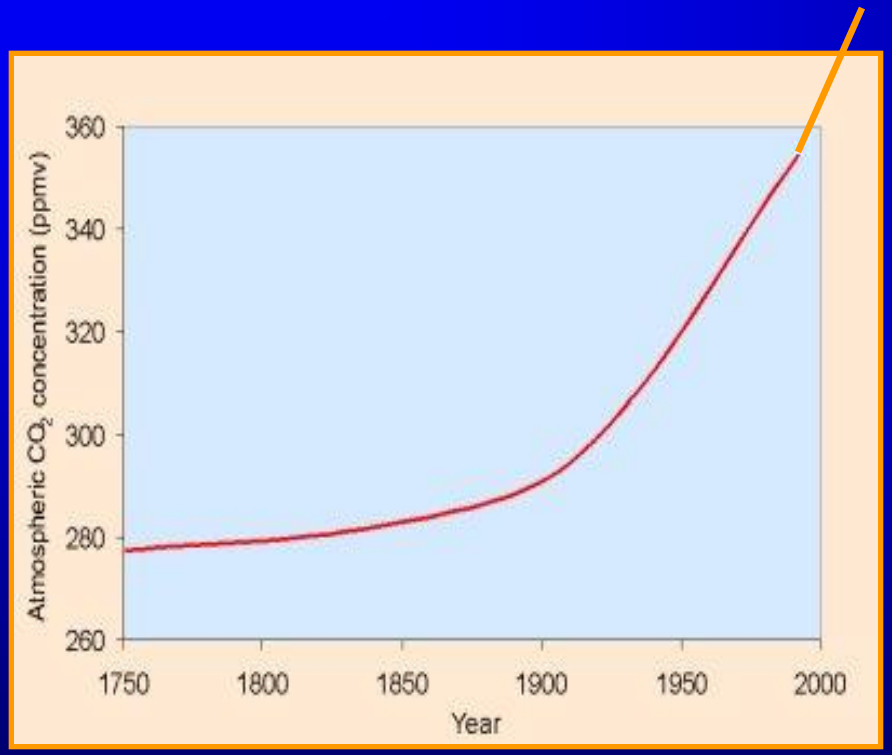
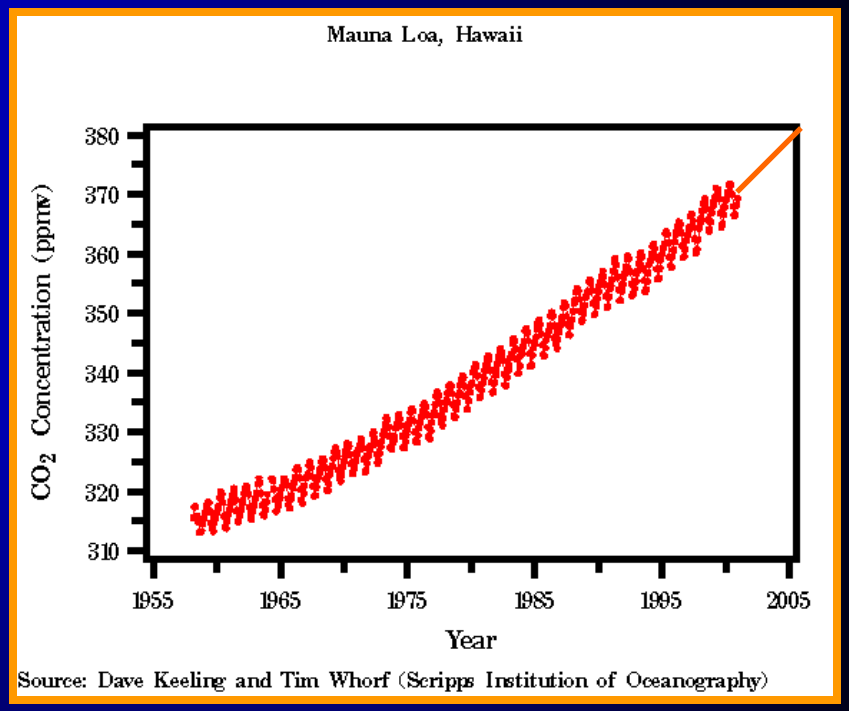
Global Warming, Rising CO_2 and Invasive Plants.

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

CO_2 is Increasing





CO_2 is the 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.

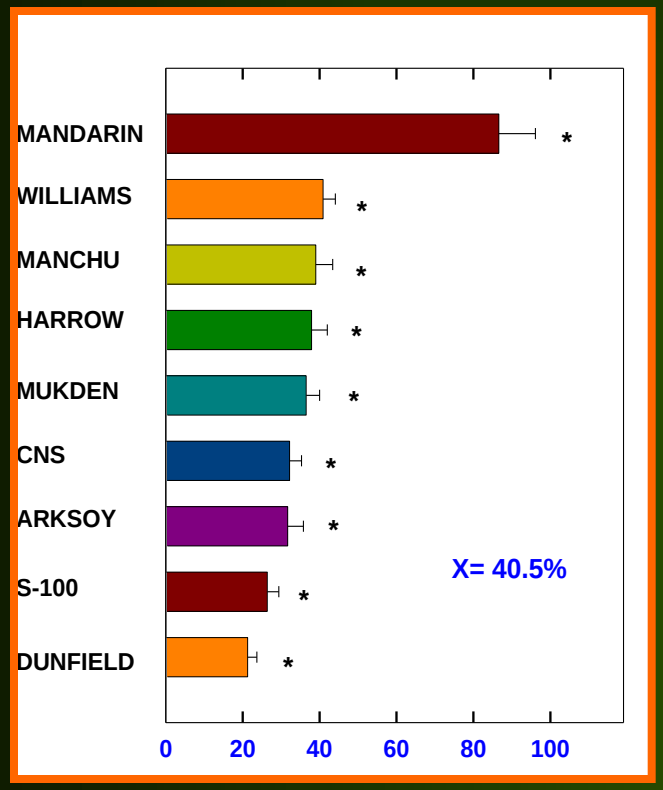
Plants are necessary for the flow of energy and carbon through ecosystems.

