Corn Irrigation

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http://www.uky.edu/Ag/GrainCrops/ |
http://graincrops.blogspot.com/

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Corn Production from 1980 to 2011 in the U.S.A.

- Per Bushel
  - Corn used **-53%** irrigation water
  - Corn generated **-36%** greenhouse gas emission
- Per Acre
  - Corn used **-28%** irrigation water
  - Corn generated **+8%** greenhouse gas emission

http://www.fieldtomarket.org/report/national-2/PNT_NatReport_Corn.pdf

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Corn Yield

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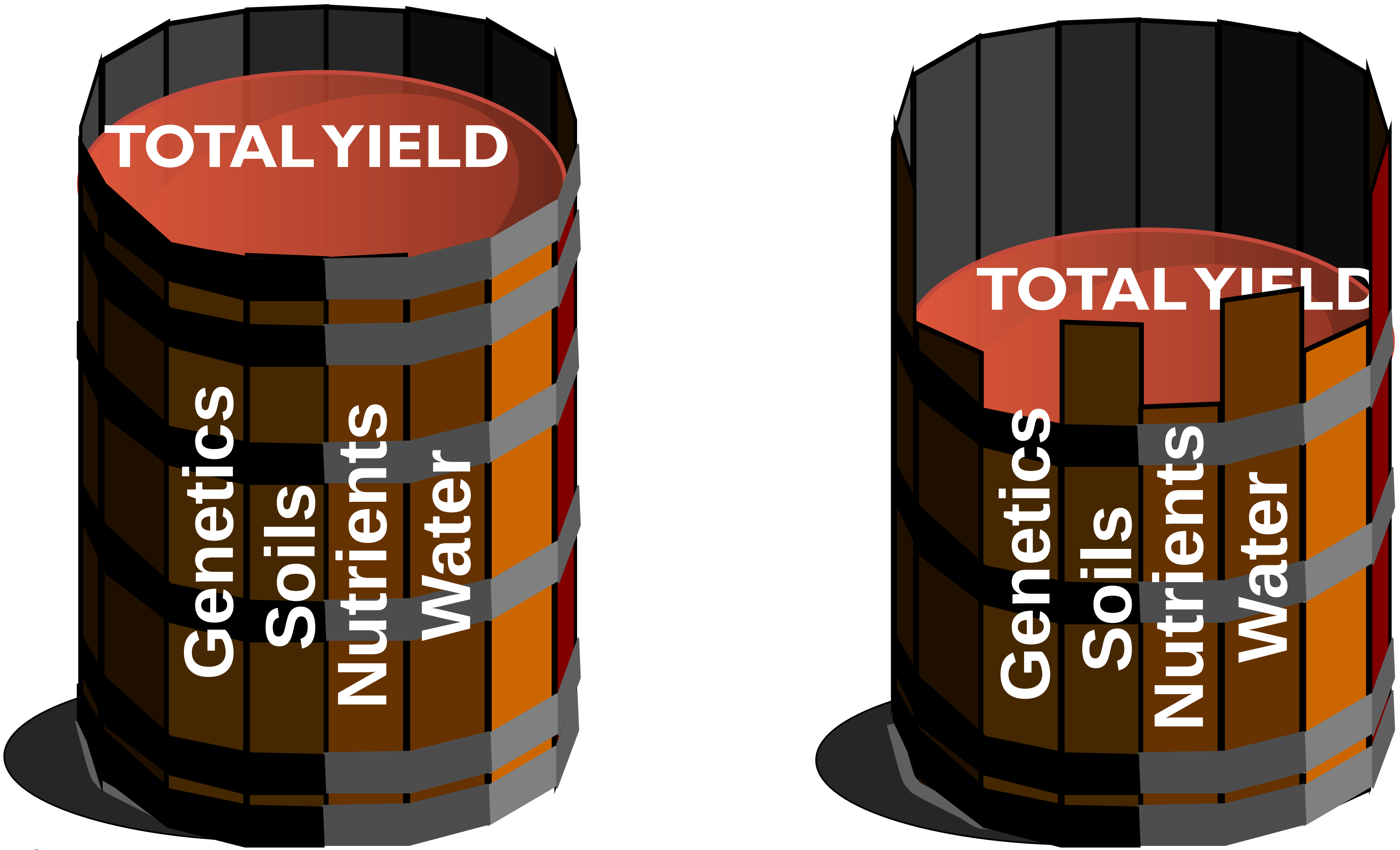
JOHN DEERE
525

Yield Limitations



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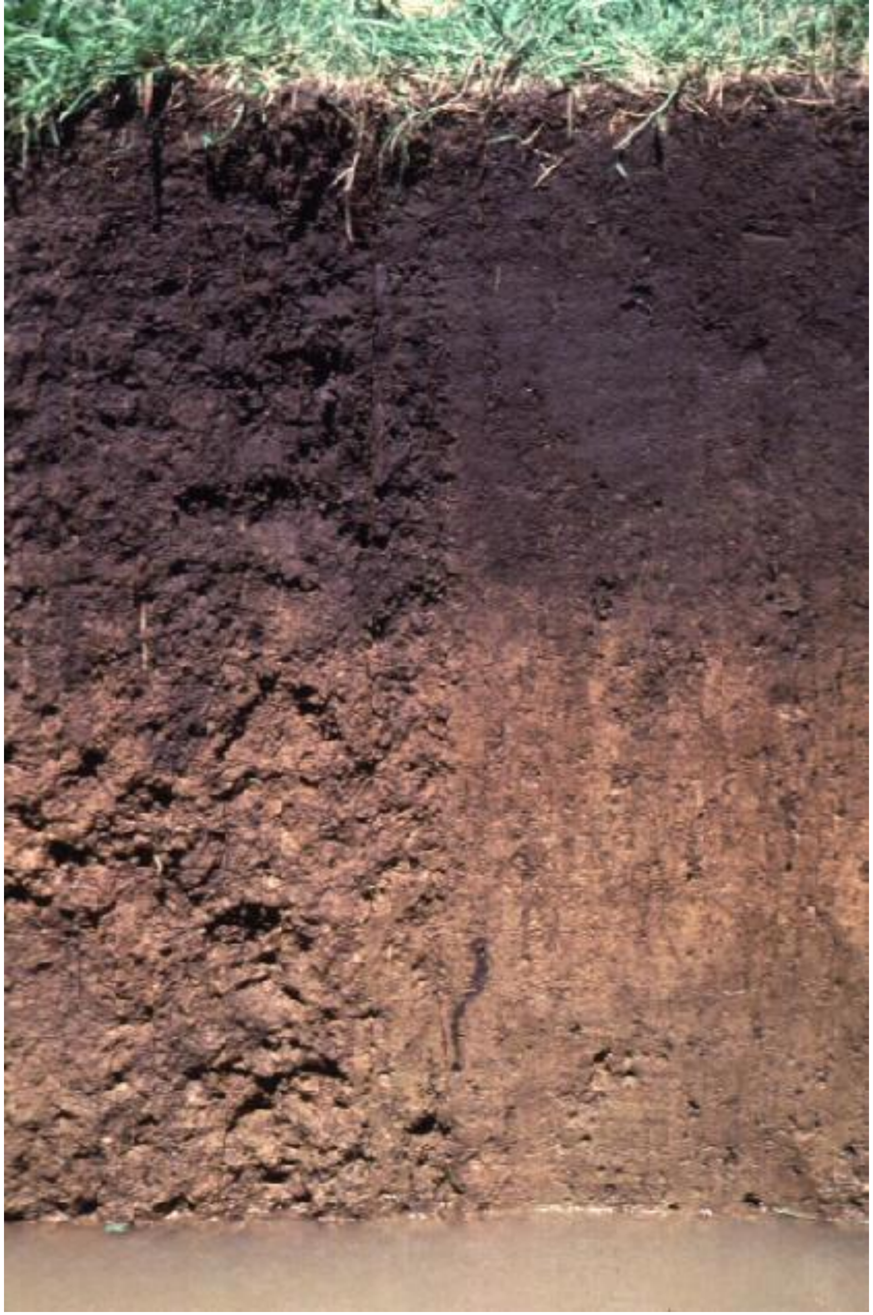

