Climate Change and Invasive Weeds.

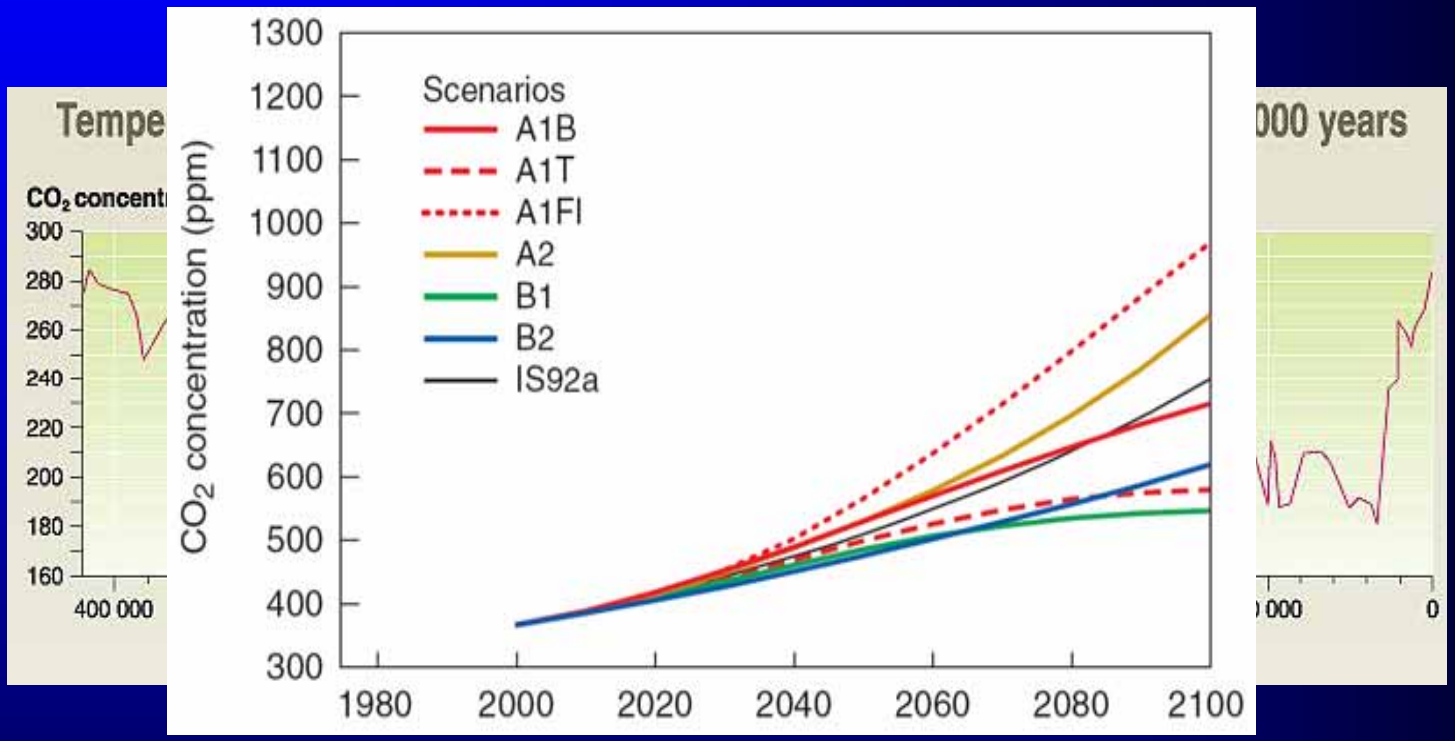
Lewis H. Ziska, USDA-ARS, Crop Systems and Global Change Lab.

USDA

ars Agricultural Research Service

Northeastern Weed Science Society Meetings, January 7-9, 2008, Philadelphia, Pennsylvania

CO_2 trends



CO_2 is a principle greenhouse/global warming gas.

CO_2 also represents the sole source of carbon for plants.
At present 96% of all plant species lack optimal CO_2 (C_3 v. C_4)

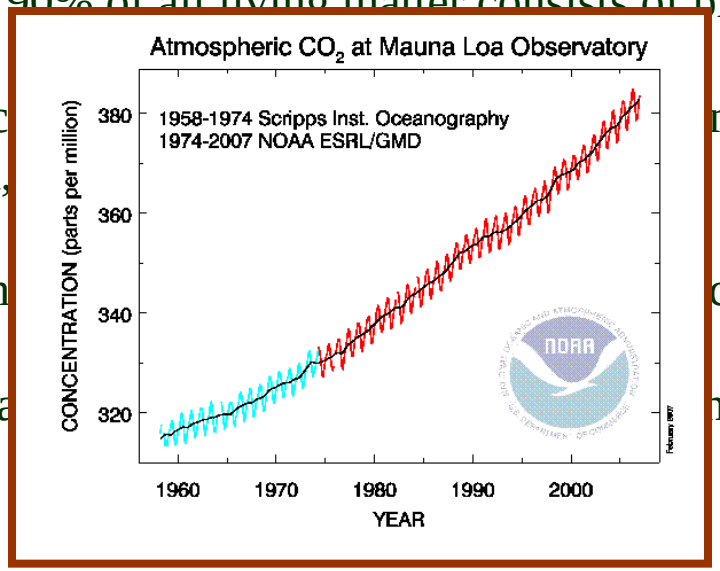
Plants are Important.

Plants are necessary for the flow of energy and carbon through ecosystems. 90% of all living matter consists of plant life.

With the exc ms, if plants did not exist,

Plant growth cal inputs.

Any perturba ng systems.

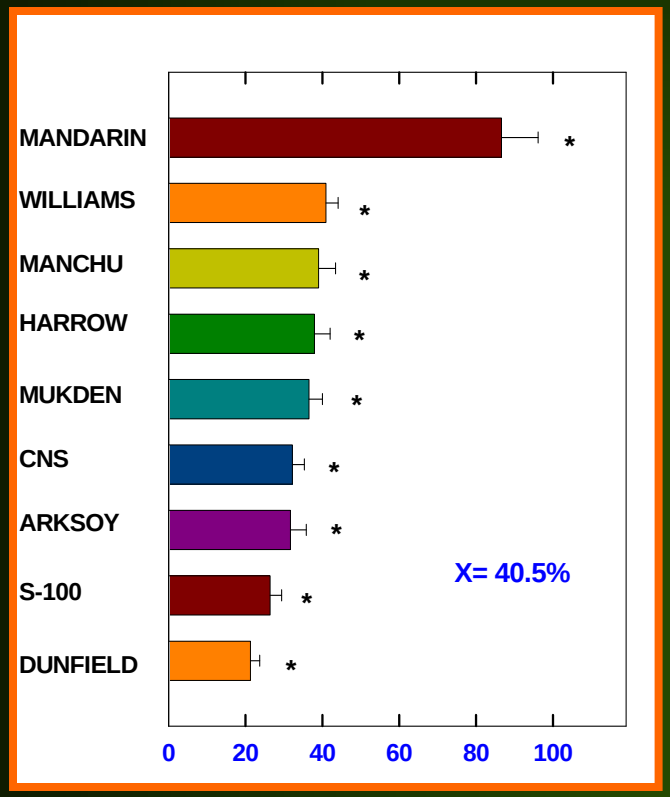


"People who imagined that life on earth consisted of animals moving against a green background, seriously misunderstood what they were seeing. That green background was busily alive. Plants grew, moved, twisted and turned, fighting for [resources]; and they interacted continuously with animals—discouraging some with bark and thorns, poisoning others, and feeding still others with pollen and seeds. It was a complex, dynamic process…one which most people didn't understand. "

Michael Crichton, Page 86, "Jurassic Park"

But isn't more plant growth, "good"?

Genetic variability in soybean with increasing CO_2



Evaluation of yield response of 9 soybean cultivars to 710 ppm CO_2.

Greenhouse study, USDA
Crop Science 41:385-391

Is green always good?

CO_2 and plant biology

Crop/weed competition

***Invasive weeds**

Weeds and public health.

