What Do We Know About Carbon in Grass Seed Crops

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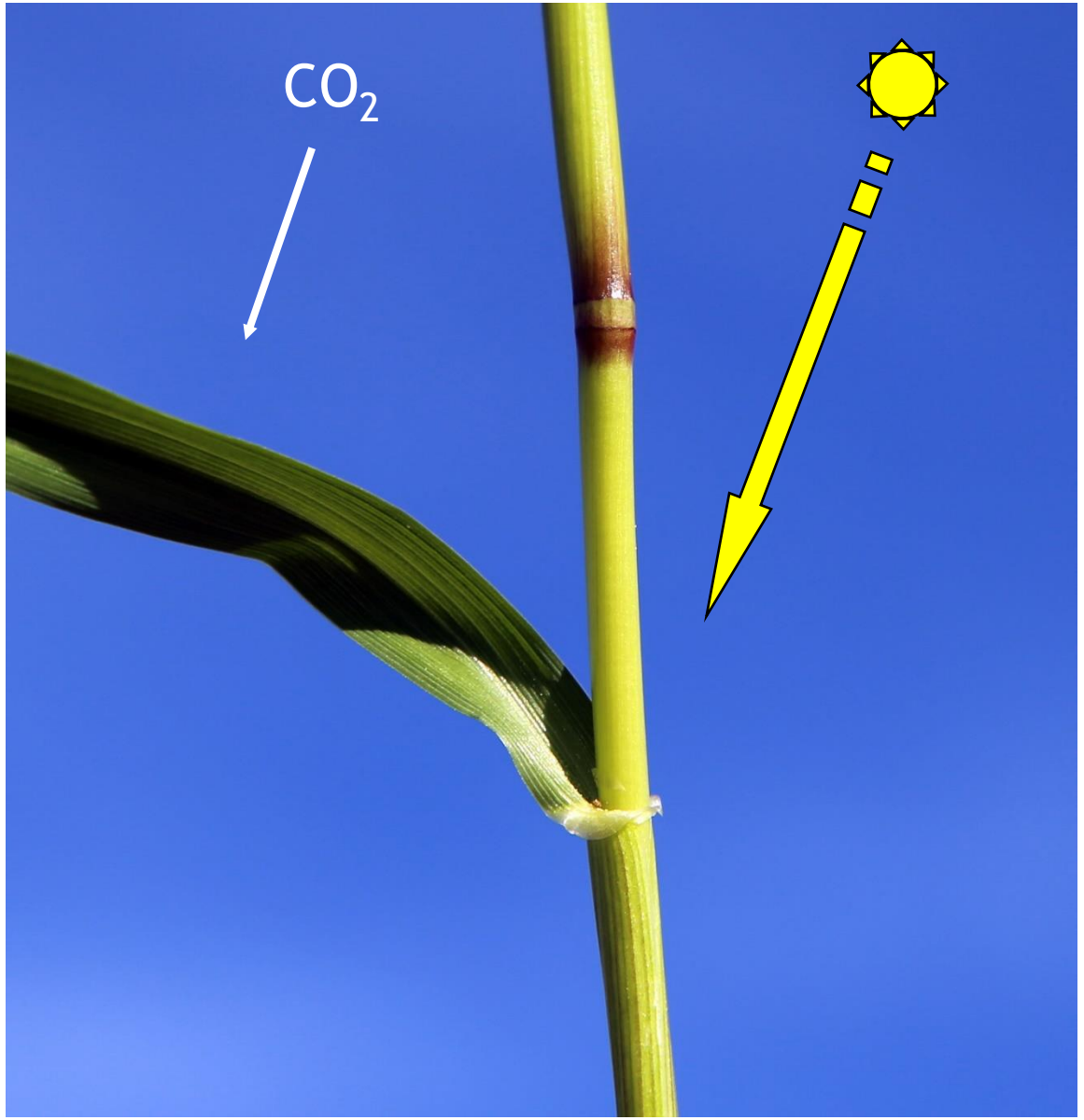
Photosynthesis, Carbon Capture, and Farming

- Grass seed crops capture solar energy and CO_2 from the atmosphere and convert this energy into a stable chemical form through a process known as **photosynthesis**.
- Carbon from atmospheric CO_2 is chemically reduced in several steps to a stable form, a carbohydrate.

$$CO_2 + H_2O \longrightarrow CH_2O$$

Oxidized Carbon — Reductant — Reduced Carbon



Annual ryegrass (T.G. Chastain photo)

Photosynthesis, Carbon Capture, and Farming

- Grass seed crops are biological solar energy and carbon collectors.
- For every acre of grass seed crop, there are 3 acres of leaves and stems deployed to collect the sun's energy and carbon.
- Nitrogen is vital to grass seed production because it stimulates growth of the crop's biological solar energy and carbon collector.
- Seed yield is low when N is low because the crop's ability to capture solar energy and carbon is reduced.

