Does the tolerance of weeds to herbicide change with elevated levels of CO_2?

Paul O. Downey[1], Tanya I. Lenz[2], William B. Sea[1], William Higgisson[1], Guillaume Lavier[1], P. Waryszak[2] and Michelle R. Lieshman[2]
[1] Institute for Applied Ecology, University of Canberra ACT 2601
[2] Department of Biological Sciences, Macquarie University NSW 2109
(paul.downey@environment.nsw.gov.au)

Summary The level of carbon dioxide (CO_2) in the atmosphere has increased substantially over the past 100 years and is predicted to continue rising over the coming decades. Whilst this change has contributed significantly to the problem of global climate change, CO_2 is important for plants, specifically during the process of photosynthesis; although high levels of CO_2 may be detrimental to some plants. Thus it is important to understand how future elevated levels of CO_2 may affect both native and non-native plants. The response of plants to elevated levels of CO_2 include: increased (i) biomass, (ii) height, (iii) inter-nodal length, (iv) pollen production, (v) woodiness due to assimilation of additional carbon, and (vi) water use efficiency due to reduced stomatal conductance. Many of these altered attributes may affect the species survival in a warmer world. They could also affect herbicide efficiency either through uptake rates of the active ingredient or by increased biomass which enables plants to better withstand the effective of the herbicide.

Several initial studies have investigated the tolerance of weed species grown under elevated CO_2 levels to herbicide. In a study of two north American weeds, *Amaranthus retroflexus* L. and *Chenopodium album* L., Ziska *et al*. (1999) found that whilst *A. retroflexus* declined and died, *C. album* was unaffected by glyphosate application under elevated CO_2. Later Ziska and Teasdale (2000) found a similar tolerance for the weed *Elytrigia repens* (L.) Desv. ex B.D. Jackson, and Ziska *et al*. (2004) found a similar tolerance for *Cirsium arvense* (L.) Scop. The reasons for this increased tolerance are unclear, but are likely to be attributed to increases in the root:shoot ratios. Manea *et al*. (2011) found that three of four exotic grasses in Australia also exhibited higher tolerance to herbicide under elevated CO_2; being *Chloris gayana* Kunth, *Eragostis curvula* (Schrad.) Nees, and *Paspalum dilatatum* Poir., whilst *Sporobolus indicus* (L.) R.Br. showed no difference between CO_2 levels. Manea *et al*. (2011) suggested that the increased tolerance may also be due to increased biomass.

In late 2011 we embarked on an expanded study to investigate the herbicide tolerance of 24 weed species (from a range of growth forms: Appendix 1) grown under ambient (approximately 390 ppm) and elevated (approximately 600 ppm) levels of CO_2. To determine herbicide tolerance, a range of assessments were made on each weed species, including leaf assessments such as chlorophyll content, stomatal conductance, and photochemical reactance, as well visual damage assessments and biomass (i.e. dry weights of roots and shoots).

Very preliminary results suggest no clear trend in the tolerance of these weeds to herbicide when grown under elevated CO_2, with some species showing higher tolerances and others no differences.

These results could have profound implications for weed management with the advent of climate change and the associated continued increases in atmospheric CO_2 because herbicide efficiency may be decreased. Given herbicide is one of the most widely used forms of weed control, any such changes in tolerance to herbicide may require new approaches to herbicide application and weed management.

Keywords Herbicide tolerance, climate change, carbon dioxide.

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Appendix 1. The list of weed species currently being examined to determine their tolerance to herbicide when grown under elevated levels of CO_2.

Species	Family	Common Name	Growth Form
Avena barbata	Poaceae	Wild Oats	grass
Bromus catharticus	Poaceae	Prairie Grass	grass
Chloris gayana	Poaceae	Rhodes Grass	grass
Ehrharta erecta	Poaceae	Panic Veldtgrass	grass
Pennisetum clandestinum	Poaceae	Kikuyu	grass
Acetosa sagittata	Polygonaceae	Turkey Rhubarb	herb
Ageratina adenophora	Asteraceae	Crofton Weed	herb
Biden pilosa	Asteraceae	Farmer's Friend	herb
Foeniculum vulgare	Apiaceae	Fennel	herb
Hirschfeldia incana	Brassicaceae	Buchanan Weed	herb
Plantago lanceolata	Plantaginaceae	Plantago	herb
Senecio madascagensis	Asteraceae	Fireweed	herb
Solanum nigrium	Solanaceae	Nightshade	herb
Sonchus sp.	Asteraceae	Sowthistle	herb
Tradescantia fluminensis	Commelinaceae	Wandering Jew	herb
Verbena bonariensis	Verbenaceae	Purple Top	herb
Asparagus aethiopicus	Asparagaceae	Asparagus Fern	shrub
Cotoneaster glaucophyllus	Asteraceae	Cotoneaster	shrub
Lantana camara	Verbenaceae	Lantana	shrub
Senna pendula	Fabaceae	Senna	shrub
Olea europaea ssp. *cuspidata*	Oleaceae	African Olive	tree
Anredera cordifolia	Basellaceae	Madeira Vine	vine
Ipomoea indica	Convolvulaceae	Morning Glory	vine
Rubus fruticosus	Rosaceae	Blackberry	vine