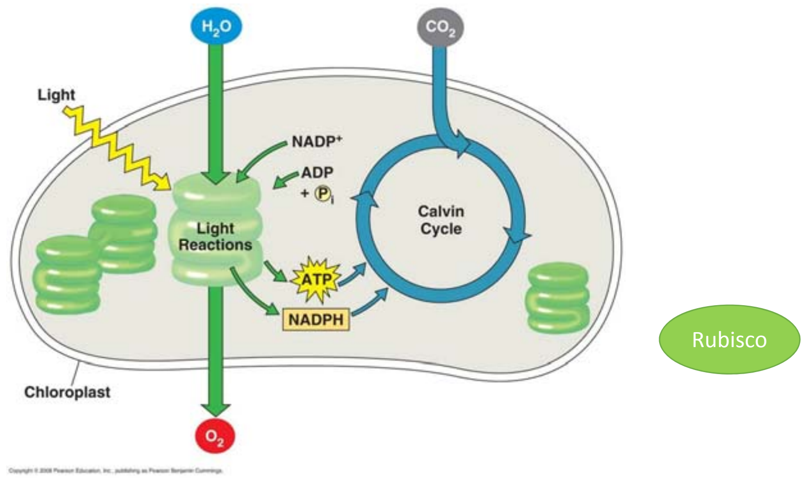
CO_2 Enrichment in Crop Production

Sam Burgner

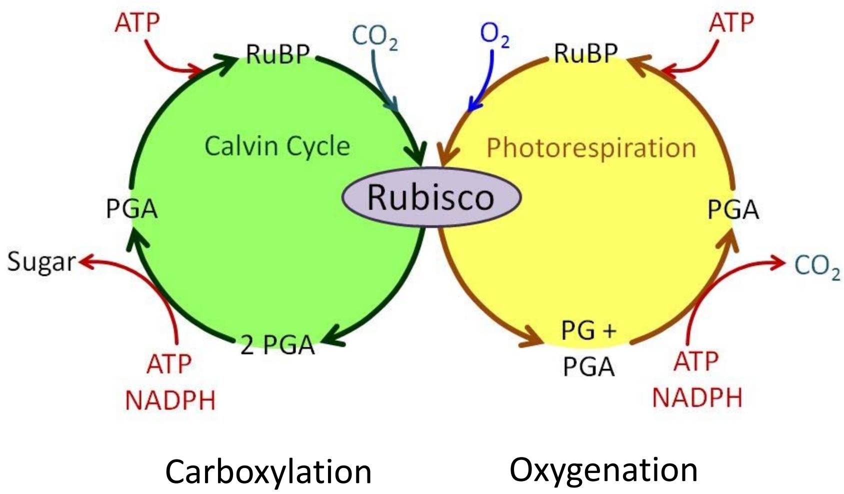
Topics

- Brief "Physiology of CO_2 enrichment"
- Benefits and risks of CO_2 enrichment
- When is the best time to apply CO_2?
- Case studies on different crops under ambient and elevated CO_2 concentrations

Rubisco & Photosynthesis



Rubisco active sites shared by CO_2/O_2



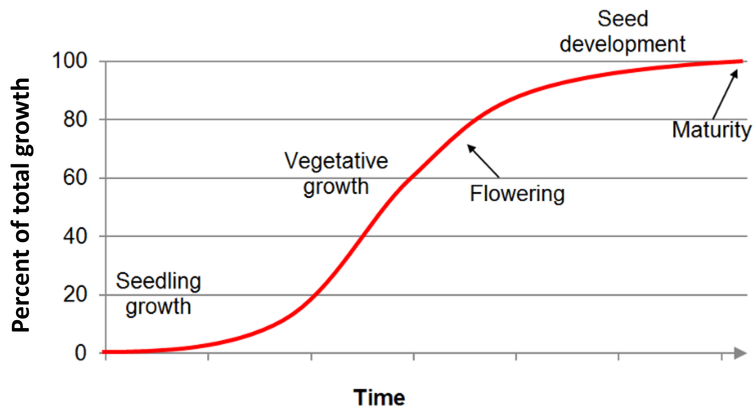
Rubisco

- Initial effects of CO_2 enrichment due to saturation of Rubisco with CO_2
- Plants acclimate to this effect
  - Reduce Rubisco content
  - CO_2 binding sites left inactive
- Short-term doses can “trick” the plant

Potential Benefits

- Luxury plant fertilization
  - More useful after optimizing nutrients, light, water, temp, etc
  - Potential increases in water use efficiency
- Short term often better than long-term
  - Plants can adapt, reduce photosynthetic capability to compensate for gains
- Faster biomass accumulation, higher yields
- Improved water use efficiency through effects on stomatal conductance

3 Phases of growth



3 Rates of growth

Deficient

Normal

Elevated

When does it make sense?