With the exception of a few subterranean organisms, if plants did not exist, life would not exist.

Plant growth however is dependent on four abiotic inputs.

Any perturbation in these inputs will alter all living systems.

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

While there are positive aspects to rising CO_2, not all plants are equally desirable.

Kudzu in North Carolina.

….and in Connecticut.

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.

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

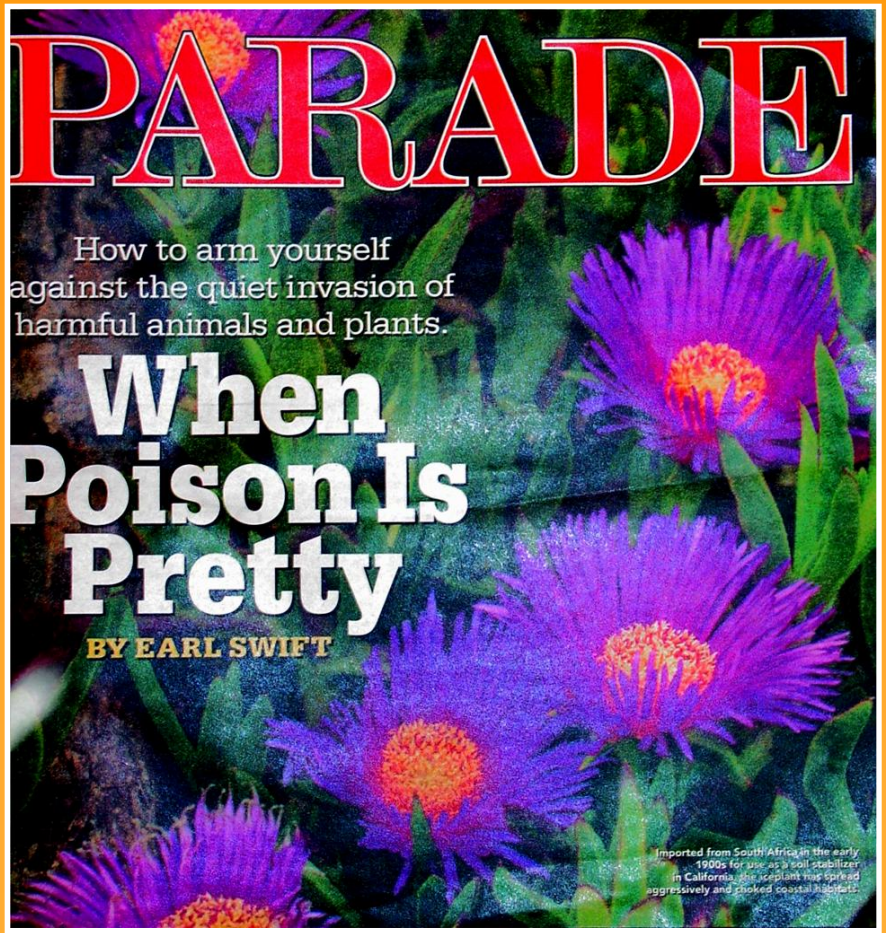
Note: Worst weeds for a crop are often similar in morphology and pathway.

Specific case: “Invasive” weeds

“Alien”? “Exotic”? Not necessarily “invasive”. Invasive may vary by region. Look at weeds which are considered “noxious”, that is, those weeds whose presence is so disruptive/costly to human activity that they are regulated by law over large areas.

Invasive weeds

- **Financial Cost: ~13 billion/ year.**
- **Environmental Cost: Loss of diversity: Only habitat destruction ranks higher.**



How has rising atmospheric CO_2 altered the success of invasives?