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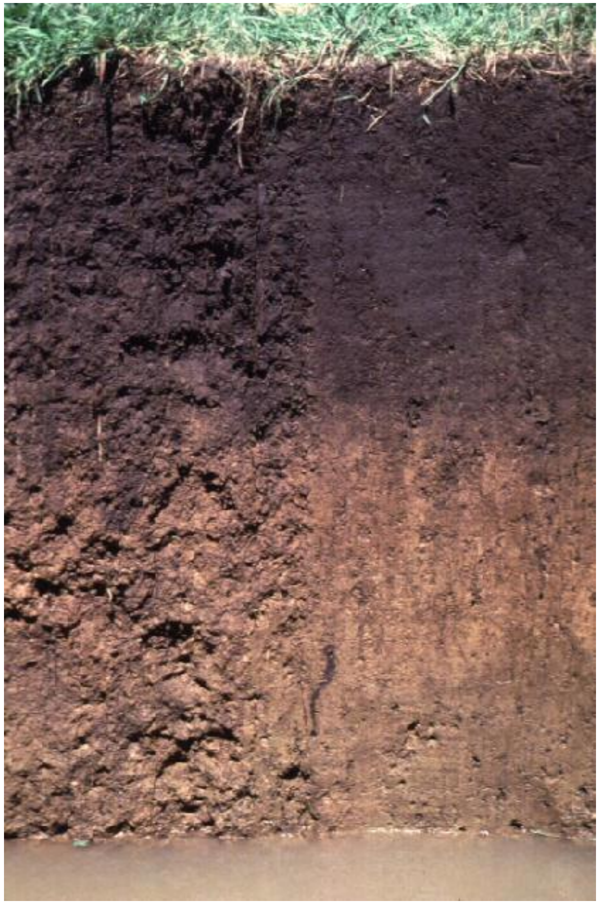
Water Holding Capacity of Most Soils

Textural Class	Water Holding Capacity, inches/foot of soil
Coarse Sand	0.25 – 0.75
Fine Sand	0.75 – 1.00
Loamy Sand	1.10 – 1.20
Sandy Loam	1.25 – 1.40
Fine Sandy Loam	1.50 – 2.00
Silt Loam	2.00 – 2.50
Silty clay loam	1.80 -2.00
Silty clay	1.50 – 1.70
Clay	1.20 – 1.50



http://passel.unl.edu/UserFiles/File/Crp.%20Prod.%20Nat.%20Res.%20Mngmt/Soils%20lesson%202/2.6.gif

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Water Holding Capacity

- Many grass-based soils can hold 10 to 15 inches of water per season.
- Soils with restriction layers may hold 5 inches or less.
- Corn needs about 20 to 25 inches of water.

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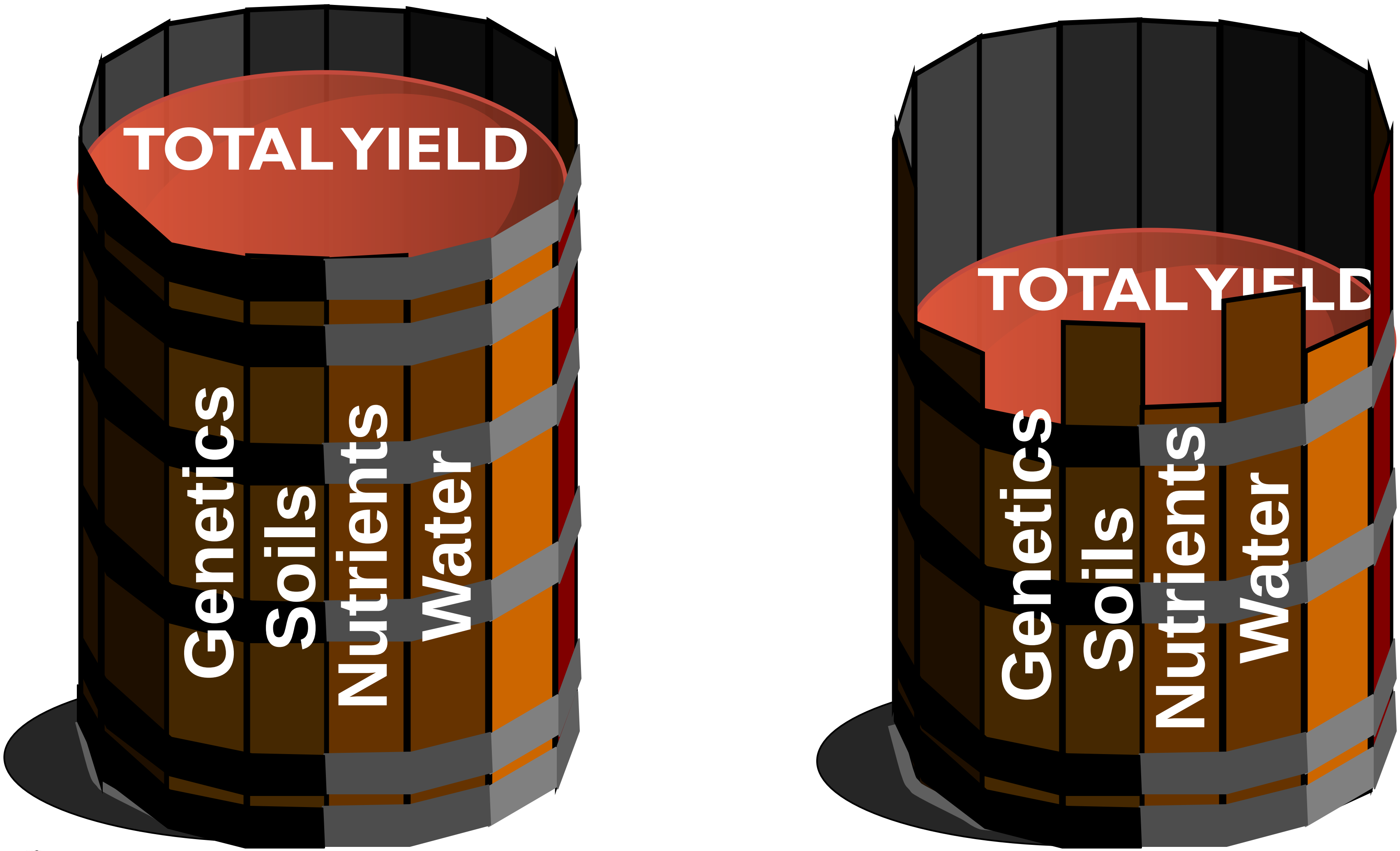
Yield Limitations



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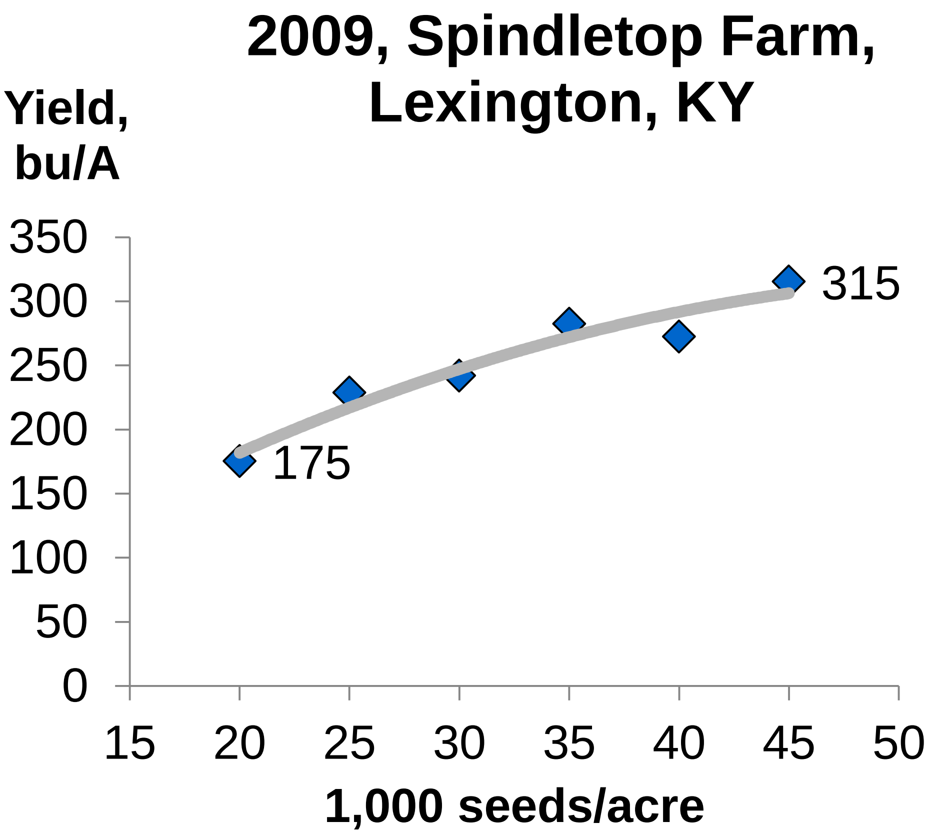
Corn with adequate water



2009, Spindletop Farm
4 hybrids: DKC63-42, DKC63-45, DKC64-44 & DKC65-47
No-Till
Loradale Silt Loam

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What caused this?