Weed/Crop Interactions.

Do all plants respond equally to the same resource?

There are 45 major crops in the U.S.

There are 410 weed species associated with yield reductions for those crops.

Weeds account for 7-10 billion dollars in agricultural losses.

Wait! Aren't most weeds "C_4" plants, and therefore won't respond to CO_2?

- Although a number of weeds have C_4 photosynthesis and should, theoretically, not respond to increasing CO_2, a number of C_4 weeds can show a strong response.
- C_3 and C_4 weeds vary with C_3 and C_4 crops by region. Almost all major crops have both C_3 and C_4 weeds in the United States.
- Many of the worst weeds for a given crop are simply "wild" relatives and therefore have the same growth habits and photosynthetic pathway (e.g. rice and red rice, oat and wild oat).

Crop/Weed Interactions

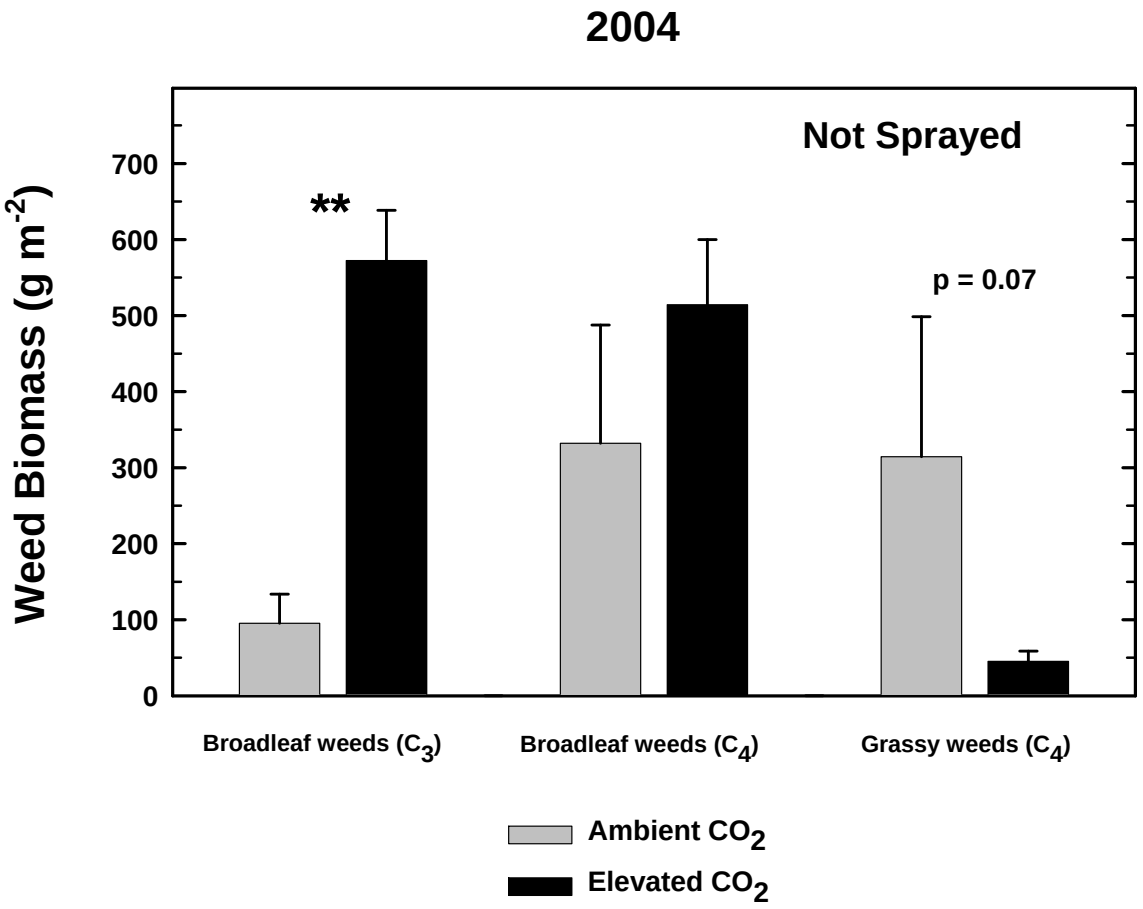
Does increasing CO_2 favor the crop or the weed?

Weed	Crop	Favored?	Environ.	Reference
Grasses (C_4)	Lucerne	Crop	Field	Bunce, 1993
Amaranthus retroflexus (C_4)	Soybean	Crop	Field	Ziska, 2000
Amaranthus retroflexus (C_4)	Sorghum	Weed	Field	Ziska, 2003
Chenopodium album (C_3)	Soybean	Weed	Field	Ziska, 2000
Taraxacum officinale (C_3)	Lucerne	Weed	Field	Bunce 1995
Albutilon theophrasti (C_3)	Sorghum	Weed	Field	Ziska, 2003
Taraxacum and *Plantago* (C_3)	Grasses	Weed	Field	Potvin and Vasseur, 1997

Note: No climate model considers impact of weeds on crop yield

Note: Worst weeds for a crop are often similar in morphology and pathway.

Does rising carbon dioxide change weed populations?



Some initial evidence suggesting that C_3 weeds could be preferentially selected.

Ziska and Goins, Crop Science 46:1354-1359.

Crop/Weed interactions

- Some evidence that agronomic weeds may reduce crop yields further in a higher CO_2 environment.
- Some evidence suggesting that rising CO_2 may be a selection factor in weed species dominance.
- A lot we don't know yet.

Invasive weeds

A weedy species, usually non-native for a given region, whose introduction results in wide-spread environmental or species degradation.

- **Financial Cost: In the billions.**
- **Environmental Cost: Loss of diversity: Only habitat destruction ranks higher.**