Invasive weeds

Noxious Agronomic 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

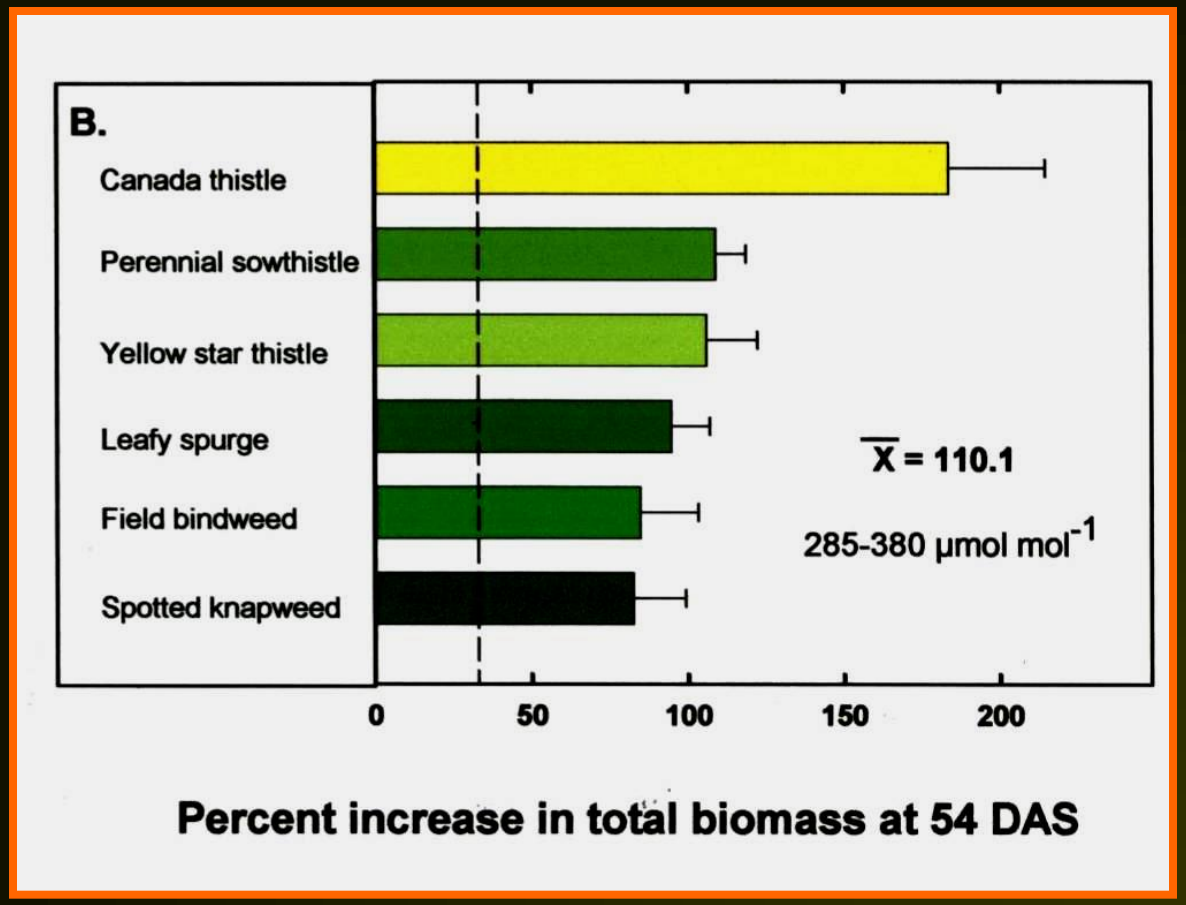
Invasive weeds

- **Is a strong growth response to pre-ambient increases in CO_2 concentrations a common characteristic of noxious species?**

- **Chose six of top 15 invasive weeds: Yellow star thistle (#15), leafy spurge (#5), spotted knapweed(#9), field bindweed (#4), perennial sowthistle (#10), Canada thistle (#1).**

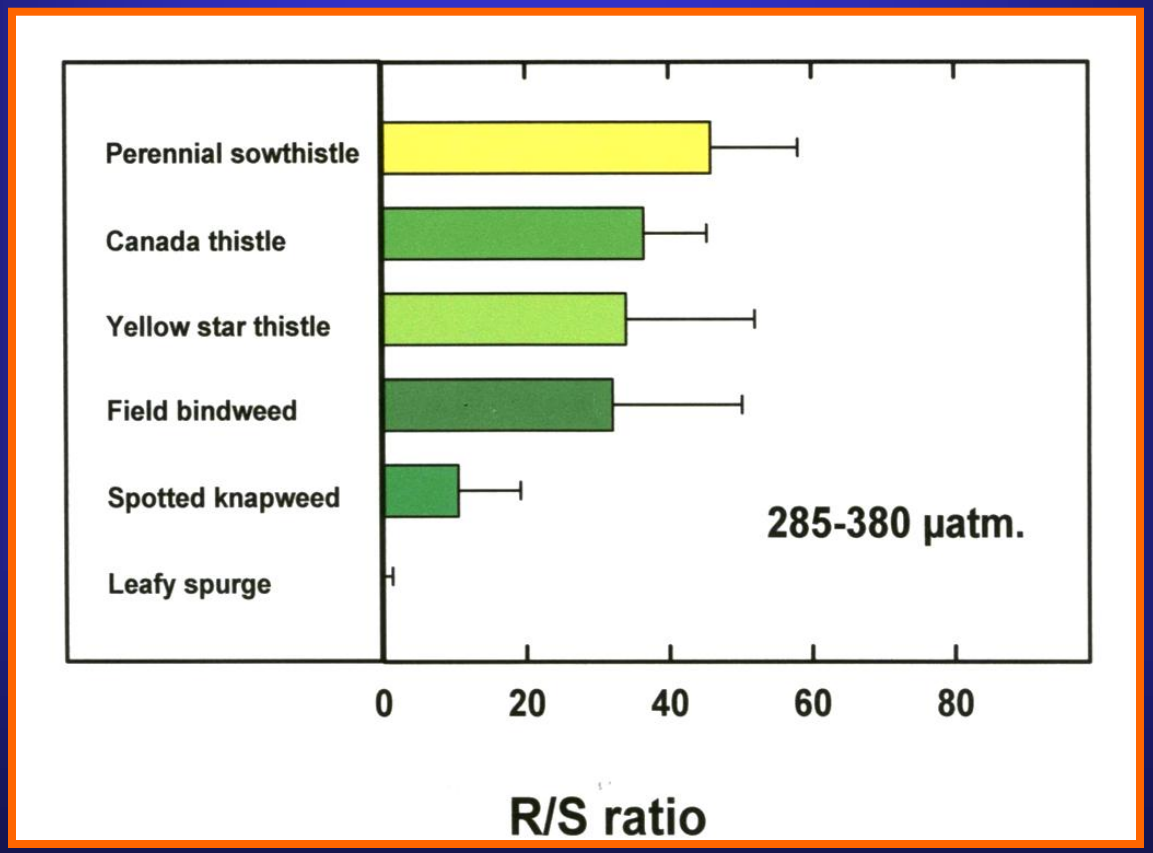
- Data published in *Journal of Experimental Botany* 54:395-404, 2003

Invasive weeds



Response is about 3x the average for recent CO_2 increases.