- CO_2 enrichment is most useful for increasing the growth rate during times of high productivity
  - Long-term enrichment requires highly productive crops
  - Increases in other inputs and sink strength may be necessary to sustain high growth rate
- Other growth parameters such as light, nutrients, temperature, and growth medium quality and quantity should be optimized first

Case Studies

Plant Physiol. (1989) 89, 590–596
0032-0889/89/89/0590/07/$01.00/0

Received for publication June 20, 1988
and in revised form September 26, 1988

Acclimation of Photosynthesis to Elevated CO_2 in Five C_3 Species[1]

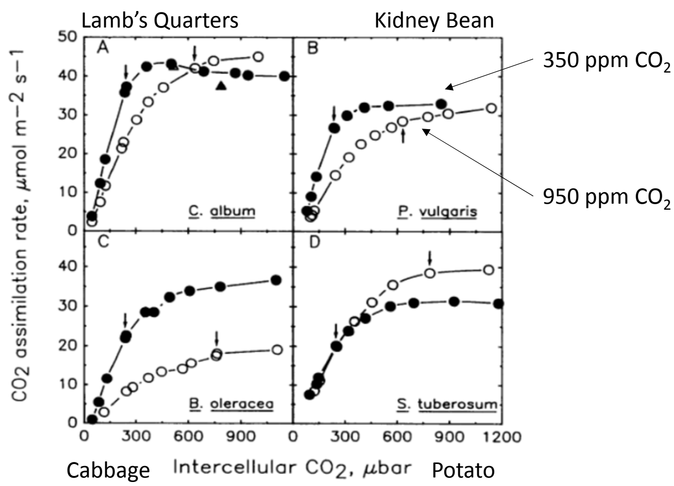
Rowan F. Sage*, Thomas D. Sharkey, and Jeffrey R. Seemann

Department of Botany, University of Georgia, Athens, Georgia 30602 (R.F.S); *Department of Botany, University of Wisconsin, Madison, Wisconsin 53706* (T.D.S); *and Department of Biochemistry, University of Nevada, Reno, Nevada 89506* (J.R.S.)

Conditions

- Greenhouse (Reno, NV), April to July
- 300 ppm CO_2 vs 950 ppm CO_2
- Light saturated, 1600-1800 µmol/m^2/s
- Sand-loam watered with full strength Hoagland solution

Effects on photosynthesis



Acclimation to High CO_2 in Monoecious Cucumbers[1]

I. VEGETATIVE AND REPRODUCTIVE GROWTH

Received for publication June 17, 1985 and in revised form July 30, 1985

MARY M. PEET
Department of Horticultural Science, Box 7609, North Carolina State University, Raleigh, North Carolina 27695-7609

Conditions

- 350 ppm CO_2 vs 1000 ppm CO_2
- 1:1:1 mix of gravel, vermiculite, and calcined clay
- Controlled environment chambers
- 12 hour photoperiod
- 25/20°C
- 70% Relative Humidity
- 500 µmol/m^2/s

Fruit yield

Growth CO_2 Concn.	Fruit Fresh Wt — Fruit Location on Plant							
	Mainstem		Axillary		Subaxillary		Total	
	350	1000	350	1000	350	1000	350	1000
	g/plant							
$\bar{X}$	74.58	76.98	7.35	65.97	1542.1	1472.03	1624.03	1614.98
SE	22.49	23.21	2.22	19.87	465	443.83	489.66	489.93

Vegetative growth

Table I. *Growth of CO_2 Enriched and Nonenriched Cucumbers Harvested at d 16, 36, 43, and 60 After Seeding*

	Growth CO_2 level	Days after Seeding							
		16		36		43		60	
	$\mu l\ L^{-1}$	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Root dry wt (g)	350	0.072	0.0048	1.34	0.11	3.46	0.24	5.19	0.48
	1000	0.122	0.007	2.12	0.17	3.49	0.46	5.40	0.42
Stem wt (g)	350	0.039	0.0018	5.86	0.43	16.11	1.27	32.97	1.78
	1000	0.051	0.006	6.00	0.26	16.92	1.54	36.91	2.45
Leaf wt (g)	350	0.157	0.012	11.55	0.70	21.56	1.60	32.87	2.55
	1000	0.322	0.039	12.79	0.44	21.50	2.62	29.40	1.46
Total wt (g)	350	0.347	0.017	18.76	1.20	41.13	2.92	71.0	6.20
	1000	0.636	0.06	20.92	0.73	41.92	4.52	71.71	4.18
Total leaf area (dm^2)	350	0.652	0.041	32.93	1.79	64.79	3.80	98.05	6.63
	1000	0.918	0.07	31.12	1.06	52.25	4.72	93.28	4.15
Leaf number	350	2.3	0.145	24.1		50.47		106.67	
	1000	2.5	0.158	22.5		43.49		107.41	

Plant Physiol. (1991) 96, 713–719
0032-0889/91/96/0713/07/$01.00/0

Received for publication November 16, 1990
Accepted February 28, 1991

CO_2-Enhanced Yield and Foliar Deformation among Tomato Genotypes in Elevated CO_2 Environments[1]