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Corn Irrigation: The Main Points

- Corn needs about 20 to 25 inches of water (in Kentucky). High yields?
- Most soils provide about 5 inches of water at field capacity.
- Corn is most sensitive to water stress around tasseling.
- Water stress at many stages of corn growth can reduce yield.

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The basic question:

- You ask: how do I increase yield?
- Answer: increase photosynthesis and/or C assimilation in the plant

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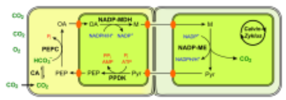
Photosynthesis:

carbon dioxide + water → sugar + oxygen

Solar energy

$$6\ CO_2 + 6\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2$$



Respiration:

sugar + oxygen + water $\xrightarrow{\text{30 steps}}$ carbon dioxide + water + 637 kcal

$$C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O \longrightarrow 6\ CO_2 + 12\ H_2O$$

Energy

Source: Dennis Gardner et al., Physiology of Crop Plants. 1985. The Iowa State University Press. Ames.

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Water makes a difference most years.

Daviess County, KY, June 27, 2012: Same Field, Same Row, Same Hybrid, Non-irrigated and Irrigated.

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Time:

- Emergence to Black-layer: about 110-118 days
- Seed fill: about 30 days

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Leaf Collar

Abendroth, L., R. Elmore, M. J. Boyer and S. K. Marlay. 2011. **Corn Growth and Development. PMR 1009.** Iowa State Univ. Extension, Ames, Iowa.

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6 Fully Emerged Leaves

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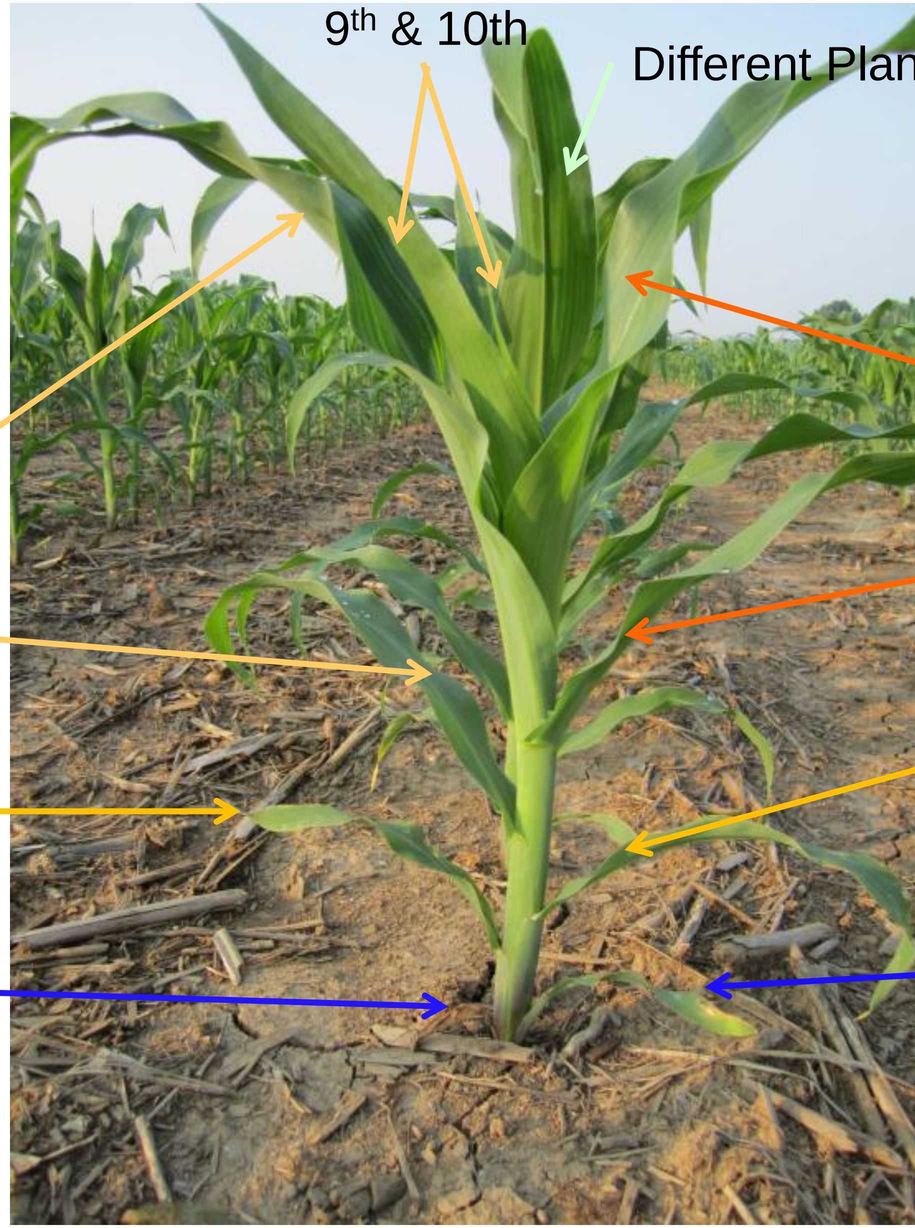
6 Fully Emerged Leaves



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VE = emergence

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V2 Corn

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Six Fully Emerged Leaves, V6

- Growing point above soil surface.
- Tassel and dominant ear development have started.
- Final node number and leaf development are set.
- Cumulative Nutrient uptake: about
  - 7% of N
  - 5% of P
  - 10% of K

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V8 Corn

- Tassel and dominant ear are continuing to grow.
- Kernel initiation is starting.
- Rapid Stem Growth
- Cumulative Nutrient uptake: about
  - 15% of N
  - 10% of P
  - 20% of K