Perennial ryegrass (T.G. Chastain photo)

Respiration

- Aerobic respiration is the controlled oxidation of reduced carbon.
- This oxidation not only provides energy for plant metabolic processes but also provides the carbon building blocks needed for crop growth and seed yield.
- Plants and seeds are built with carbon building blocks.

$$CH_2O + O_2 \rightarrow CO_2 + H_2O + ATP$$

Reduced Carbon | Oxidized Carbon | Chemical energy

Grass growth (T.G. Chastain graphic)

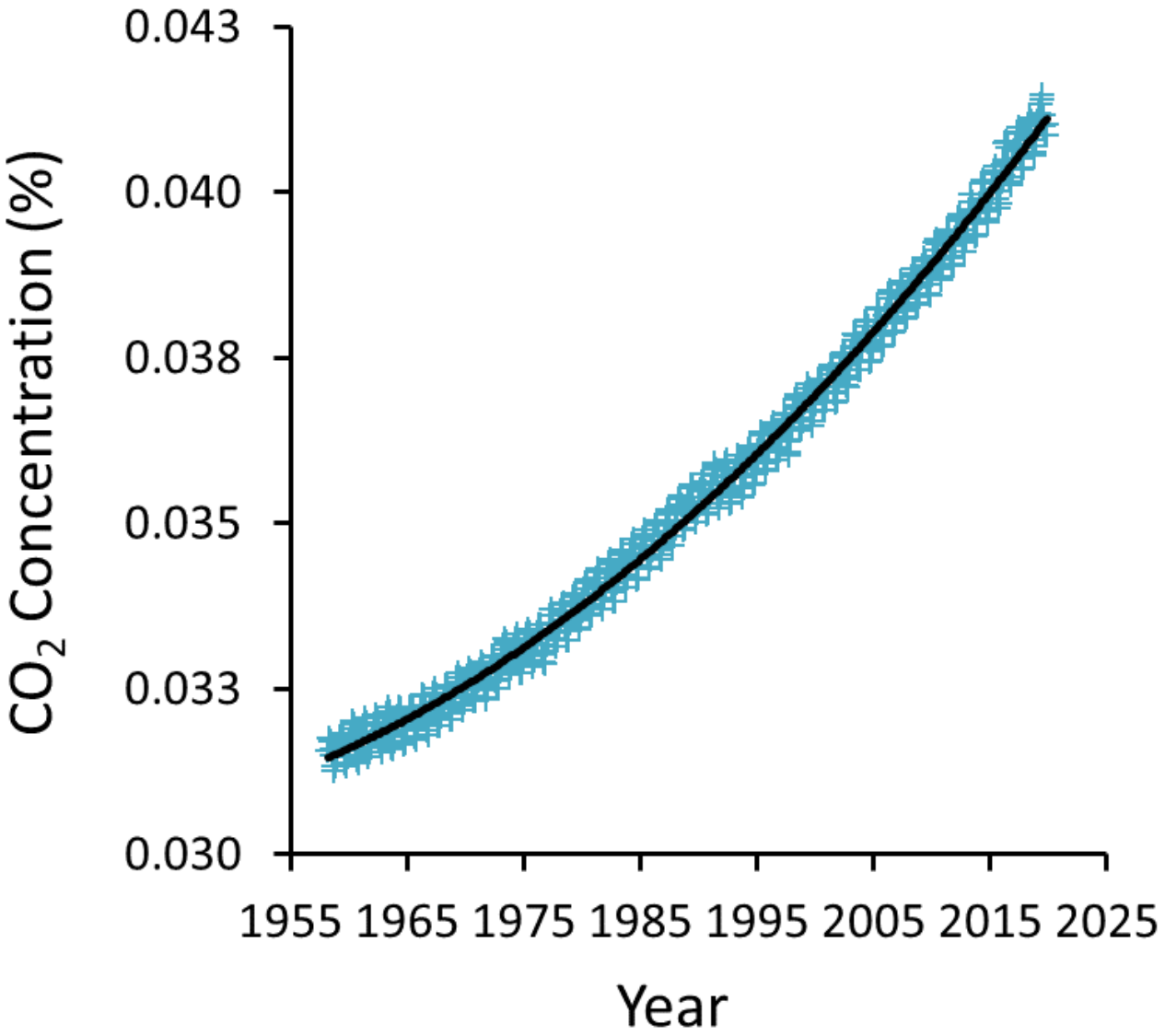
Carbon: Plant Macronutrient

Nutrient	Plant Content (%)	Source	Available Form
Carbon	42-45	Air	CO_2
Oxygen	41-44	Air	O_2
Hydrogen	6	Water	H_2O
Nitrogen	0.8-9	Soil Organic and Inorganic	NH_4^+, NO_3^-
Potassium	0.4-3	Soil Inorganic	K^+
Calcium	< 1	Soil Inorganic	Ca^{+2}
Phosphorus	< 1	Soil Organic and Inorganic	HPO_4^{-2}, $H_2PO_4^-$
Magnesium	< 1	Soil Inorganic	Mg^{+2}
Sulfur	< 1	Soil Organic and Inorganic	SO_4^{-2}

Data sources: Banowetz et al., 2009; Hart et al., 2013; Anderson et al., 2014; Chastain et al., 2017; Chastain unpublished

Carbon: Where does it come from?