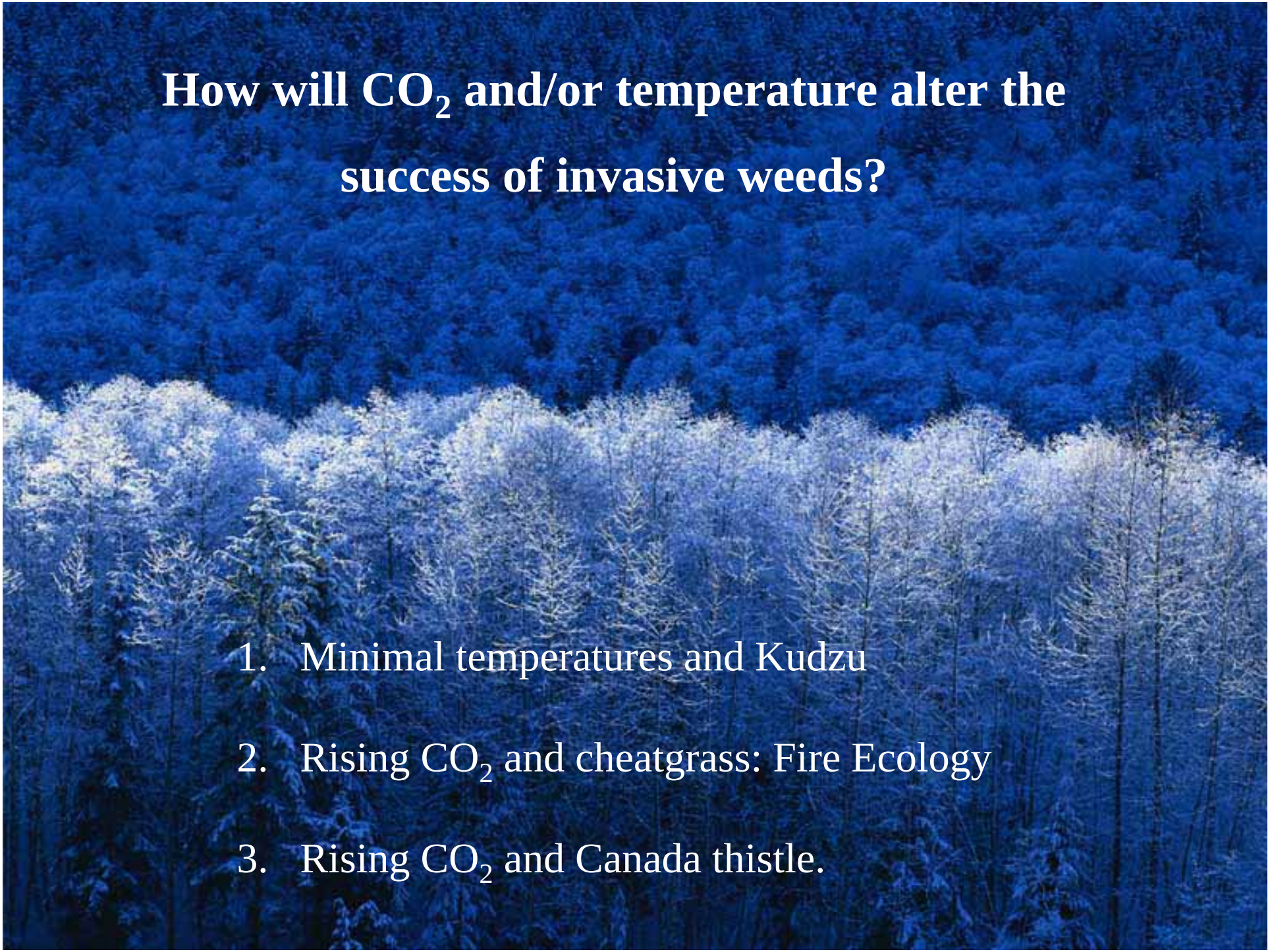
8 million acres of Kudzu

8 million acres of yellow star thistle

3 million acres of leafy spurge

5 million acres of Canada thistle

60 million acres of cheatgrass



How will CO_2 and/or temperature alter the success of invasive weeds?

1. Minimal temperatures and Kudzu
2. Rising CO_2 and cheatgrass: Fire Ecology
3. Rising CO_2 and Canada thistle.

What is the thermal limit for kudzu? Does it vary depending on population?

Examined 8 populations throughout the U.S., over a 1300 km N-S transect. Vegetative stems (asexual reproduction at N limit).

RC	Tissue Temp. (°C)
0.10	-7.0+0.9°
0.25	-10.8+0.9°
0.50	-16.1+0.8°
0.75	-21.7+1.0°
→ 0.95	-28.6+1.1°

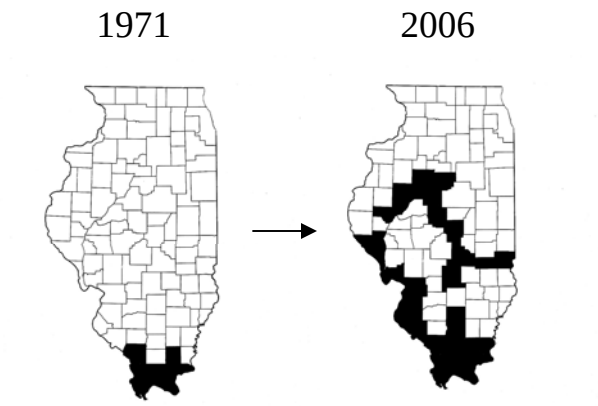
Where was kudzu growing in 1971?

Data are from Clyde Reed, a USDA scientist. Published in "Common Weeds of the United States.

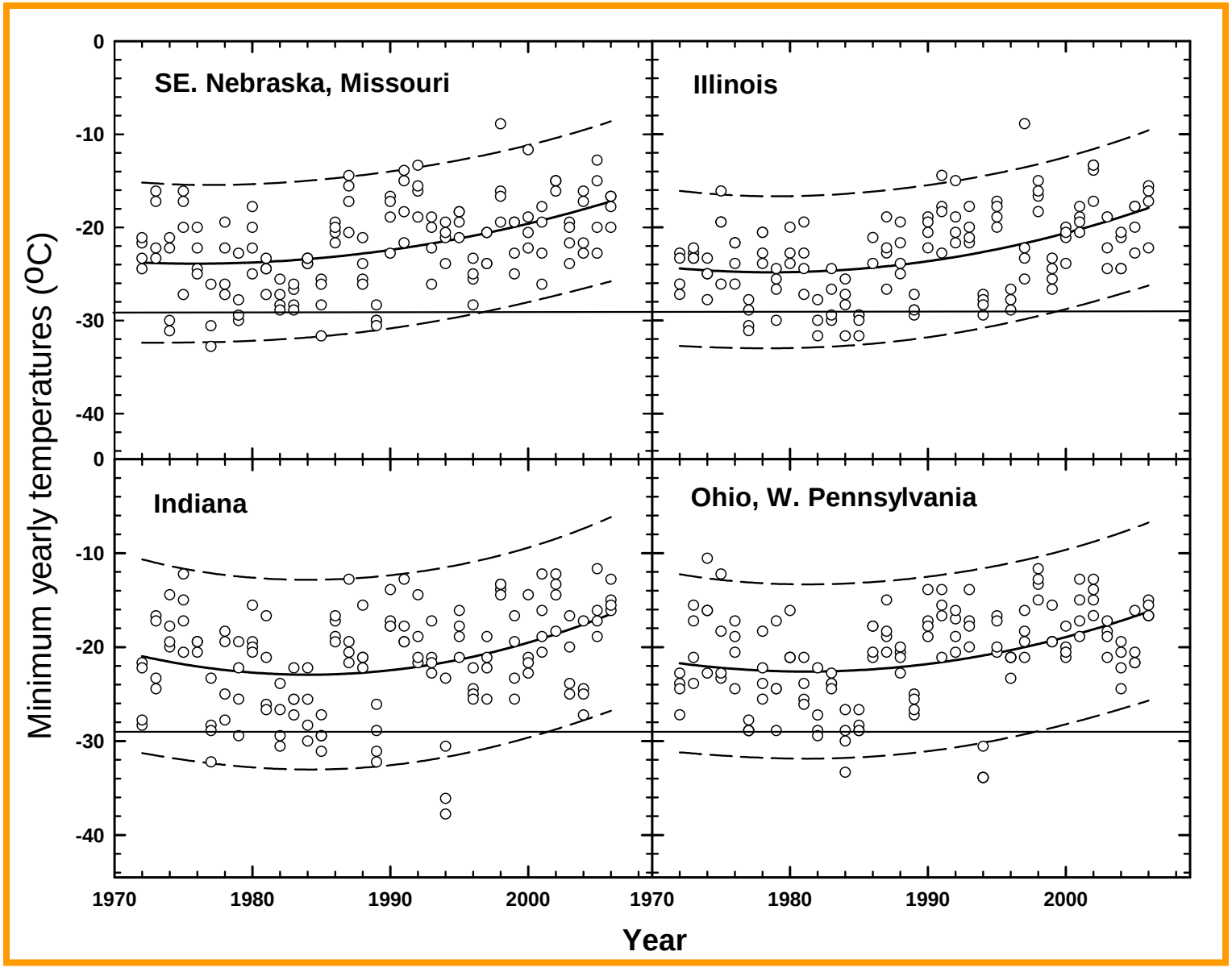
Focus on mid-western populations, away from urban centers or mountains.

Where is it growing now?

Current estimates of kudzu distribution for Nebraska, Missouri, Illinois, Indiana, Ohio and Pennsylvania were evaluated using three separate sources: a) National Resource Conservation Service NRCS), database of invasive U.S. Species (plants.usda.gov/java/profile?symbol=PUMO) b) the National Agricultural Pest Information Service (NAPIS) in cooperative agreement between the Animal Plant Health Information Service (APHIS) and Purdue University as part of their Cooperative Agricultural Pest Survey (CAPS) program (ceris.purdue.edu/napis/pests/weeds/imap/kudzu.html), and c) the Department of Natural Resources (DNR) for the states of Pennsylvania, Ohio, Indiana, Illinois, and Missouri, including the publication of “The Green Plague Moves North” by the Illinois DNR.