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V8 Corn

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Pollen Drop

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Tassel / Silking, VT/R1

- Cumulative Nutrient uptake: about
  - 60% of N
  - 35% of P
  - 75% of K

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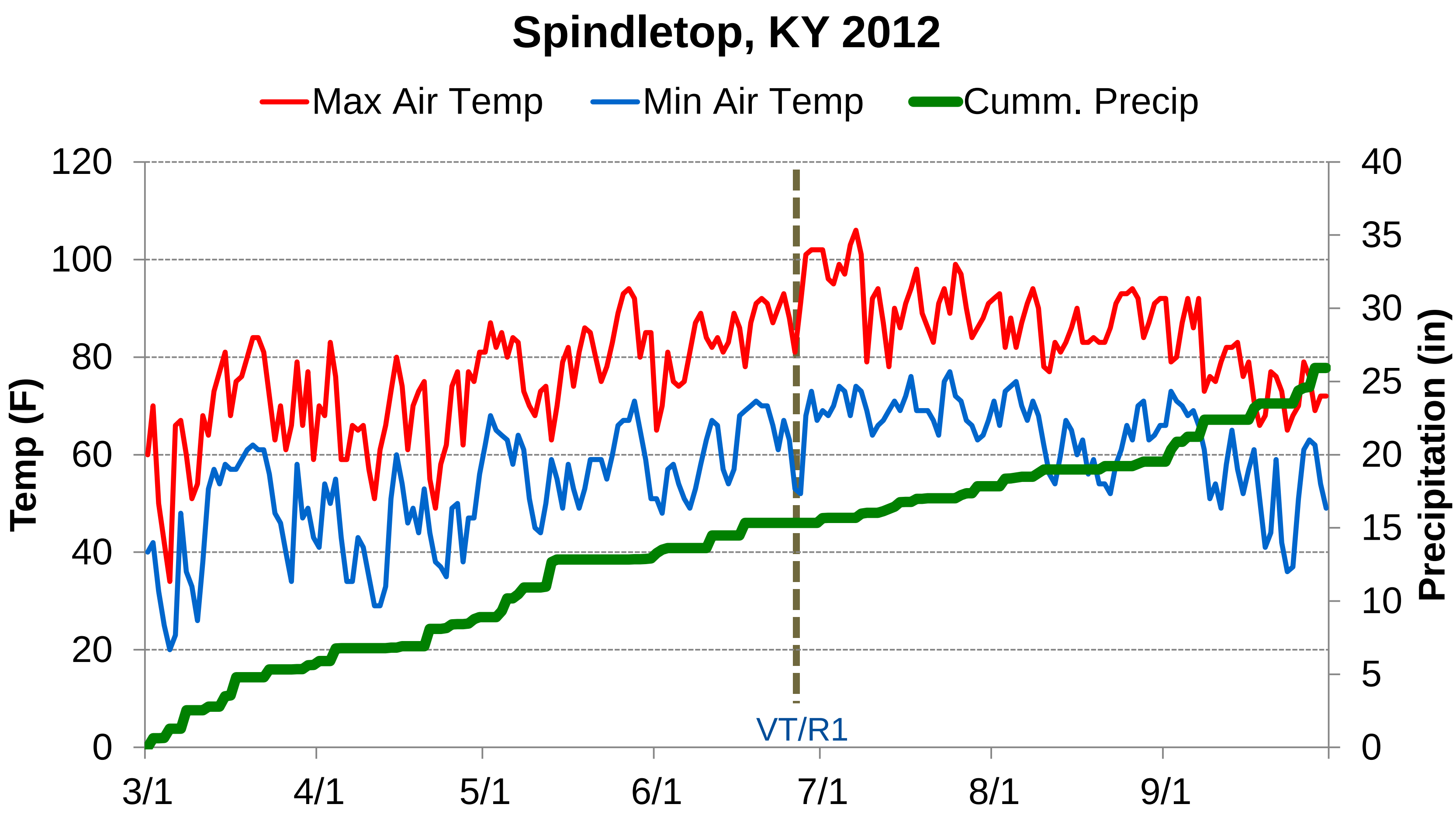
Hot and Dry

Corn and Soybeans require about 20 to 24 inches of water per season.



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Corn and Heat

- Temperatures about 77 to 91 F
- Corn can survive temps above 100 F depending on water availability

Elmore, R. and E. Taylor. 2011. Corn and “a Big Long Heat Wave on the Way” Iowa Integrated Crop Management Newsletter Iowa State Univ.
http://www.extension.iastate.edu/CropNews/2011/0715elmoretaylor.htm

Nafziger, E. 2011. High Temperatures and Crops. University of Illinois
http://bulletin.ipm.illinois.edu/article.php?id=1537

Thomison, P. 2011.High Temperature Effects on Corn. C.O.R.N. Newsletter, Ohio State Univ.
http://corn.osu.edu/c.o.r.n.-newsletter#2

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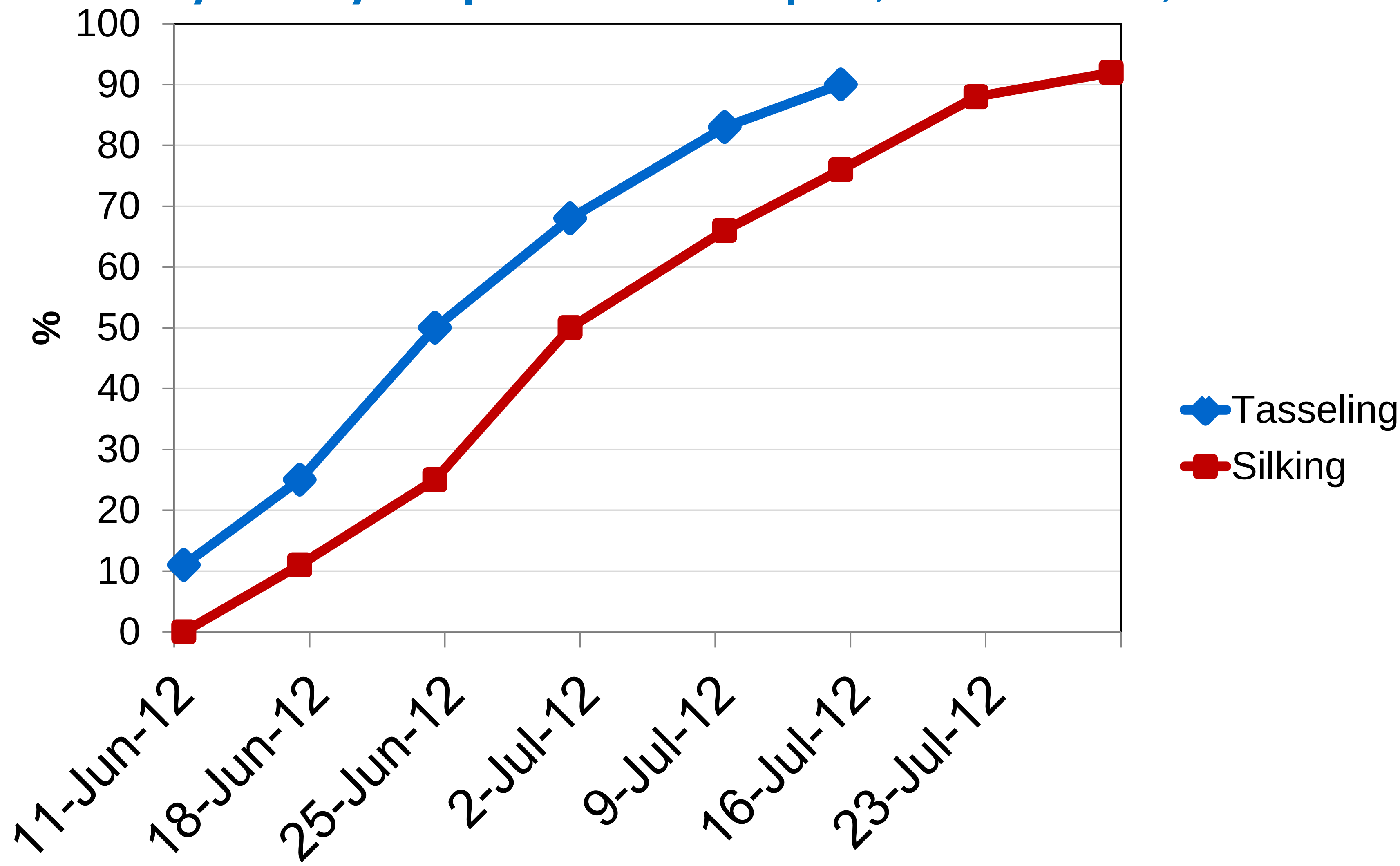
Kentucky Weekly Crop & Weather Report, USDA-NASS, 2012



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“Trapped Tassel”

- Drought/heat hurts pollination
- Timing of pollen drop and silking
- Dries out pollen
- Dries out silks
- Aborts fertilized ovules

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Dent Stage, R5

- About 30 days.
- About 45% dry matter accumulation at start.
- About 90% dry matter accumulation at ½ milk line.
- Cumulative Nutrient Uptake
  - 90% of N
  - 80% of P
  - 95% of K