Invasive weeds



Many noxious species reproduce vegetatively, from below-ground structures. Plants with large below-ground sinks show a strong response to CO_2.

Have examined initially, invasive weeds in managed systems. What about unmanaged systems?

Cheatgrass (*Bromus tectorum*)

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.

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.

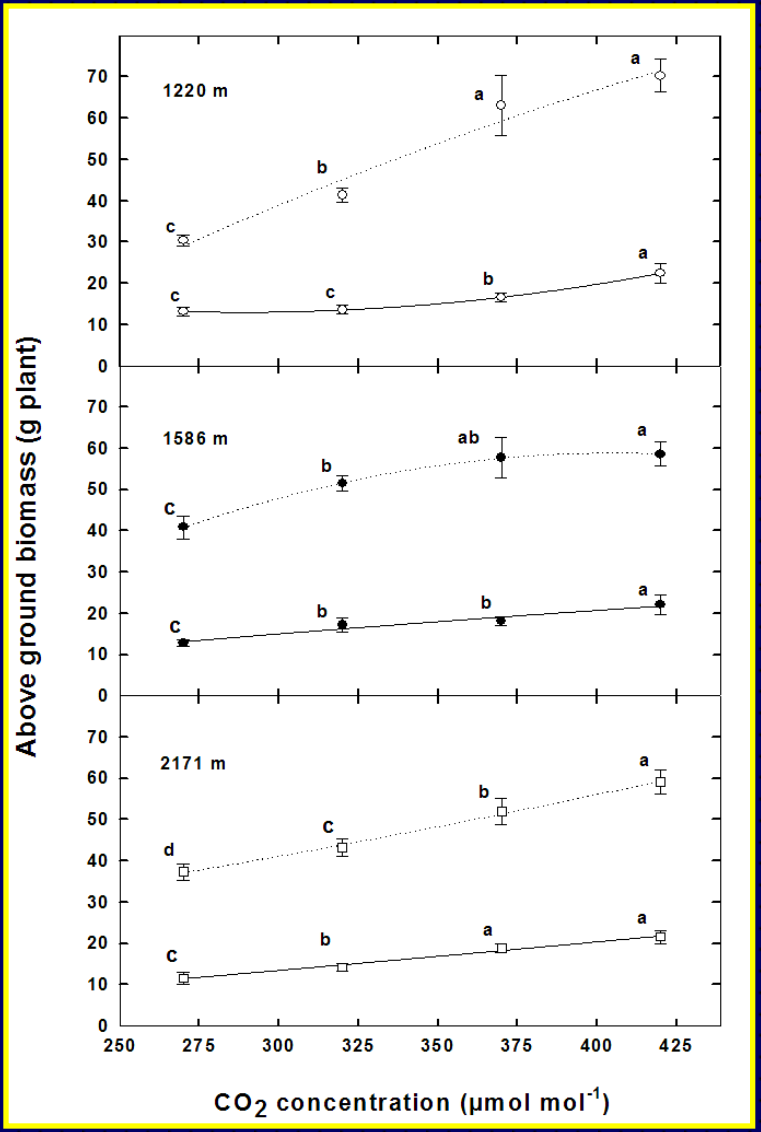
Used small, recent changes in CO_2 concentration (270, 320, 370, 420 ppm).

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)

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

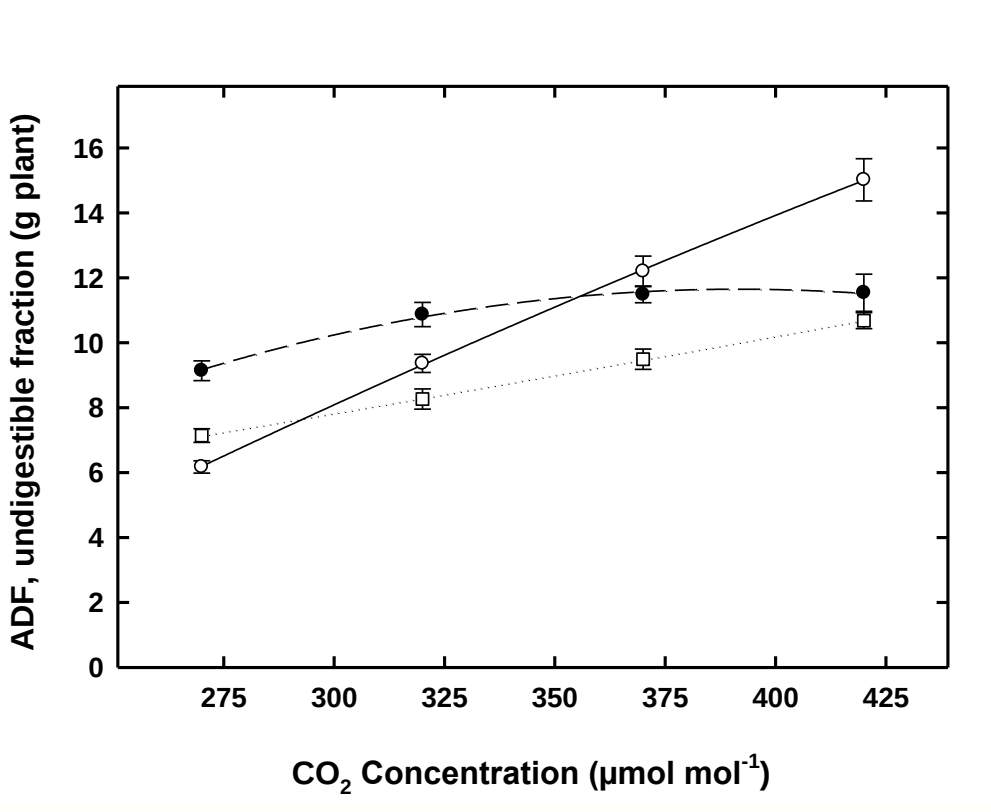


By 59 and 87 DAS, biomass of all populations was affected by CO_2.