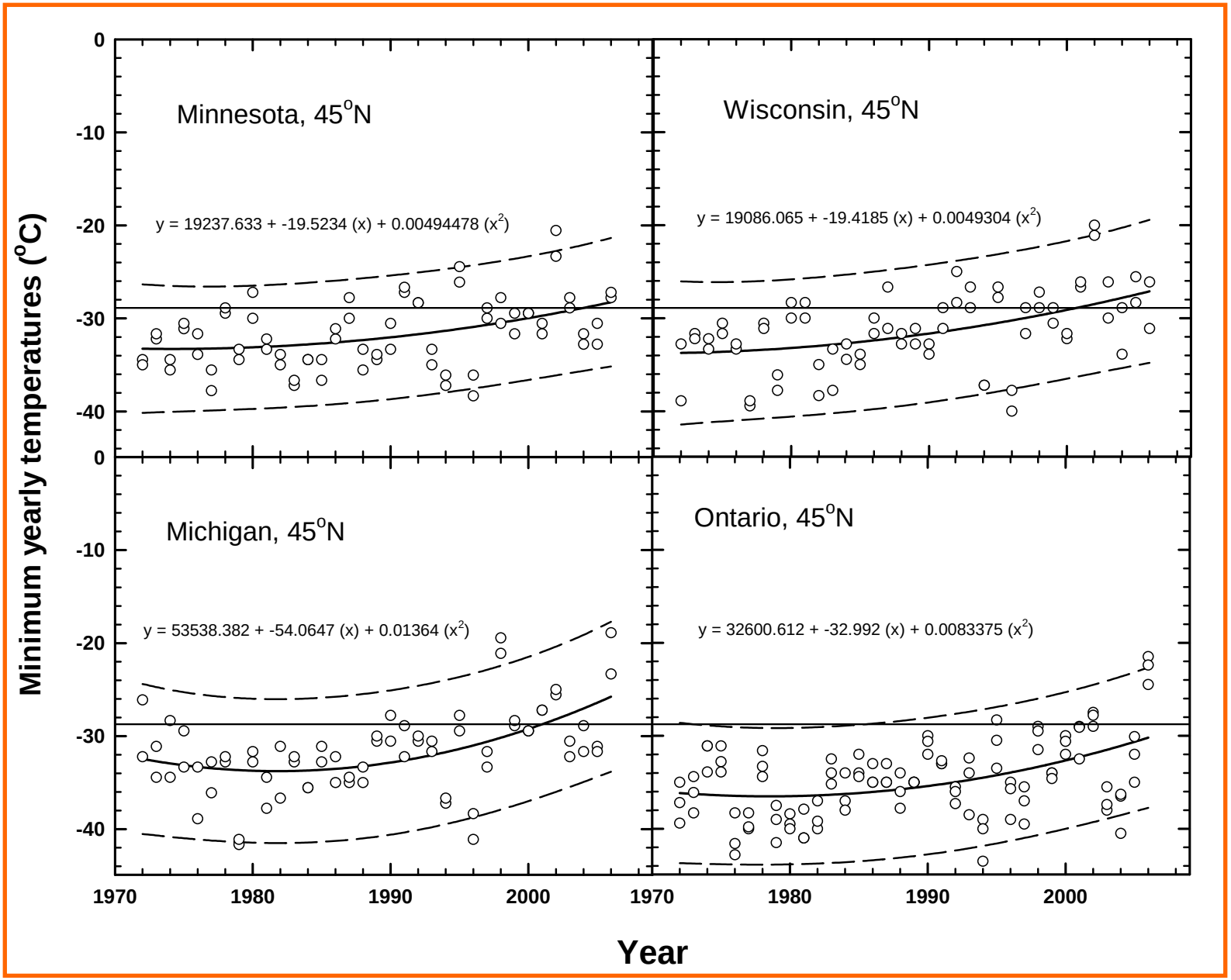
Has the minimum temperature threshold changed?



How will it change in the future?

45°N

When will the minimum temperature threshold change?



Where will kudzu be

10-15 years from now?

Date at which there is a <5% chance of location experiencing a temperature below the -28°C threshold.

Some implications.

1. Data suggest that the link between global warming and the spread of an invasive species is real, not hypothetical. First data to show this.

2. It seem unlikely that kudzu will be the only species affecting by global warming.

Cheatgrass (*Bromus tectorum*) and Rising Carbon Dioxide

Invasive weed of rangelands in Western U.S.

Impacts fire ecology:

Dries 4-6 weeks earlier than perennials.

Develops dense stands

Grows in 6-22 inch precipitation area (high fire)

Readily ignites. (Fires return times < 5 years)

Overall:

Elimination of woody non fire adapted perennials large monocultures of cheatgrass and reductions in species diversity.

How have the changes in pre-ambient atmospheric carbon dioxide altered cheatgrass productivity?

Examined cheatgrass from three different populations (differing elevations) collected in Sierra Nevada range.

Used small, recent changes in CO_2 concentration (270, 320, 370, 420 ppm).

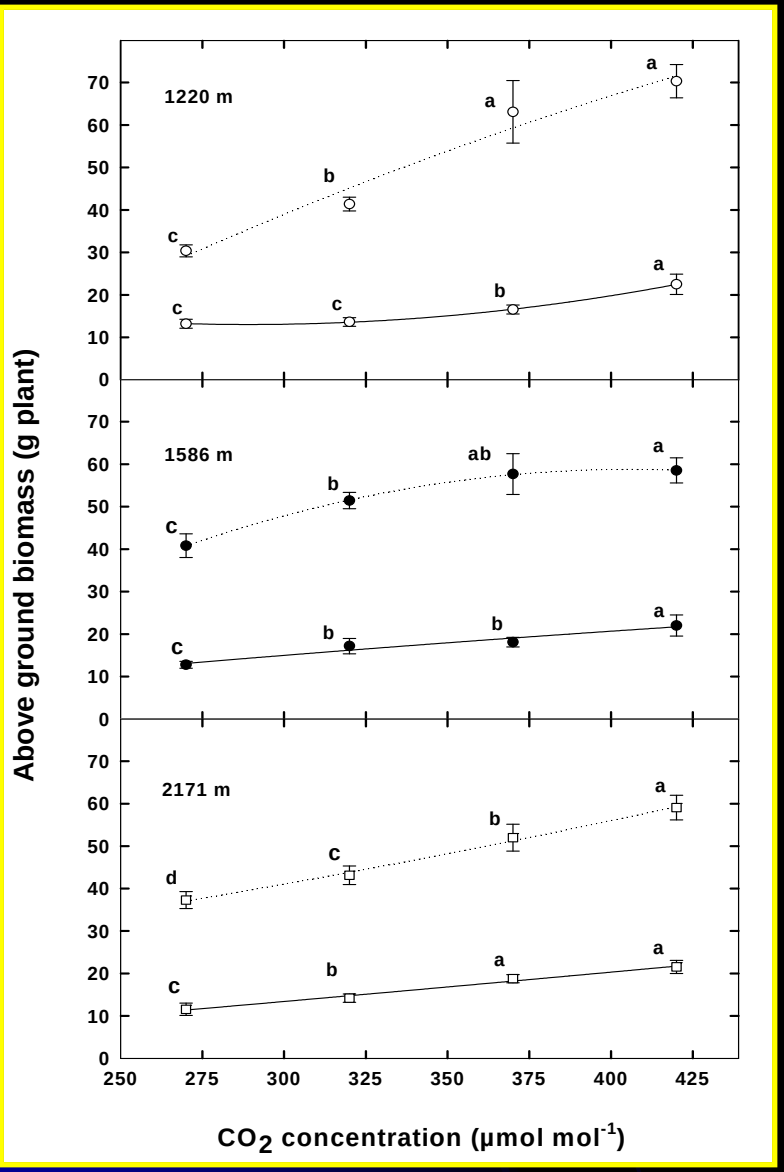
Used environmental growth chambers to simulate past and current CO_2.