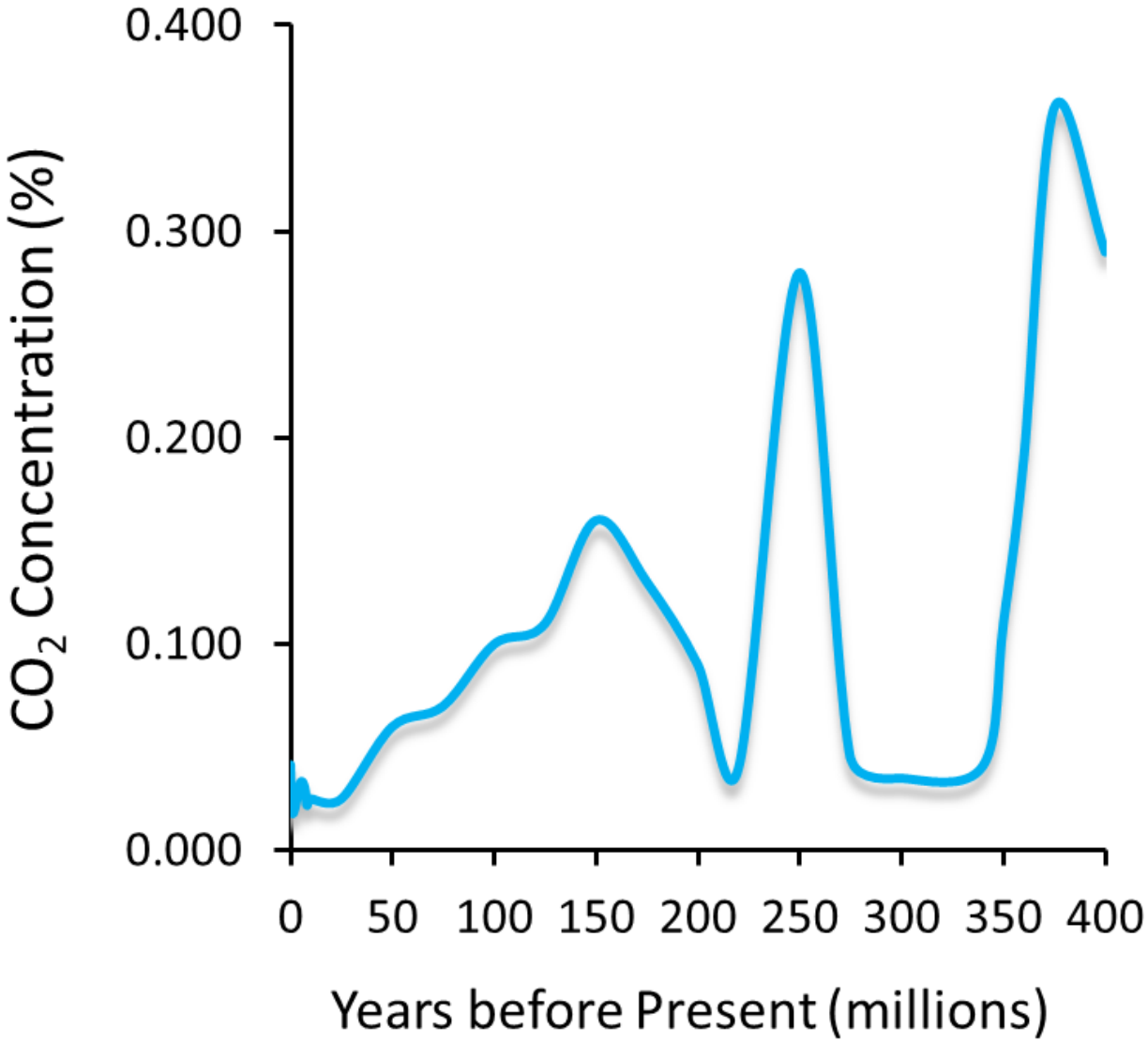
- The source of carbon for crops is atmospheric CO_2.
- CO_2 is the 4th or 5th most abundant constituent in the atmosphere:
  - Nitrogen (N_2 = 78.08%)
  - Oxygen (O_2 = 20.95%)
  - Argon (Ar = 0.93%)
  - Carbon dioxide (CO_2 = 0.042%)
  - Water vapor (H_2O up to 3%)
- The concentration of CO_2 in the atmosphere is increasing and thus is not a limited resource.