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

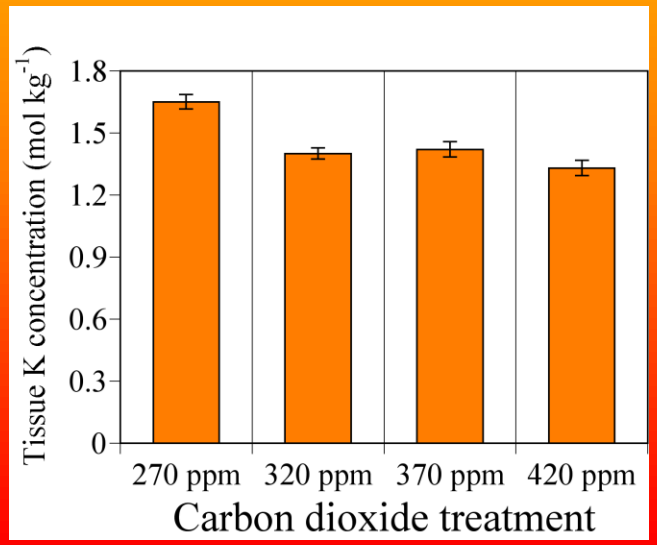
Rising CO_2 may have affected fuel load of cheatgrass.

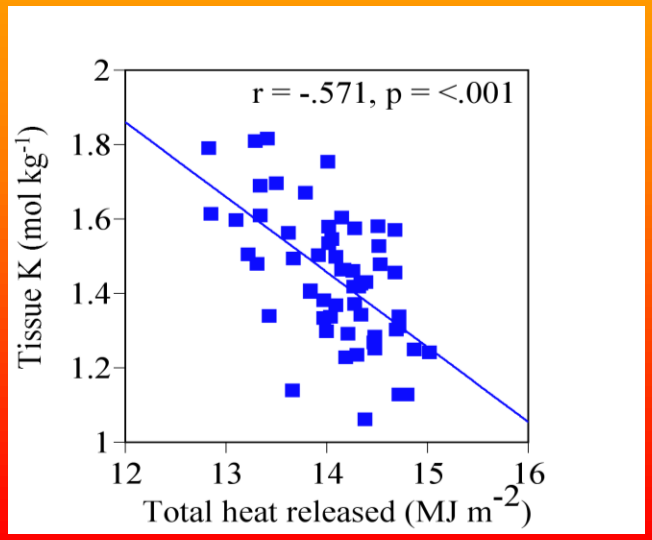
Cheatgrass and fire ecology: CO_2 and digestibility.



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

Cheatgrass and fire ecology: CO_2 and combustibility.





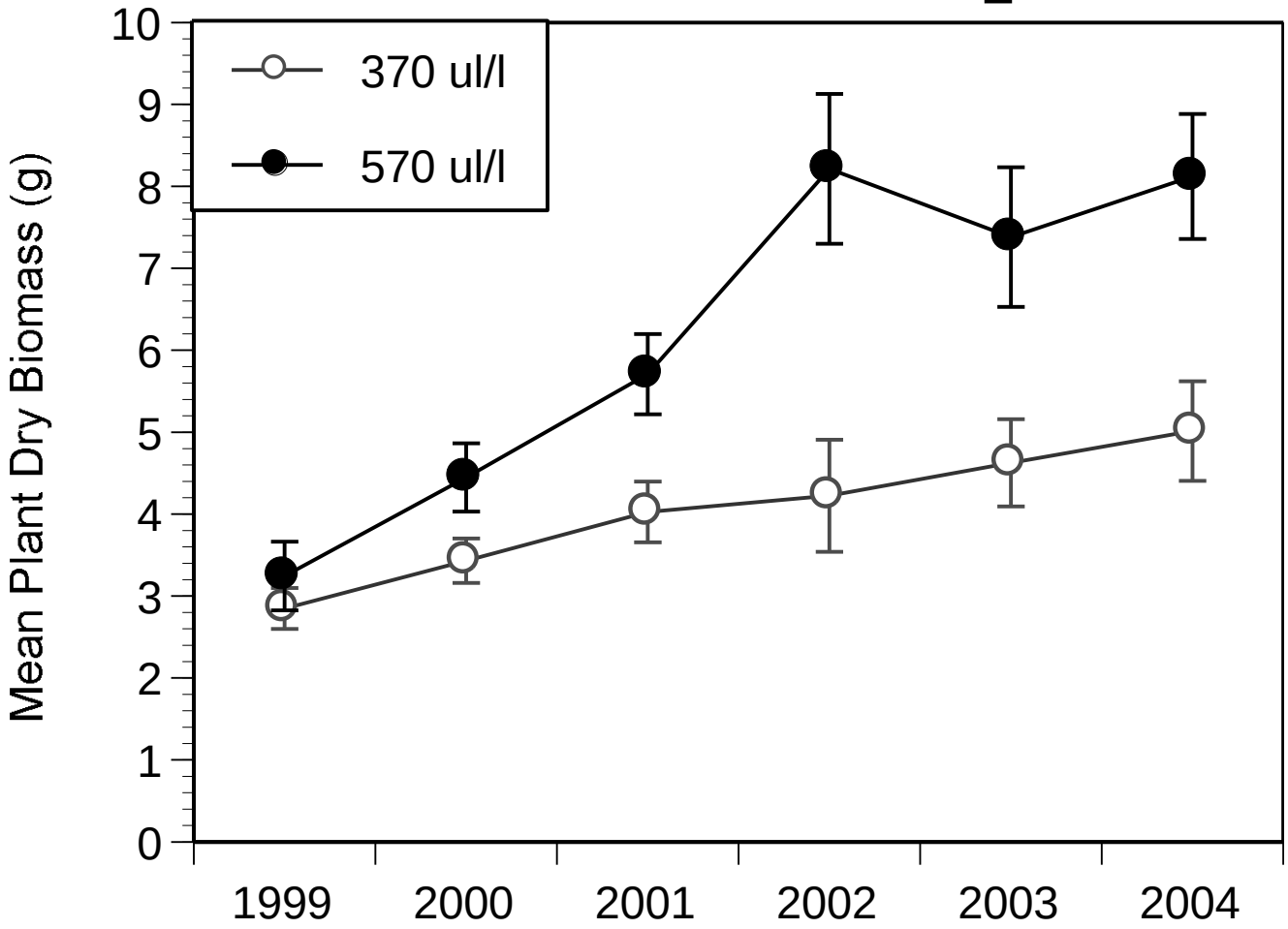
Public Health: CO_2, plants and contact dermatitis