How has rising CO_2 contributed to the fuel load?

(growth rate, biomass, above ground retention)

Data published in Global Change Biology, 11:1325-1332, 2005

Invasive weeds: biomass response of three cheat-grass ecotypes to CO_2

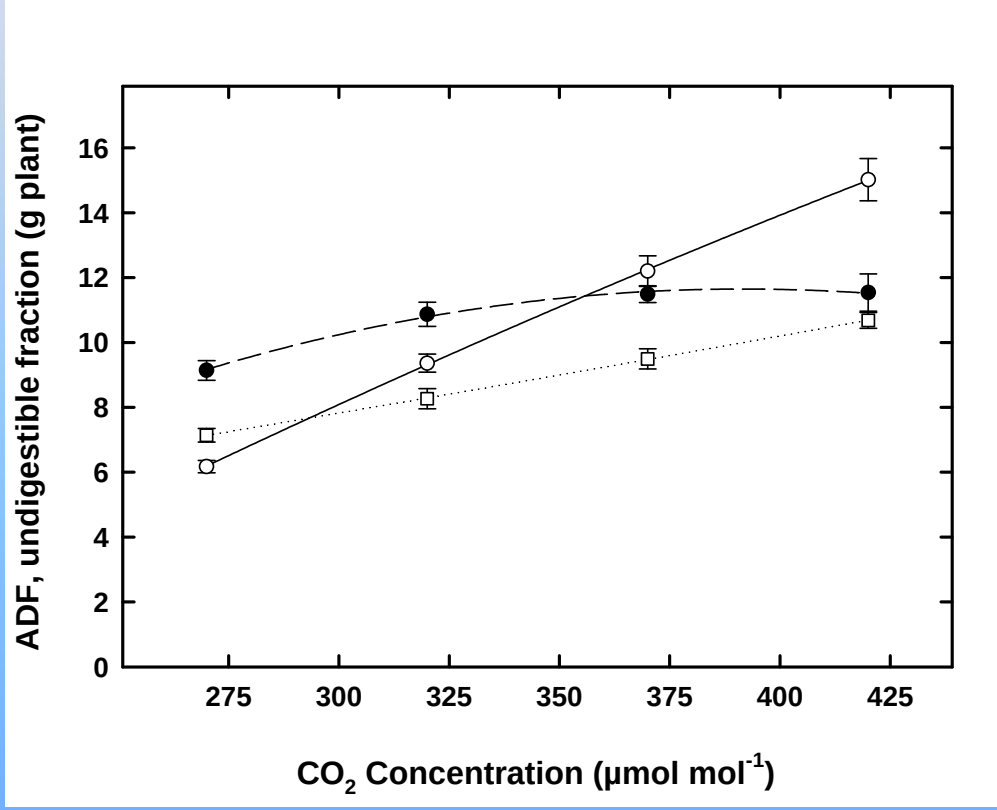


By 59 and 87 DAS, biomass of all populations was affected by CO_2.

Fire frequency is dependent on fuel load, which is dependent on biomass

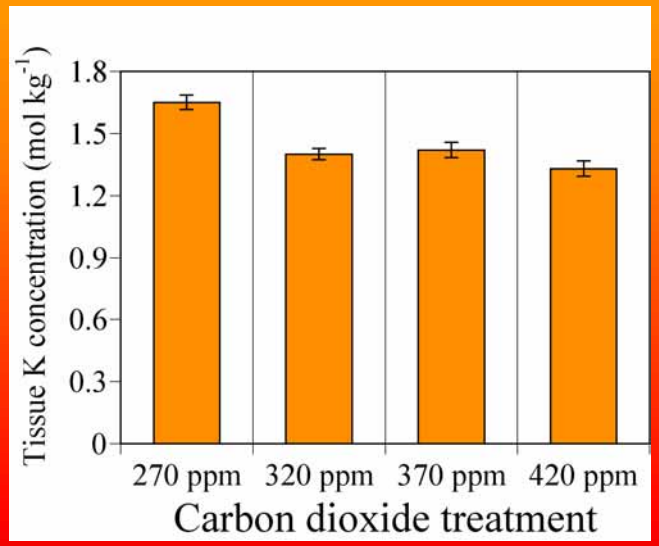
Rising CO_2 may have affected fuel load of cheatgrass.

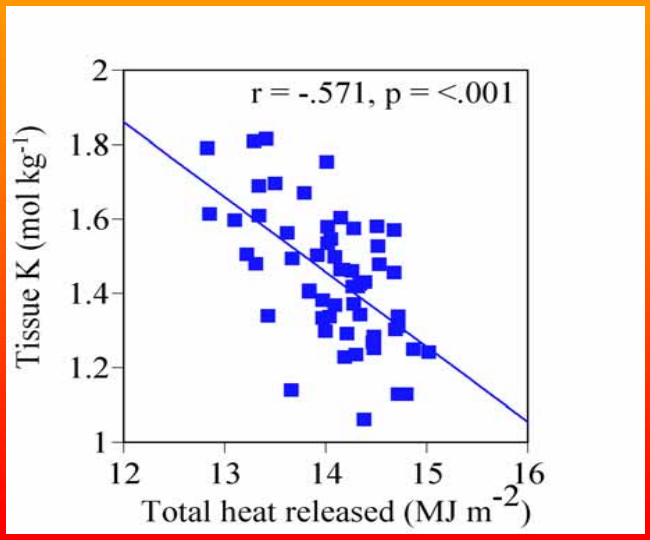
Cheatgrass and fire ecology: CO_2 and digestibility.



If cheatgrass is less digestible, will this affect above-ground retention?

Cheatgrass and fire ecology: CO_2 and combustibility.





As tissue K decreases with CO_2, combustibility increases.

Cheatgrass, CO_2 and fire ecology.

- Recent changes in atmospheric carbon dioxide are associated with changes in growth rate and reduced digestibility.
- CO_2-induced changes in growth and biomass suggest faster time to fuel (biomass) threshold needed to sustain fire and greater fire intensity.
- CO_2-induced decreases in mineral composition (K) may increase combustibility; however, additional data are needed.
- Overall, ignition probabilities (likelihood of fire) have increased as a function of recent increases in atmospheric carbon dioxide for cheatgrass.