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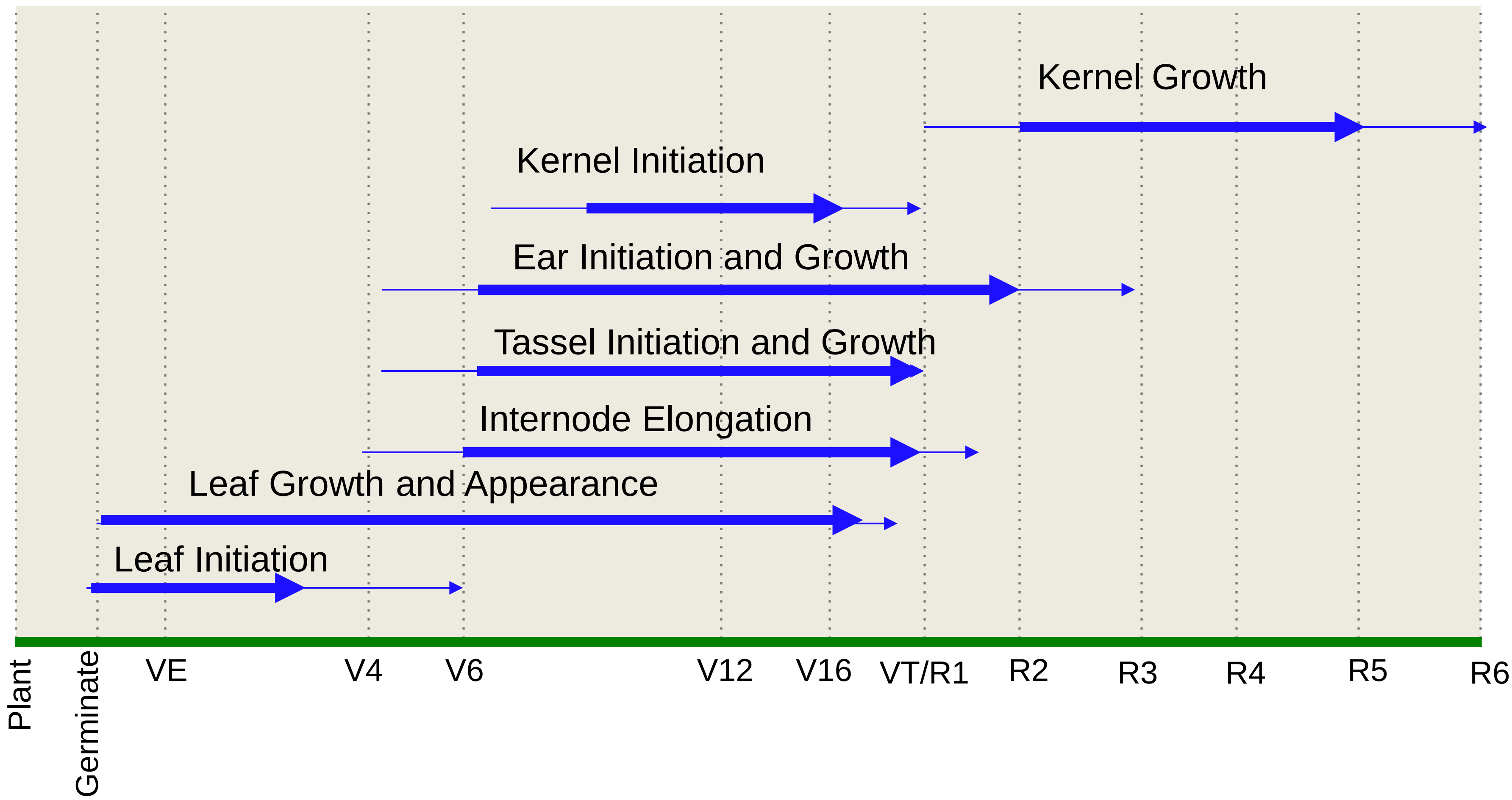
Initiation and Duration



Adapted from Figure 1.
in Abendroth, L., R. Elmore, M. J. Boyer and S. K. Marlay. 2011. Corn Growth and Development. PMR 1009. Iowa State Univ. Extension, Ames, Iowa.

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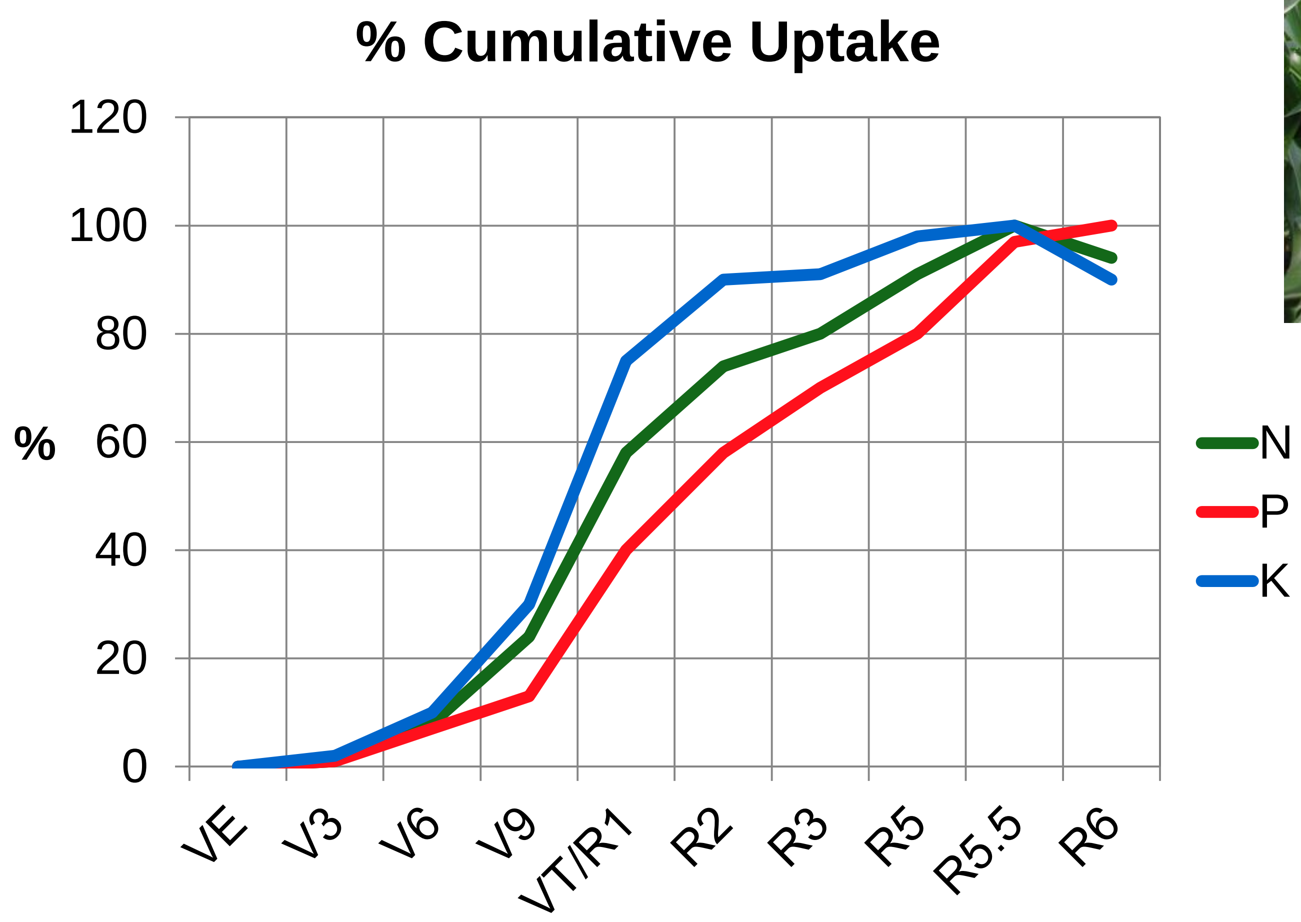
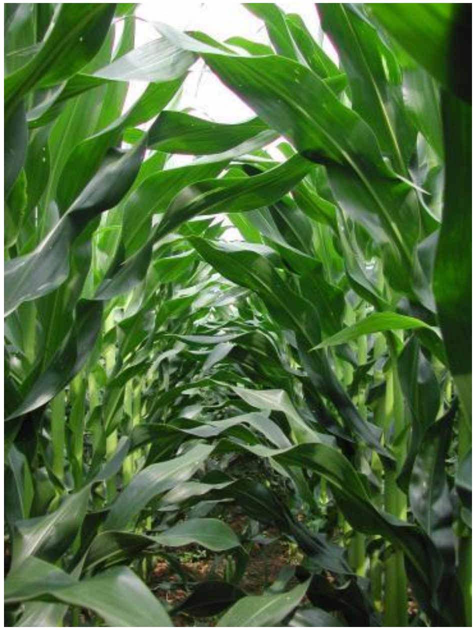
Nutrient Uptake