Can rising CO_2 alter the growth or toxicity of poison ivy?

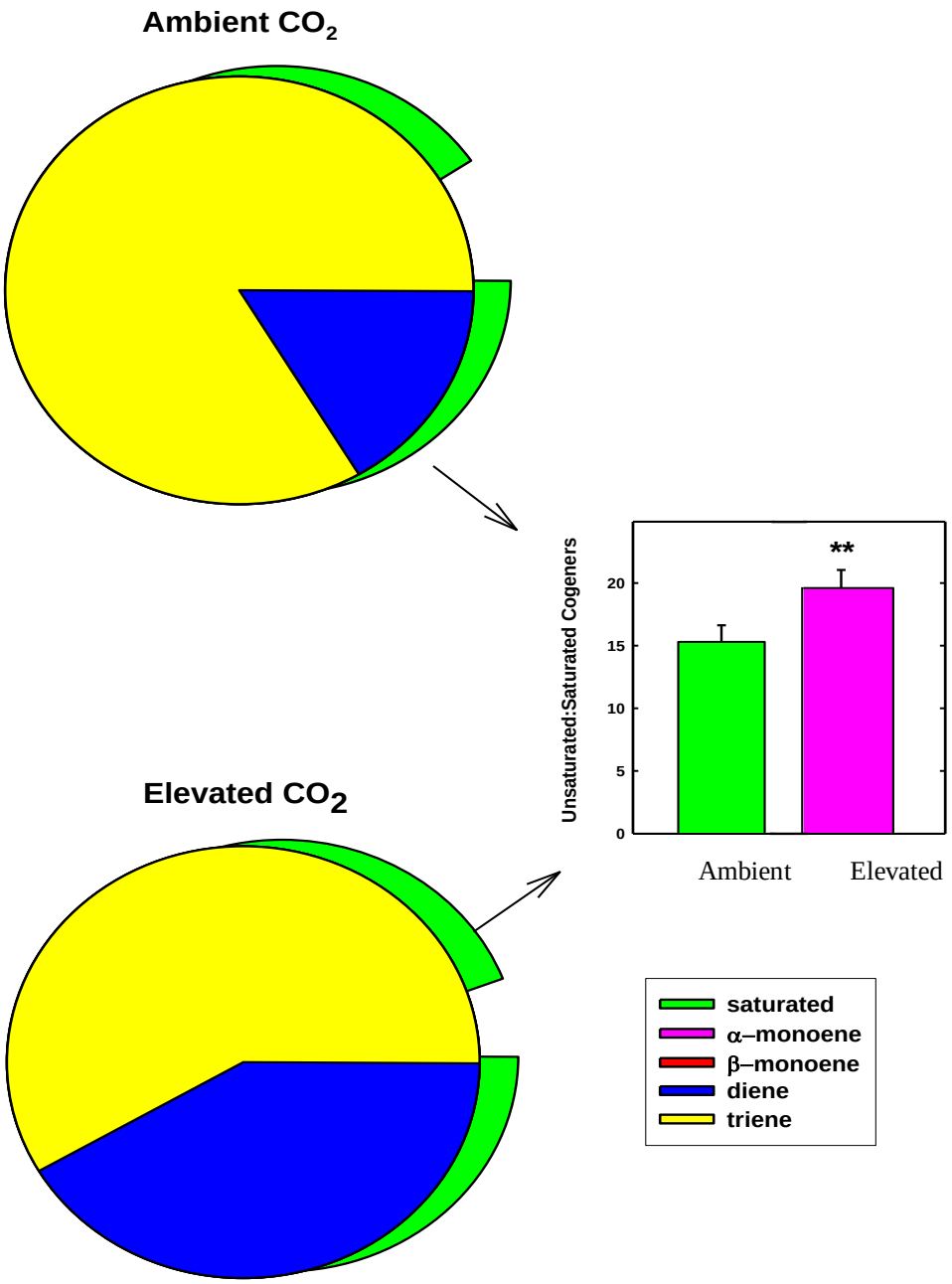
The Duke University FACE Site: State of the Art.

Poison ivy at Duke Face ring.