Monthly Atmospheric CO_2 concentration - data source: NOAA Earth System Research Laboratory (T.G. Chastain graphic)

Carbon: Past and Future

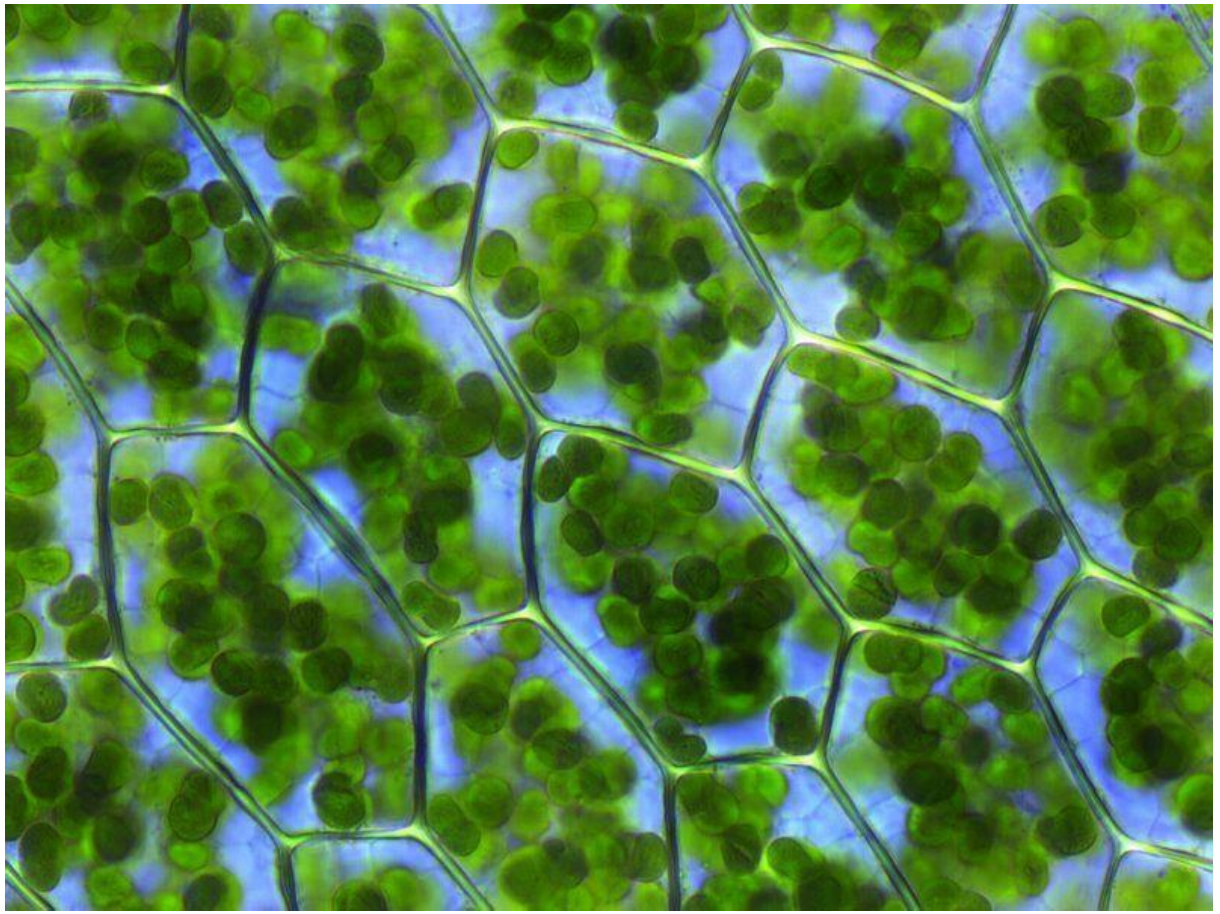
- Vascular plants such as grass seed crops (C3 plants) evolved during high CO_2 concentrations of the distant past. These concentrations were 10 times present levels.
- CO_2 concentrations decline during ice ages. At low CO_2 , C3 plants exhibit low rates of photosynthesis and thus grow poorly. Photosynthesis and yield increases in C3 plants with increased CO_2
- C4 plants (corn, sugarcane) evolved more recently during low CO_2 and are adapted to grow well in this environment. Yield does not increase appreciably with increasing CO_2 in C4 plants.



Historical changes in atmospheric CO_2 concentration (redrawn from Gerhart and Ward, 2010)

Carbon: Primary Building Block of Plants

Component	Chemical Composition
Cell contents	Non-structural carbohydrates (sugars, fructans, starch)
	Proteins
	Lipids
	Chlorophyll
	DNA, RNA
Cell walls	Cellulose
	Hemicellulose
	Lignin



Plant cells with chloroplasts (Kristian Peters-Fabelfroh, photo)

Carbon in Grass Seed Crops – Plant Components

- The carbon content of grass seed crops vary with the plant component.
- The shoot system is made up of 42% carbon by weight.
- The root system contains a somewhat smaller amount of carbon – 35% by weight.