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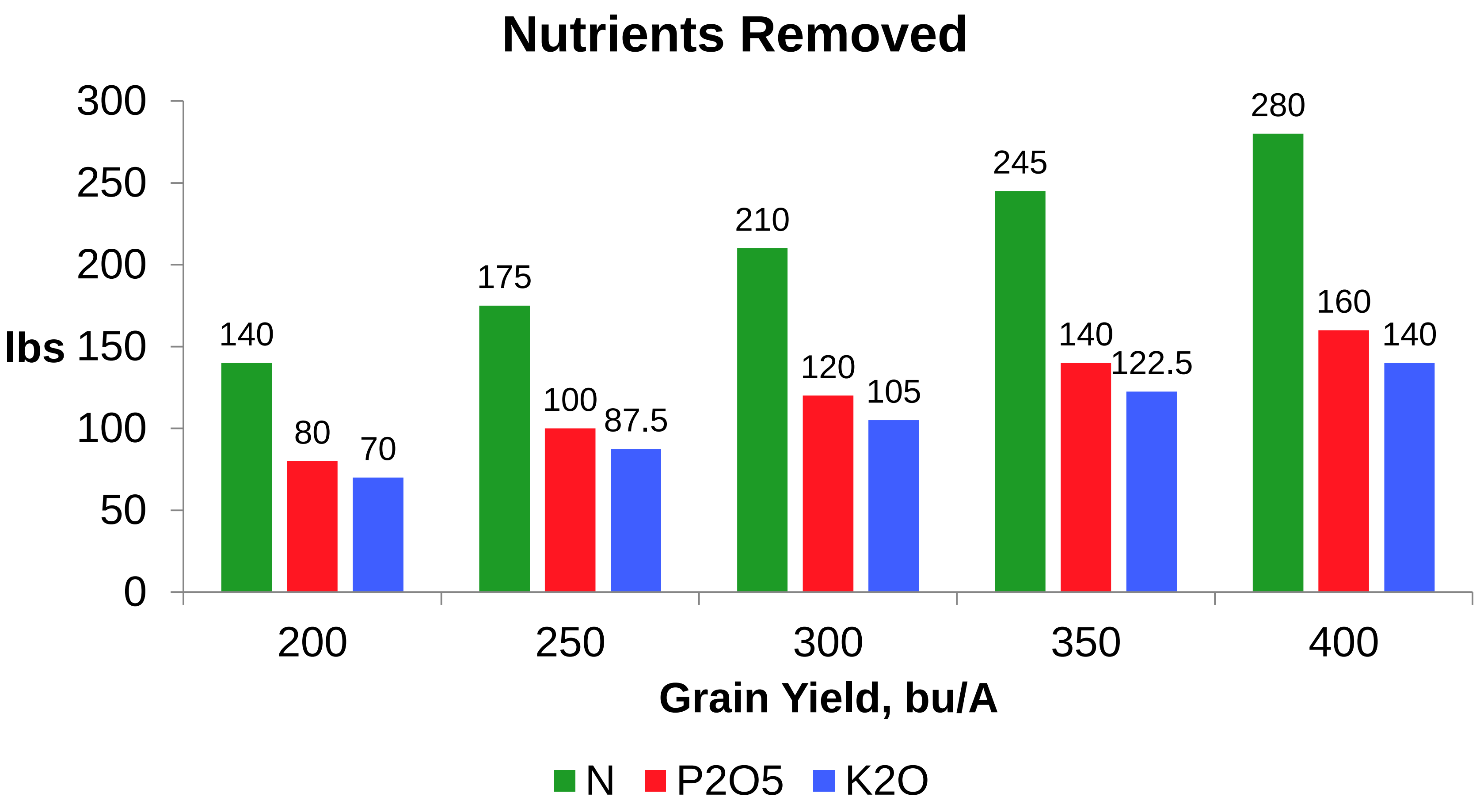
Nutrients Removed by the Kernels



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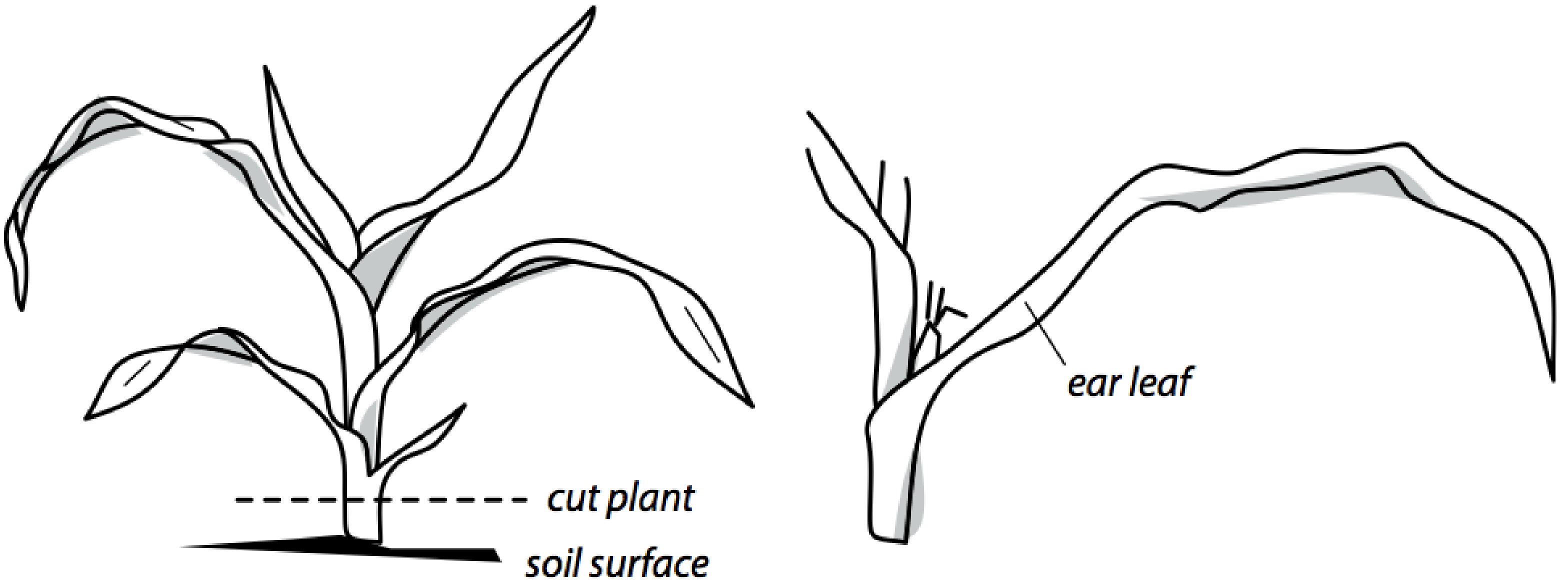
Nutrient Sampling



AGR-92: Sampling Plant Tissue for Nutrient Analysis

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Nutrient Sufficiency Levels

Macronutrient sufficiency range for crops grown in Kentucky.

Growth Stage	Plant Part	N	P	K	Ca	Mg	S
		%					
Seedling, < 4 in	Whole Plant	4.0-5.0	0.-0.6	3.0-4.0	0.3-0.8	0.2-0.6	0.18-0.50
Vegetative	Uppermost mature leaf	3.0-4.0	0.3-0.5	2.0-3.0	0.25-0.8	0.15-0.6	0.15-0.4
Tasseling	Ear Leaf	2.8-4.0	0.25-0.5	1.8-3.0	0.25-0.8	0.15-0.6	0.15-0.6

Micronutrient sufficiency range for crops grown in Kentucky.

Growth Stage	Plant Part	Fe	Mn	Zn	Cu	B	Mo
		ppm					
Seedling, < 4 in	Whole Plant	40-250	25-160	20-60	6-20	5-25	0.1-2.0
Vegetative	Uppermost mature leaf	30-250	20-150	20-70	5-25	5-25	0.1-2.0
Tasseling	Ear Leaf	30-250	15-150	20-70	5-25	5-25	0.1-2.0

AGR-92: Sampling Plant Tissue for Nutrient Analysis

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Water

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Water: Transpiration Efficiency of Crops

Species	Type	TE_B (g aboveground dry matter / kg of water)	TE_Y (g dry matter yield / kg of water)
Corn	C4	4.8 (1.7-8.3)	1.9 (1.2-2.2)
Wheat	C3		1.7 (0.9-2.1)
Soybean	C3		1.9 (1.6-2.2)
Potato	C3		5.4 (5.7-6.0)
Sugarcane	C4		--
Grain sorghum	C4		1.9 (1.2-2.2)
Rice	C3		--

200 bu requires about 22 inches.

300 bu requires about 33 inches (based on average number).

300 bu corn likely is more efficient and would require less than 33 inches.