Poison ivy plants grow faster at elevated CO_2



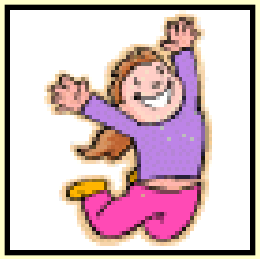
Poison ivy allergenicity



Yes, but is rising CO_2 <u>really</u> a problem?

1. Rise in CO_2 is slow, only 1-2 ppm per year! (Mauna Loa data)

2. Just step up our efforts to control….Round-up & more plowing are the solutions!



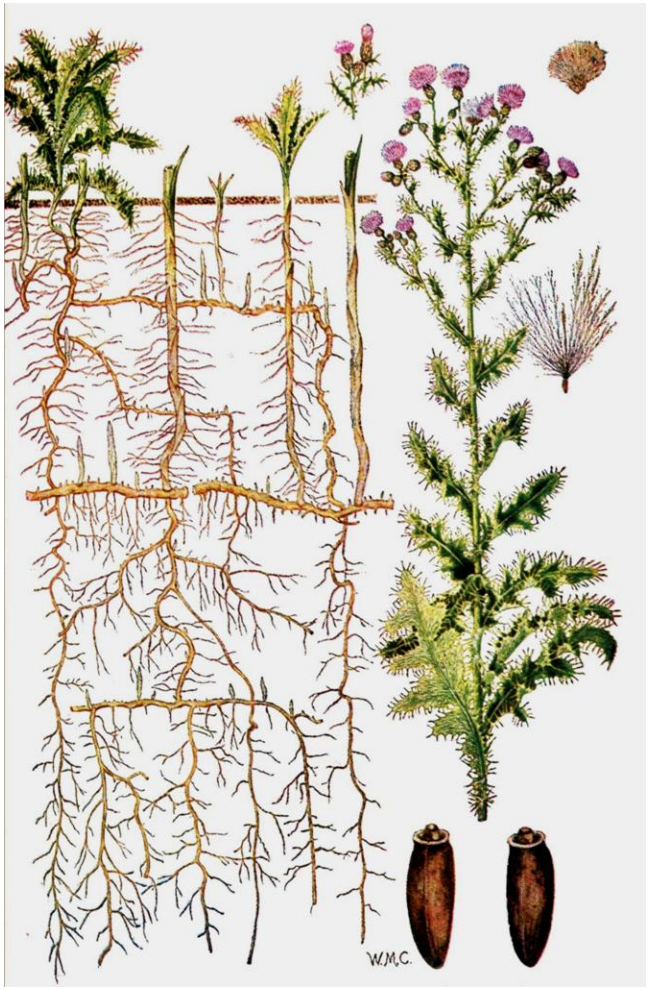
CO_2 and Round-up

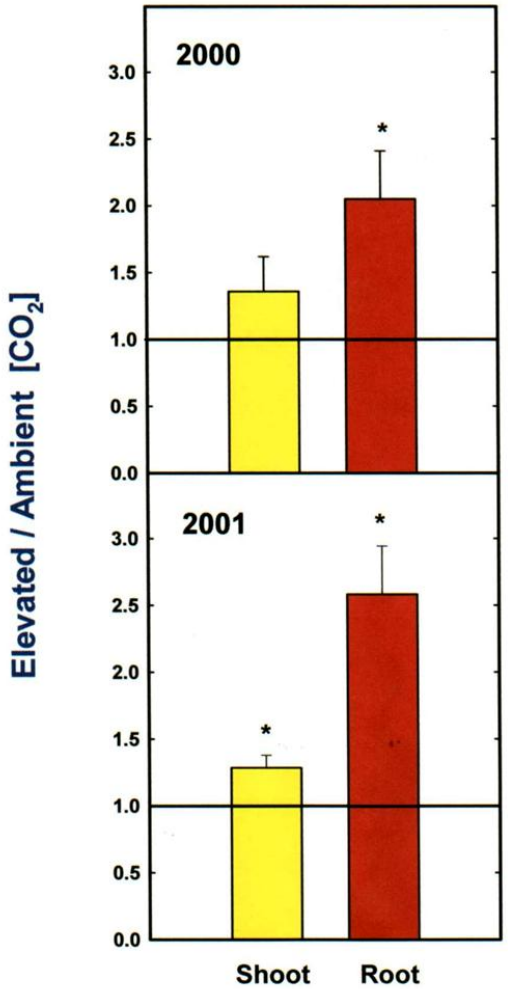
Ambient CO_2 **Future CO_2**

Increasing CO_2 reduces herbicide efficacy.

e.g. Ziska et al. *Weed Science* 2004

Rising CO_2 and mechanical control.