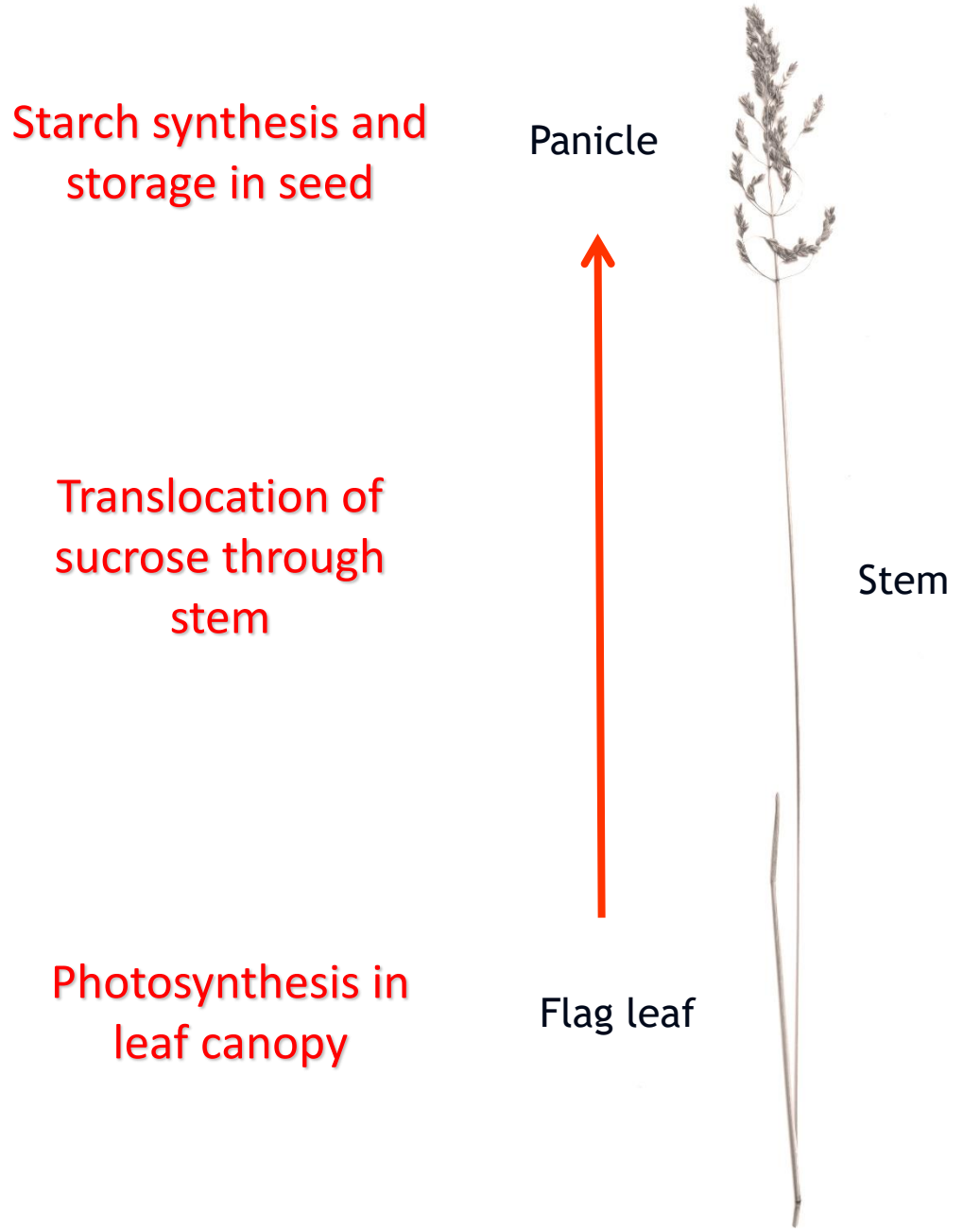
Shoots 42%

Roots 35%

Data source and photos: T.G. Chastain

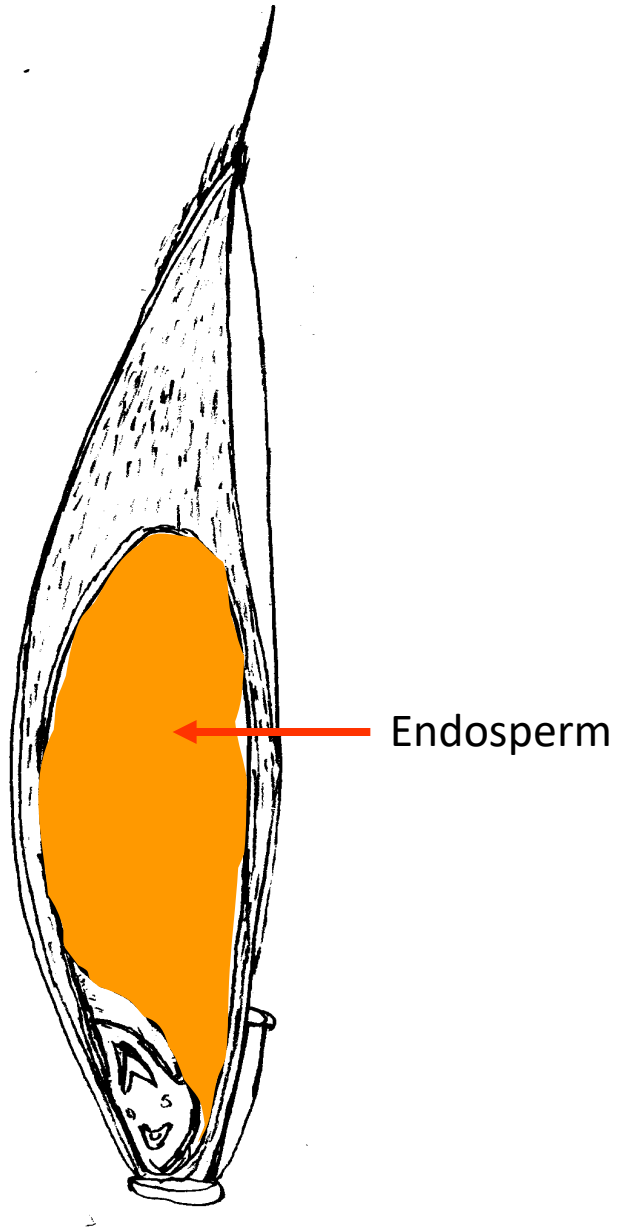
Partitioning of Carbon to Grass Seed

- Partitioning is the preferential distribution of carbon to various locations within the plant.
- Carbon moves from source (flag leaf) to seed (sink) during seed filling.
- The primary transport form for carbon translocation to seed is sucrose.
- The more carbon that is captured and partitioned to seed, the greater the seed yield.



Partitioning of Carbon to Grass Seed

- The endosperm is the primary food reserve for seed germination and the source of most of the weight of the seed at harvest.