Connor, Loomis and Cassman. 2011. Crop Ecology: Productivity and Management in Agricultural Systems. Cambridge University Press. New York. (p. 259, Table 9.4)

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Water needs

- About 20 to 25 inches of water needed to grow corn in our region. (Possibly more for higher yields.)
- Peak demand around tassel and silk is about 0.3 inches per day

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Corn Water Use, Nebraska

113-day hybrid in South Central Nebraska

Growth Stage	Average Water Use Rate (in/day)	Duration (days)	Water Needed to Reach Stage (inches)	Water needed cumulative (inches)
VE	0.08	0-10	0.8	0.8
V4	0.10	11-29	1.8	2.6
V8	0.18	30-46	2.9	5.5
V12	0.26	45-55	1.8	7.3
Early Tassel	0.32	56-68	3.8	11.1
Silking	0.32	69-81	3.8	14.9
Blister Kernel	0.32	82-88	1.9	16.8
Beginning Dent	0.24	89-104	3.8	24.5
Full Dent	0.20	105-125	3.8	24.5
Maturity	0.10	126-140	1.4	25.9

Kranz, Irmak, Donk, Yonts and Martin. 2008. Irrigation Management for Corn. G1850. University of Nebraska-Lincoln.

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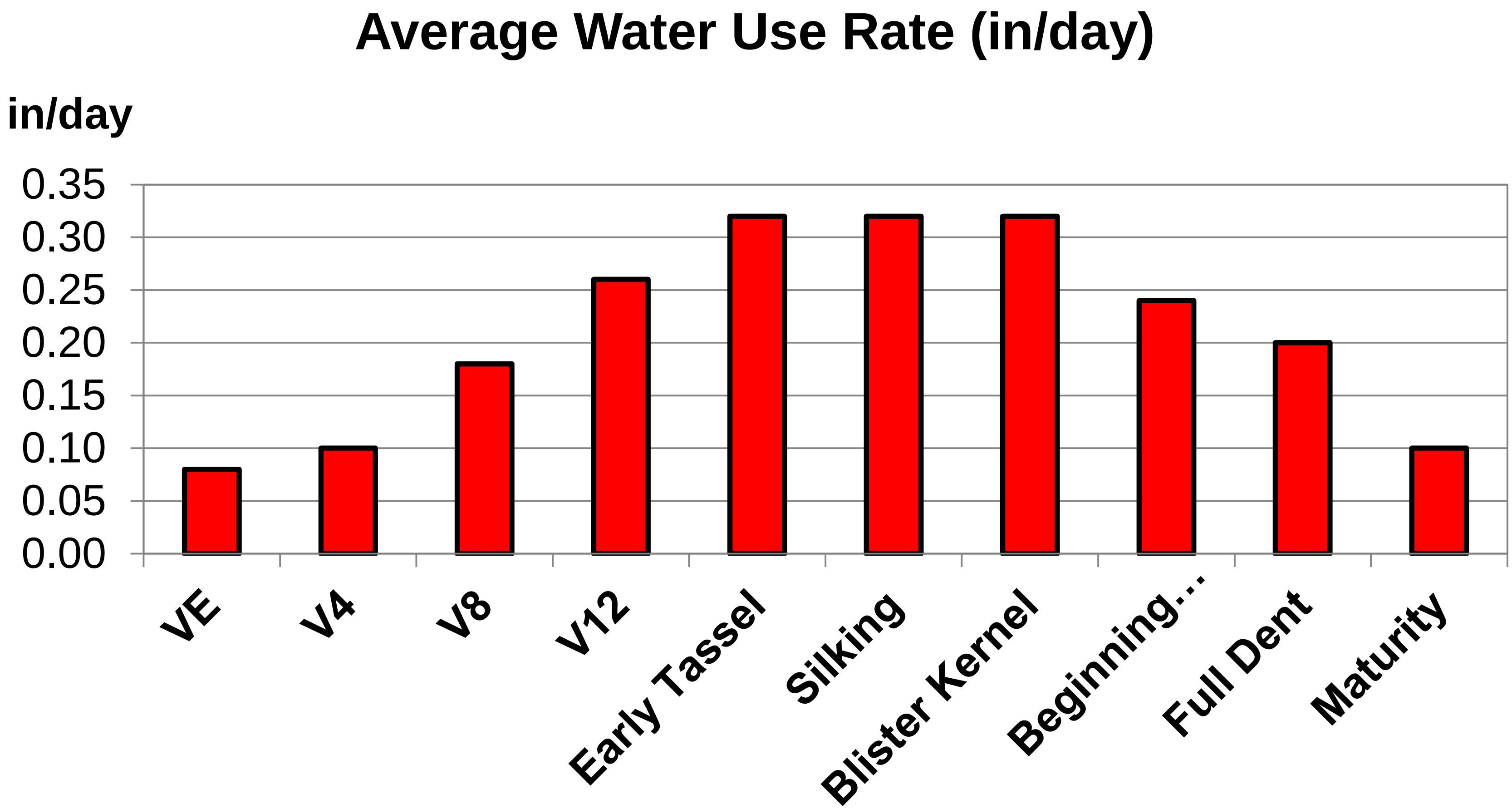
Corn Water Use, Nebraska

113-day hybrid in South Central Nebraska



Kranz, Irmak, Donk, Yonts and Martin. 2008. Irrigation Management for Corn. G1850. University of Nebraska-Lincoln.

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Recorded daily water use versus long-term water use curve

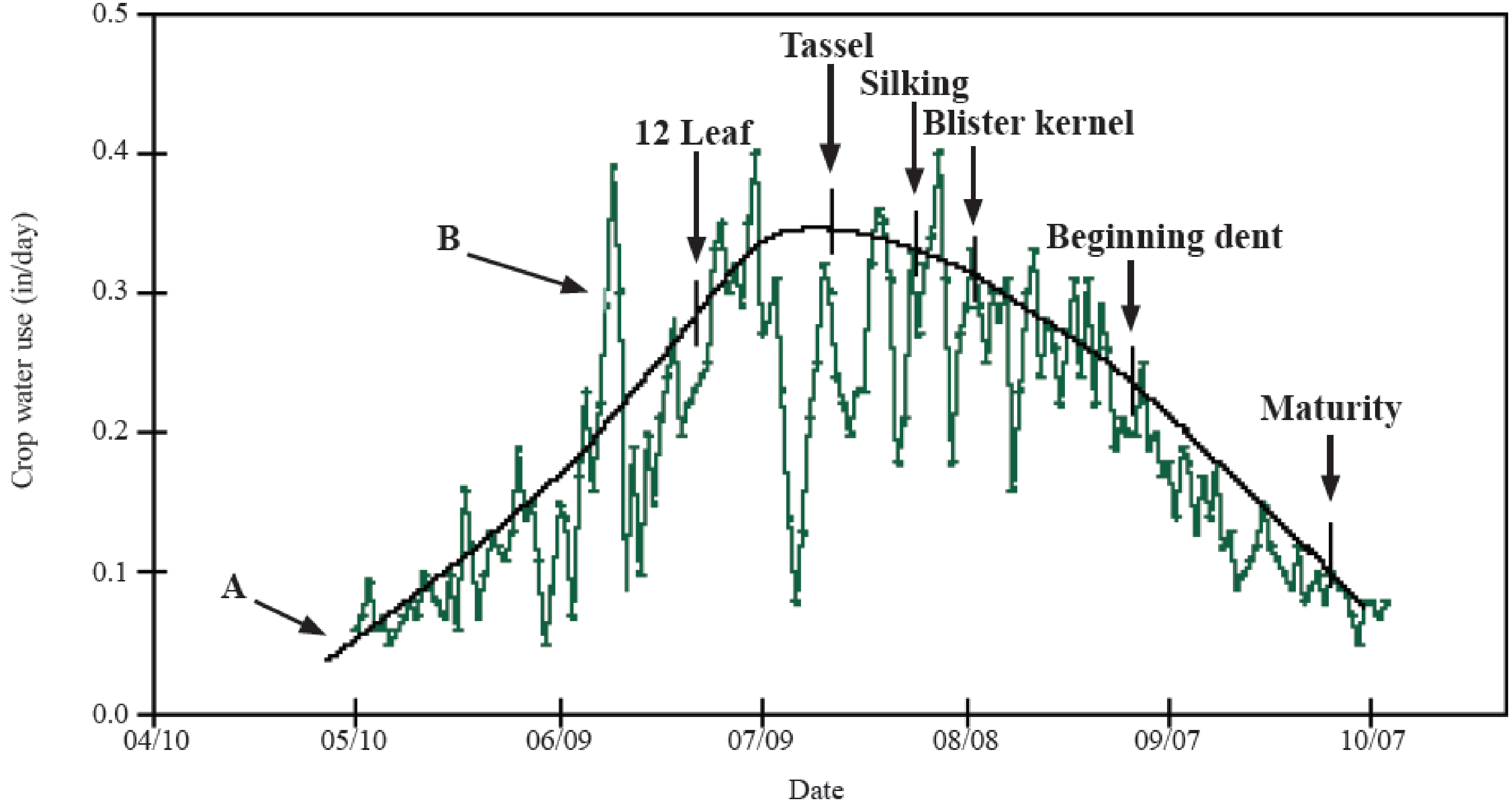

Figure 1. Long-term daily average and individual year corn water use with select growth stages.

