L)	**** (L>M>H)	**** (H>M>L)	**** (L>M>H)	**** (H>L>M)	**** (M>H, L)
Biotype × Treatment		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*P <0.1, **P < 0.05, ***P < 0.01, ****P < 0.001, NS not significant

RMF, SMF and LMF, root, shoot and leaf mass fractions; QB, Queensland Bronze; QG, Queensland Green; QP, Queensland Purple.

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