- Carbon is stored in grass seed primarily as starch and proteins in the endosperm.
- Starch concentrations increase in the endosperm until they reach about 1/3 of the weight of the seed.



Longitudinal section of a grass seed
(TG Chastain graphic)

How much Carbon in Grass Seed Crops?

Crop	Component	Biomass	Total C
		(lbs/acre)	(lbs/acre)
Tall Fescue	Shoots	18500	7770
	Roots	11200	3920
	Seed	1600	672
	Total		12362
Perennial Ryegrass	Shoots	10400	4368
	Roots	8500	2975
	Seed	1500	630
	Total		7973

Data source: T.G. Chastain

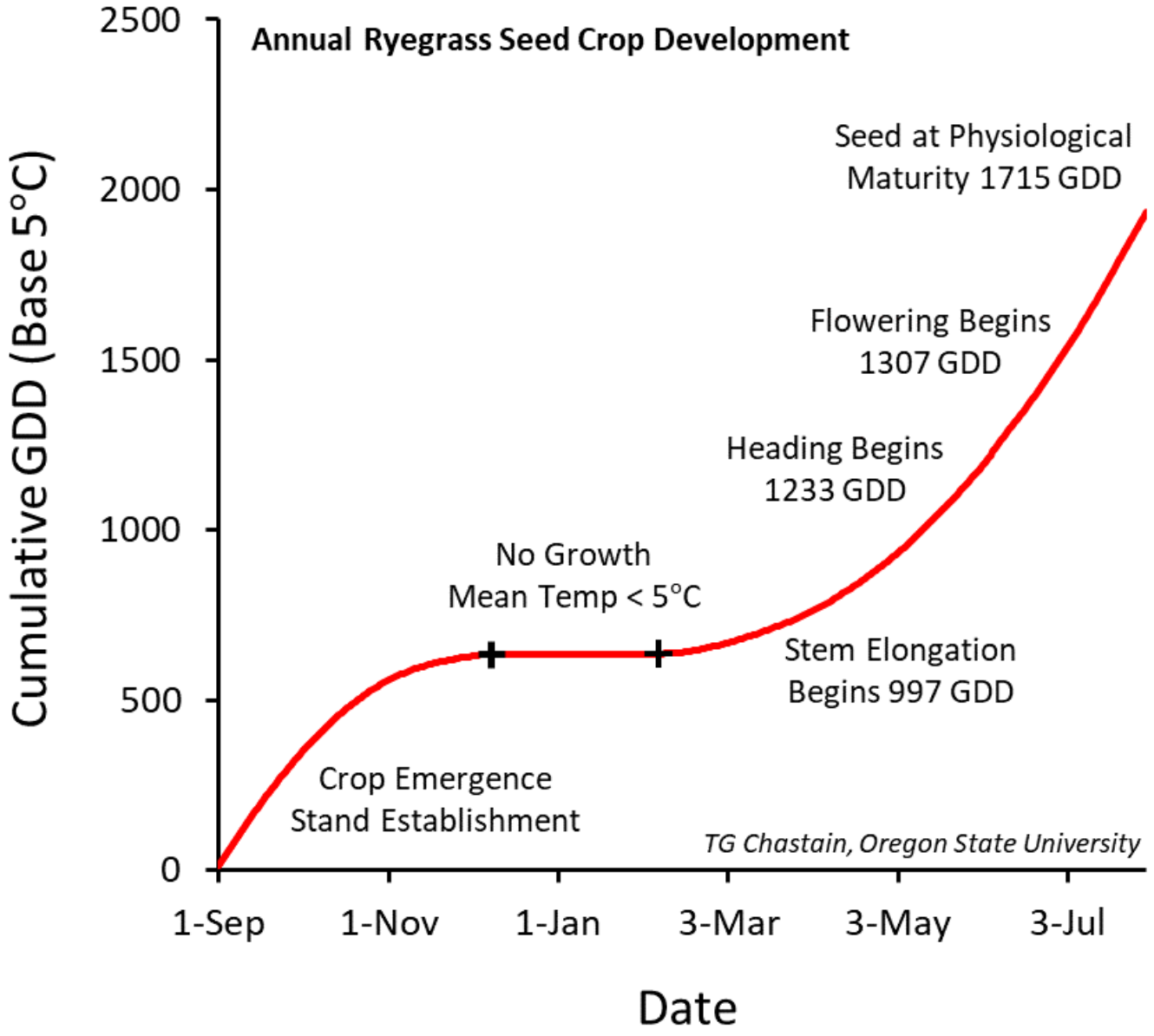
How much Carbon in Grass Seed Fields?