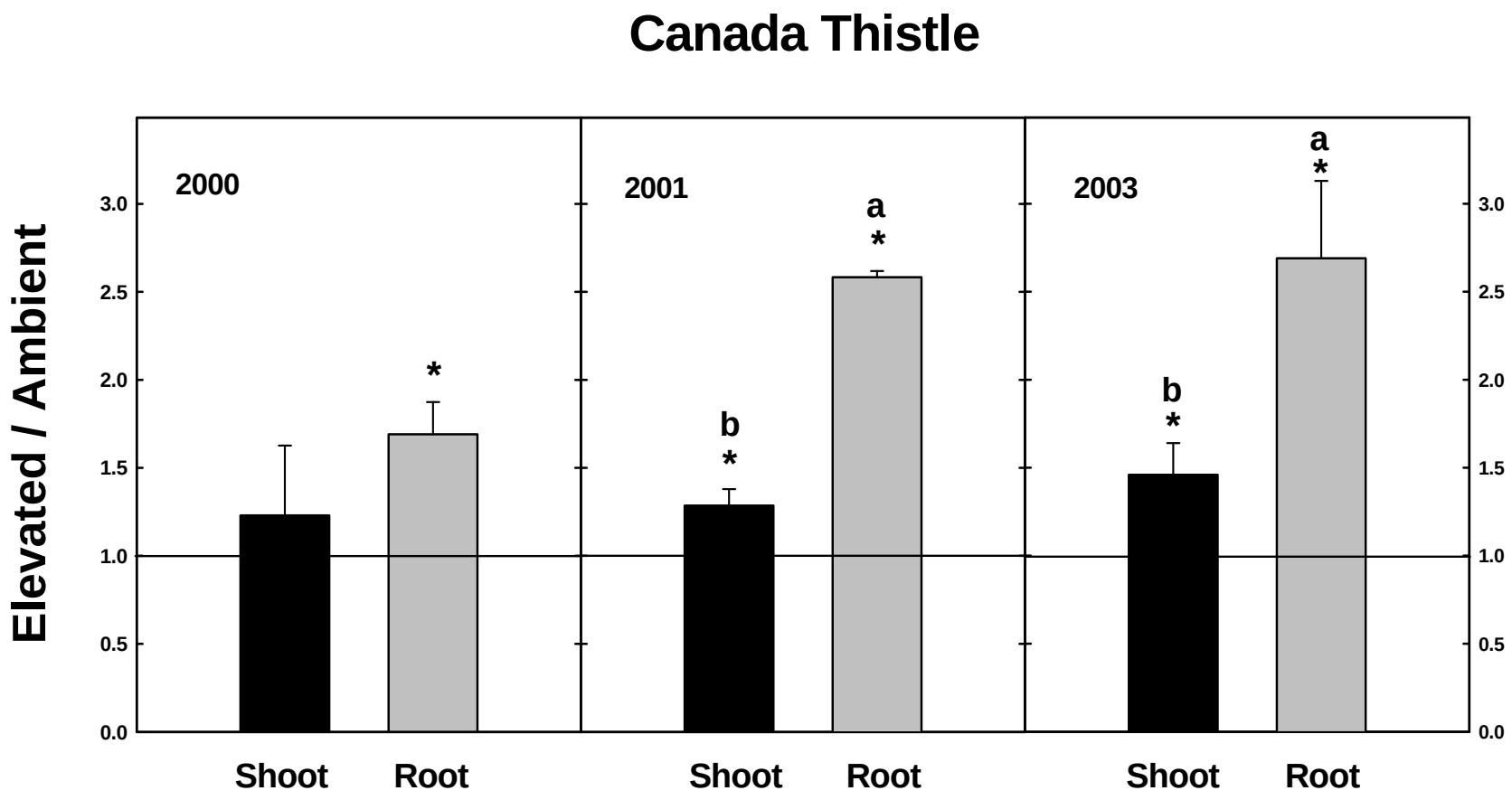
CO_2 and Canada thistle

Some Noxious Weeds: The best of the worst.

Skinner et al. Weed Science, 48:640

1.	Cirsium arvense, Canada thistle	33 lists
2.	Carduus nutans, musk thistle	24 lists
3.	Lythrum spp., loosestrife	24 lists
4.	Convolvulus arvensis, field bindweed	23 lists
5.	Euphorbia esula, leafy spurge	22 lists
6.	Acroptilon repens, Russian knapweed	20 lists
7.	Sorghum spp., sorghum	20 lists
8.	Cardaria spp., whitetop	17 lists
9.	Centaurea maculosa, spotted knapweed	17 lists
10.	Sonchus arvensis, perennial sowthistle	17 lists
11.	Centaurea diffusa, diffuse knapweed	16 lists
12.	Elytrigia repens, quackgrass	16 lists
13.	Cuscuta spp., dodder	12 lists
14.	Linaria dalmatica, Dalmation toadflax	12 lists
15.	Centaurea solstitialis, yellow starthistle	11 lists

Canada thistle: Best of the worst.



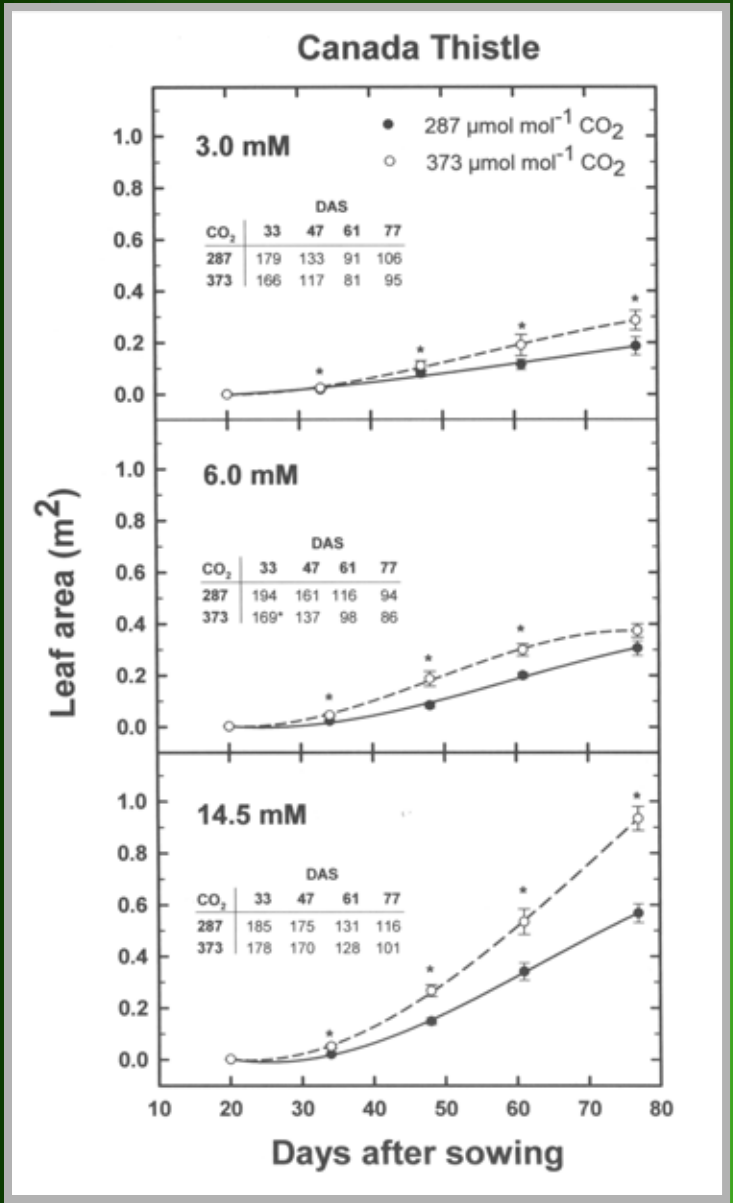
3 years of field trials at +250 ppm above ambient.

Canada thistle, CO_2 and N

One of the assumptions regarding rising CO_2, is that it will have no effect because any stimulation will be limited by other resources (e.g. nutrients).

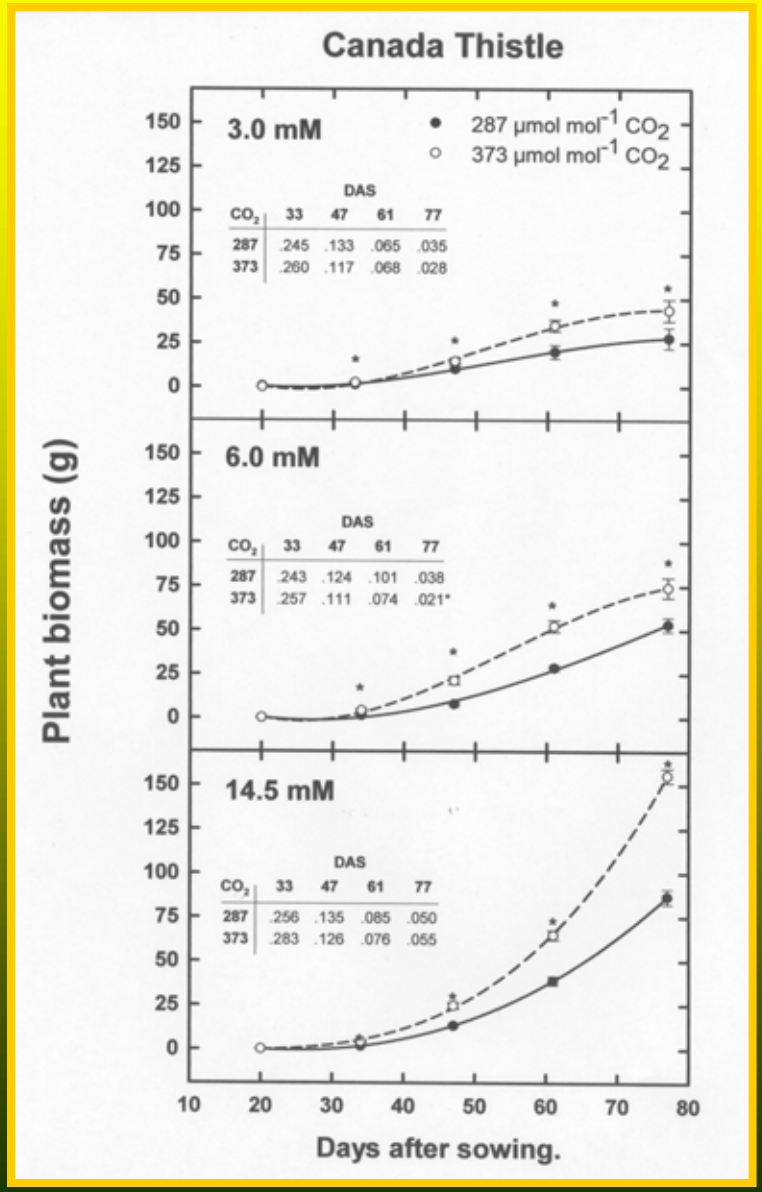
Examined response of Canada thistle from 287 to 373 µppm CO_2 at N levels of 3, 6 and 14.5 mM during vegetative stage of growth.