Kim E. Tripp, Mary M. Peet*, D. Mason Pharr, Daniel H. Willits, and Paul V. Nelson

Department of Horticultural Science (K.E.T., M.M.P., D.M.P., P.V.N.), Department of Biological and Agricultural Engineering (D.H.W.), North Carolina State University, Raleigh, North Carolina 27695–7609

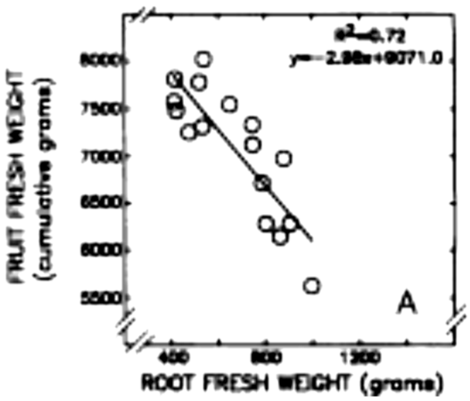
Conditions

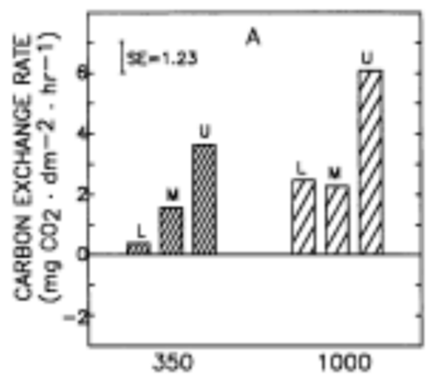
- Eight tomato cultivars
- Grown in polyethylene bags, Pro-Mix BX with 20-20-20 liquid fertilizer
- 350 ppm CO_2 vs 1000 ppm CO_2
- Temperature maintained between 21°C and 28°C
- Transplant grown for 7 weeks, then 16 more in bags

Effects on yield

Genotype	16 Week Yield @ 1000ppm CO_2		16 Week Yield @ 350ppm CO_2
TRVE13	7832 (grams per plant)	+1.59 lbs	7110 (grams per plant)
Laura	7816	+2.36	6743
B83.977	7838	+1.22	7280
Michigan-Ohio	7750	+4.34	5781
Perfecto	7480	+3.97	5677
Dombito	7092	+1.45	6432
Caruso	7373	+1.12	6866
Hotset	7120	+1.9	6258

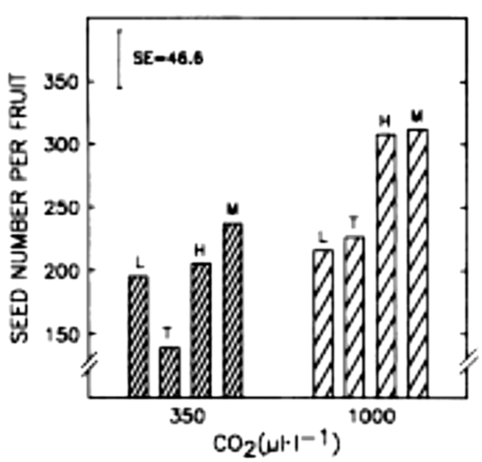
Effects on yield





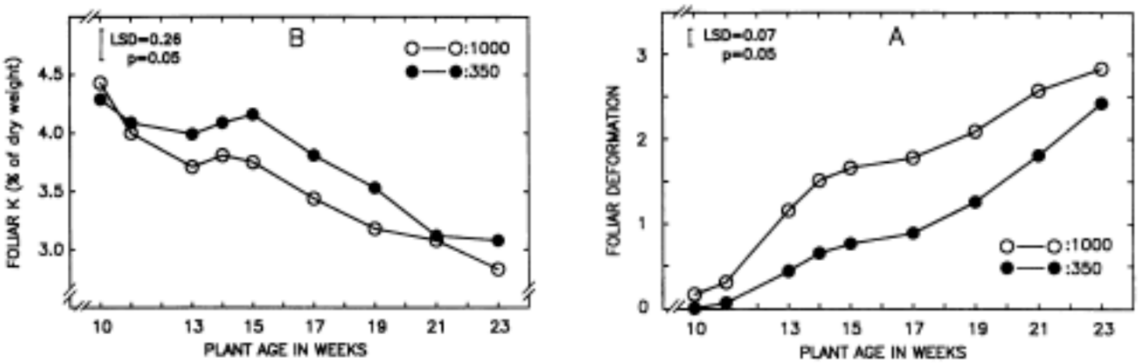
Lower
Middle
Upper

Number of seeds



L – “Laura”
T – TRVE13
H - Hotset
M – Michigan-Ohio

Foliar deformation



Key Points

- Some species acclimate well to CO_2-enriched environments while others undergo stress
- Short-term enrichment benefits more species than long-term enrichment
- Long-term requires highly productive species and increases in other inputs
- CO_2 enrichment may not increase yield in some species but could be used to enhance hardiness of plugs/transplants

Thanks!

Sam Burgner
sburgner@purdue.edu