- Tall fescue is the top crop with more than 800,000 tons of carbon captured in a year.
- The total carbon capture by Oregon's grass seed production acreage is over 2.2 million tons in a year.
- The state average is 5.45 tons carbon per acre of grass seed field.
- 20 tons of CO_2 equivalents captured per acre per year.

Crop	Acreage (acres)	Total C (tons)
Annual ryegrass	120250	743265
Perennial ryegrass	83450	332673
Tall fescue	134370	830541
Kentucky bluegrass	20650	82321
Rough bluegrass	1080	4305
Orchardgrass	15190	93889
Chewings fescue	8790	35041
Red fescue	11370	45327
Hard fescue	2280	9089
Colonial bentgrass	3030	12079
Creeping bentgrass	3590	14312
Sum	404050	2202843

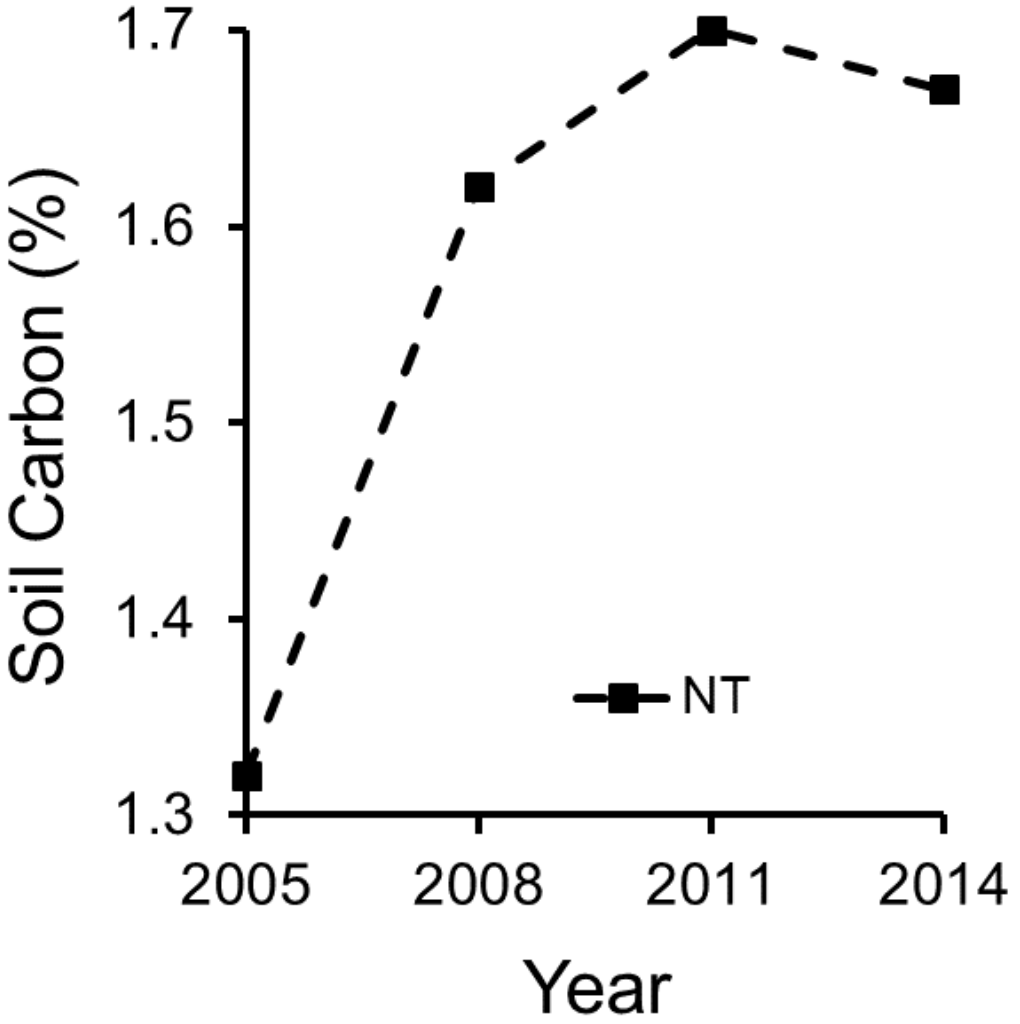
Timing of Carbon Capture

- Developmental stages of annual ryegrass seed crops in relation to GDD from September 1st in Oregon
- Biomass production is least in the fall, minimal during winter, and is greatest in spring leading up to seed harvest.
- Annual carbon capture is maximum at seed crop maturity.



Soil Carbon in Grass Seed Cropping Systems

- Soil carbon is slow to change through changes in cropping system practices. After 9 years, changes in soil carbon were small in annual ryegrass cropping systems (Chastain et al., 2017).
- Carbon stocks in soil increase with perennial crops and no-tillage.