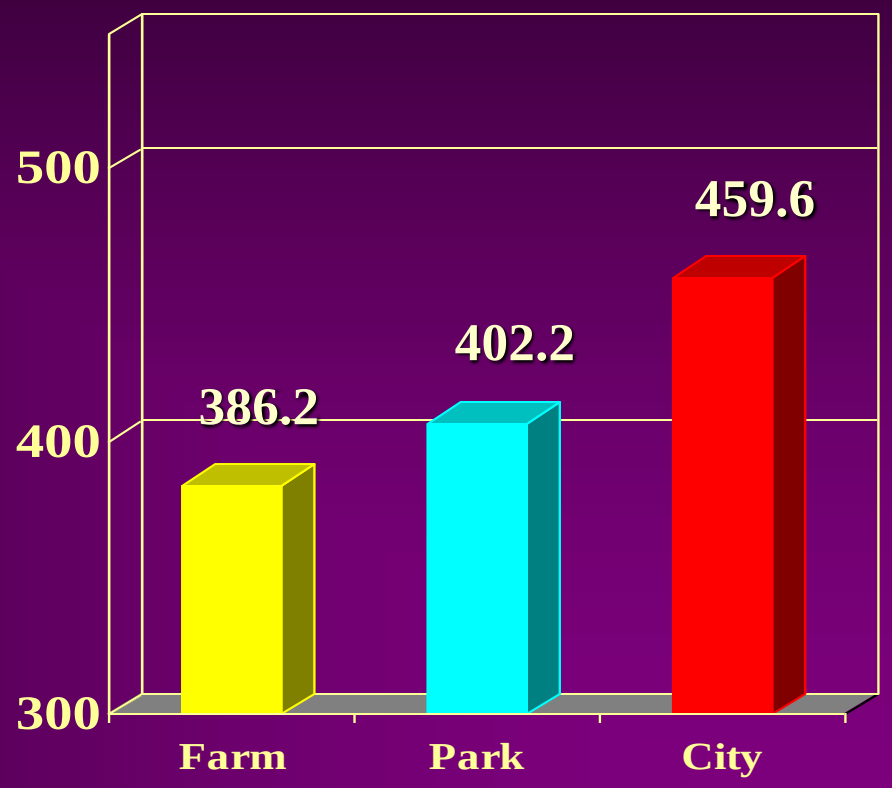
NO!

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

Is the rise in CO_2 really "slow"?

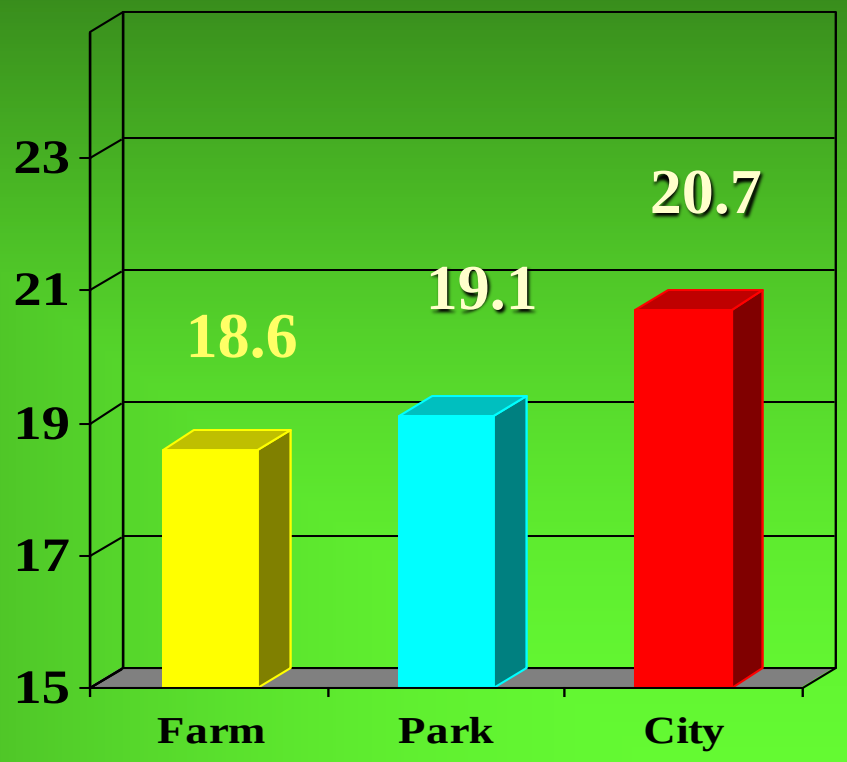
CO_2 along an urban gradient in 2002

- **Change in average day-time CO_2 concentration (ppm) from downtown Baltimore to an organic (rural) farm.**



Assumptions

- Change in average daily temperature (ºC) from downtown Baltimore to an organic (rural) farm (2002).



Can we utilize this gradient to study plant responses?

Placing four 2x2 m^2 plots Near downtown Baltimore. Use same soil in suburban and rural locations.

First year response, rural farm, 2002

First year re-growth of fallow soil, 97% lambsquarters, 6-8 feet in height.

(About as big as it gets)

Lambsquarters

First year response, urban Baltimore, 2002

First year re-growth, 80% lambsquarters, 10-12 feet in height. More annual weeds present.

No other meteorological factors (wind speed, ozone, etc.) varied along the transect.

And what about invasive weeds?

Tree of heaven

Canada thistle

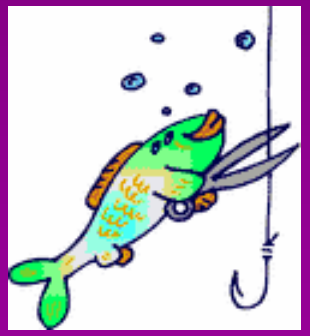
Does elevated CO_2 favor invasive species in plant communities?

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

CO_2 and Weed Biology: Overall.

- **Evidence to date indicates rising CO_2 *per se* has, or could potentially:**
  - **Effect quantity and quality of crop production**
  - **Effect weed/crop interactions, with greater crop losses due to weedy competition.**
  - **Alter invasive success with potential changes in productivity of rangelands and agriculture.**
  - **Alter invasive success and fire ecology.**
  - **Affect public health in numerous ways, not only contact dermatitis (e.g. poison ivy), but allergies, toxicology, pharmocology and nutrition.**
  - **Reduce efficacy of herbicides applied and mechanical control.**

Where do we go from here?

Recognition-Impact-Adaptation

Ignorance>>Knowledge