Canada thistle, CO_2 x N



No change in relative stimulation of leaf area.

Canada thistle, CO_2 x N

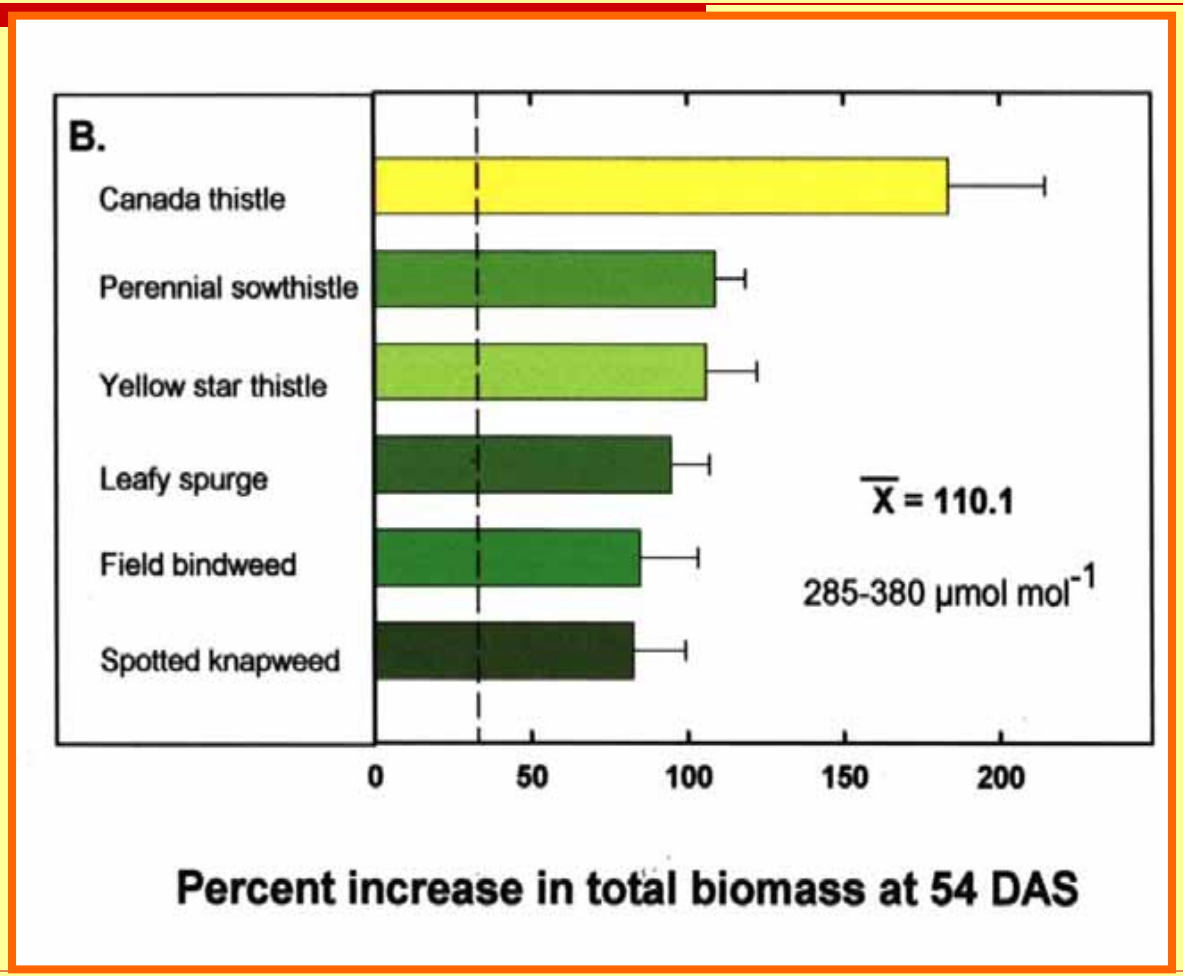


No change in relative stimulation of plant biomass.

Overall for Canada thistle.

- Strong response to rising carbon dioxide with differential response of root>>shoot.
- The response to recent changes in carbon dioxide appears independent of N concentration.

Present vs. Past



Does elevated CO_2 favor invasive species in plant communities?

System	Invasive Species	CO_2 Favors?	Reference
Desert	*Bromus madritensis*	Yes	Smith et al. 2000
Prairie	*Prosopis glandulosa*	Yes	Polley et al. 1994
Woods	*Prunus laurocerasus*	Yes	Hattenschewiler and Korner 2003

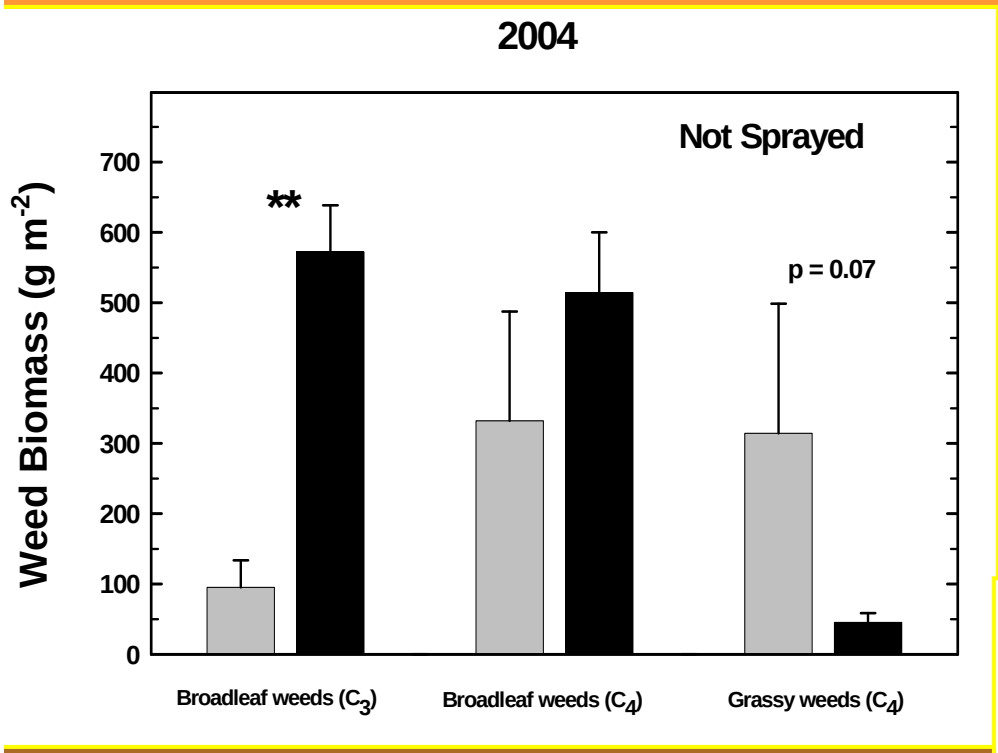
Summary: Invasive weeds and CO_2 / temperature