- Griffith et al. (2011) reported that soil carbon in Willamette Valley grass seed cropping systems ranged from 26 to 36 lbs C per ton soil in the top 4 inches of soil and ranged from 22 to 28 lbs C per ton soil in the next 4 inches of soil.

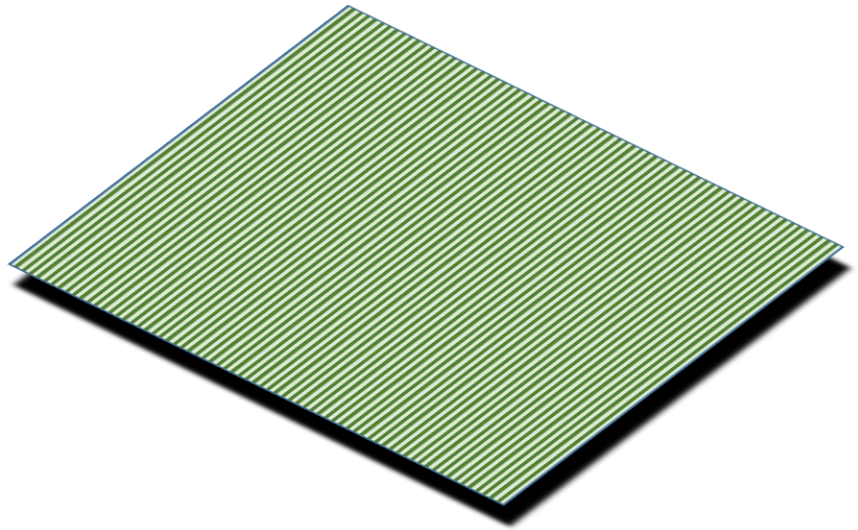


No-till management effects on soil carbon in annual ryegrass seed crops (Chastain et al., 2017)

Soil Carbon in Grass Seed Cropping Systems

How much carbon is found in an acre furrow slice under a grass seed field?

Crop	Soil Carbon (tons/acre furrow slice)	Authors
Annual Ryegrass		Chapin and Huddleston, 1992
Burn	17.9	
Conv. Tillage	22.3	
Various	17.4 to 25.1	Banowetz et al., 2009
Annual Ryegrass	14.9 to 15.7	Griffiths et al., 2010
Perennial Ryegrass	11.2 to 15.4	
Annual Ryegrass		Chastain et al., 2017
Conv. Tillage	15.5	
No Tillage	16.9	



Acre furrow slice = the volume or weight of soil under an acre of land to the depth of 6.7 inches

Carbon in Grass Seed Cropping Systems

- Carbon is a plant nutrient.
- The source of carbon is atmospheric CO_2.
- CO_2 concentrations in the atmosphere are increasing and this nutrient is not in short supply.
- Carbon is the building block of grass seed crop growth and yield.
- Crop management practices are aimed at optimizing carbon partitioning to seed.
- Grass seed crops capture more than 5 tons of carbon per acre each year although some of that is removed as seed and straw.
- The soil contains as much as 25 tons of carbon per acre.

Atmosphere (NASA photo)