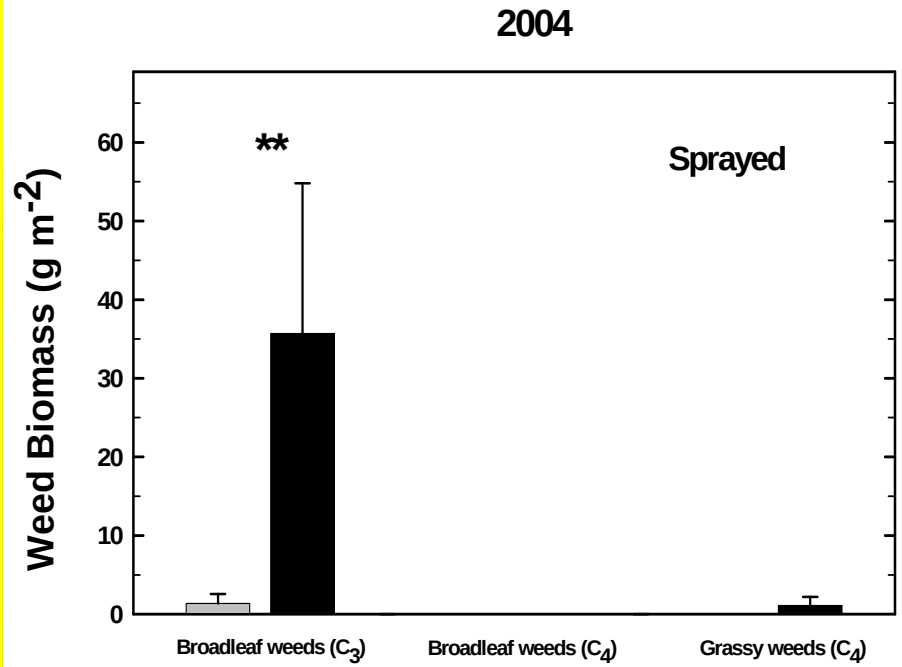
- Initial evidence indicates that increasing minimum winter temperatures associated with climatic change may be a factor in the northward spread of kudzu.
- Small changes (~50 ppm) in CO_2 may also effect growth, digestibility and combustibility of cheatgrass, with subsequent changes in fire ecology.
- Canada thistle, the “worst” invasive, shows a strong response to CO_2, but greater below ground, relative to above ground growth. Response to CO_2 is nitrogen independent.
- Suggestion that CO_2 may select for invasives within assemblages of plants.

Plants and herbicides…is rising CO_2 <u>really</u> a problem?

Just step up our efforts to control weeds!!!!!!

CO_2 and Round-up





As carbon dioxide increases, glyphosate efficacy is reduced.

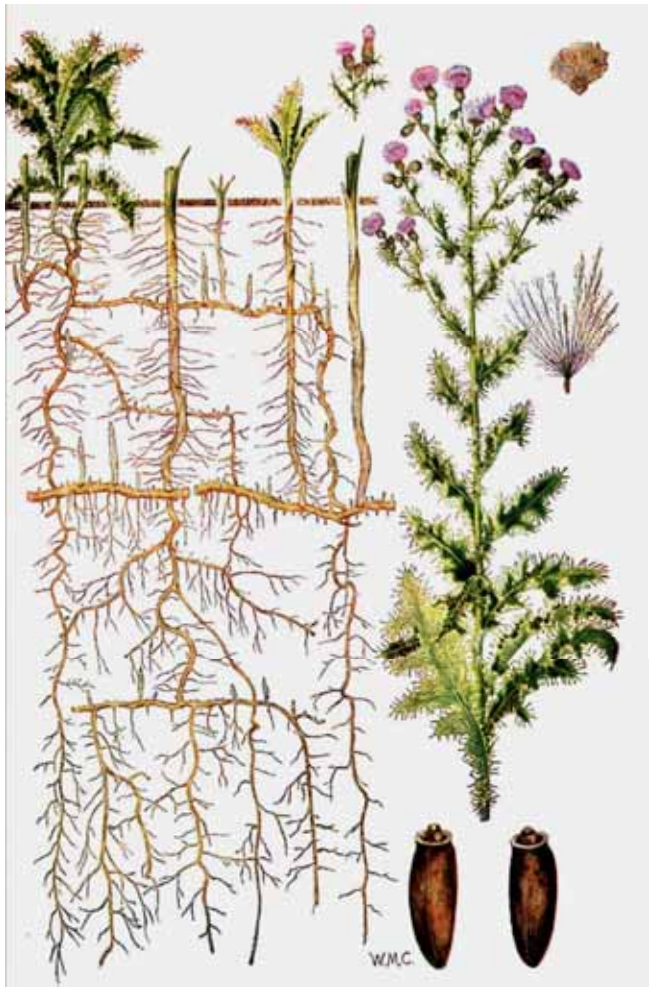
CO_2 and Round-up

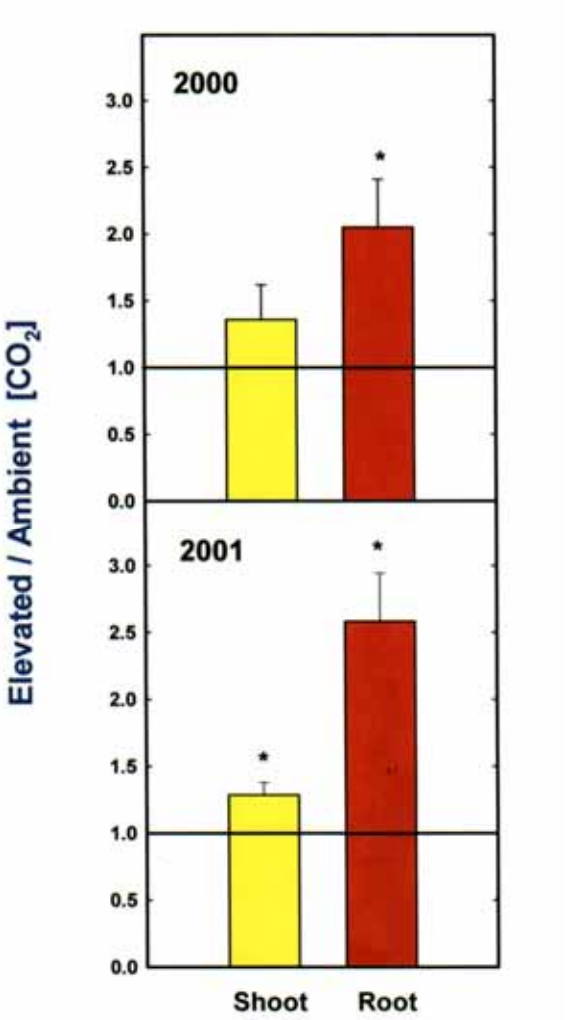
Ambient CO_2 **Future CO_2**

Increasing CO_2 reduces herbicide efficacy.

e.g. Ziska et al. *Weed Science* 52:584-588, 2004

Rising CO_2 and mechanical control.





NO!

Understanding weed control with increasing CO_2 is still in its infancy.

Weed Management

1. Control of invasives by any means, is difficult. The acreage occupied by some invasives is so great, that such efforts are time-consuming, and costly (but not impossible).

2. Where control (mechanical, chemical) is available, rising carbon dioxide and temperature may hamper current efforts.

3. What strategies would be suitable?

Where do we go from here?

As climate and carbon dioxide change, weed populations will change. Invasives in particular may be more of a threat.

Need simple models for land managers (e.g. cheatgrass spread in the context of fire occurrence).

Need new management strategies. Can no longer assume that what worked in the past will work in the future.

Adapt as needed. See www.climateandfarming.org