Kranz, Irmak, Donk, Yonts and Martin. 2008. Irrigation Management for Corn. G1850. University of Nebraska-Lincoln.

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Estimated daily water losses from evaporation and transpiration from the U.S. Corn Belt †

U.S. Region	Weather	May	June	July	August	Sept
		Water Loss, Inches per Day				
Southern	Cloudy	0.13	0.14	0.14	0.13	0.09
	Partly Cloudy	0.16	0.17	0.17	0.16	0.13
	Clear	0.22	0.23	0.23	0.22	0.16

5.1 inches / month

† From Table 10.2 in Hoeft, Nafziger, Johnson and Aldrich. 2000. Modern Corn and Soybean Production. MCSP Publications, Champaign, IL.

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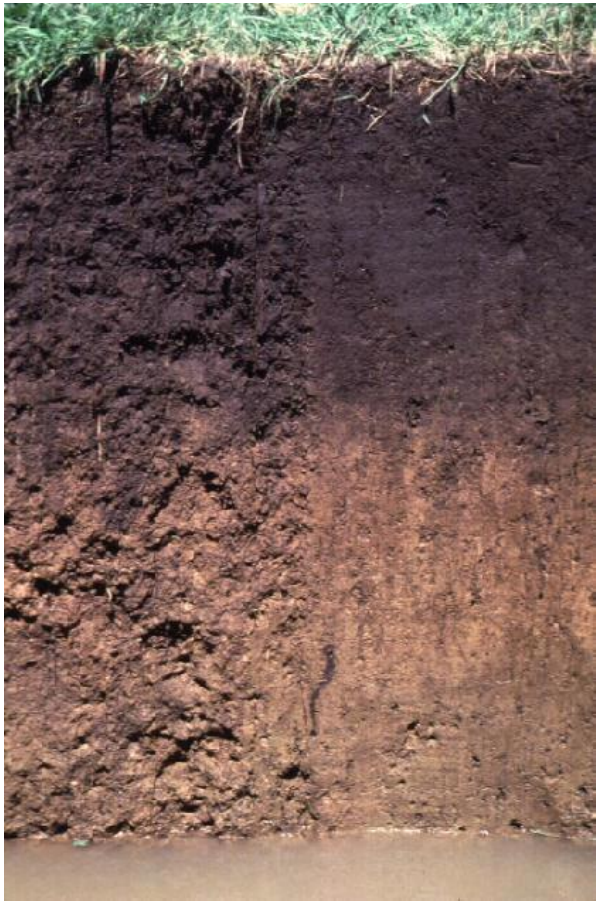
Water Holding Capacity of Most Soils

Textural Class	Water Holding Capacity, inches/foot of soil
Coarse Sand	0.25 – 0.75
Fine Sand	0.75 – 1.00
Loamy Sand	1.10 – 1.20
Sandy Loam	1.25 – 1.40
Fine Sandy Loam	1.50 – 2.00
Silt Loam	2.00 – 2.50
Silty clay loam	1.80 -2.00
Silty clay	1.50 – 1.70
Clay	1.20 – 1.50



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Yield losses from water and heat

Situation	Expected Yield Loss
For every 4 hours of leaf rolling during silking	1%
4 consecutive days above 93 F (w/ moisture)	1%
5th consecutive day above 93 F	2%
6th consecutive day above 93 F	4%
High night temperatures	?

Elmore, R. and E. Taylor. 2011. Corn and "a Big Long Heat Wave on the Way" Iowa Integrated Crop Management Newsletter Iowa State Univ. http://www.extension.iastate.edu/CropNews/2011/0715elmoretaylor.htm

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Kentucky Climate 2012

	Mayfield, KY	Mx Temp	Mn Temp	Yield Loss from Heat	Yield Loss from Leaf Rolling	Cumulative
Day 1	July 27	94	48		2%	
Day 2	Jun 28	99	53		2%	4
Day 3	Jun 29	103	63		2%	6
Day 4	Jun 30	102	64	1%	2%	9
Day 5	Jul 1	101	65	2%	2%	13
Day 6	Jul 2	98	68	4%	2%	19
Day 7	Jul 3	93	71	8?	2%	29
Day 8	Jul 4	99	68	16?	2%	47
Day 9	Jul 5	101	69	32?	2%	81
Day 10	Jul 6	81	48		2%	83

† Assumes good pollination.

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Yield is maximized by maximizing light interception and conversion to sugars.

- Photosynthesis
  - Captures sunlight and converts CO_2 and H_2O into sugar (glucose)
- Respiration
  - Uses sugar to build structures (leaves, kernels, etc.)
  - Uses sugar to maintain the plant.

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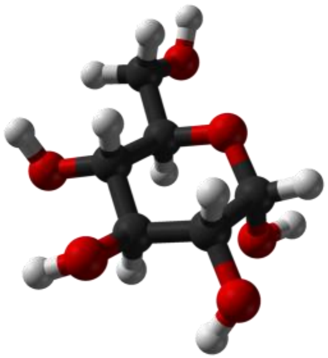
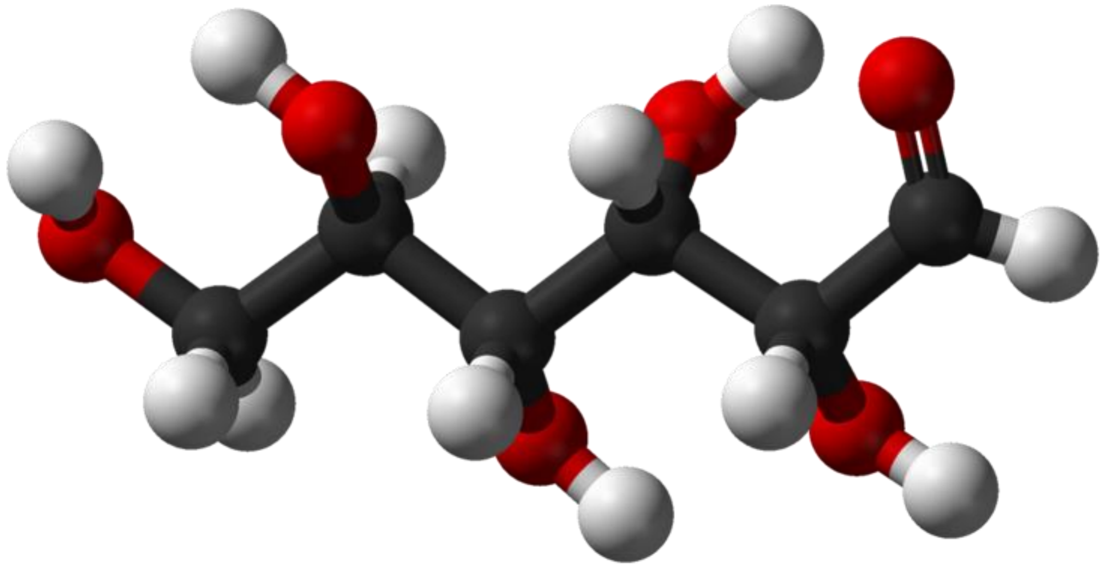
Glucose





- Corn uses the glucose sugar it produced from photosynthesis for:
  - Cell division and elongation (plant growth)
  - Cell maintenance
  - Storage (to be used in the seed later)

Respiration

Image source: en.wikipedia.org

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Glucose needs for yield

Crop	Pounds of Glucose Needed to produce one Bushel
Corn	77.9
Soybean	119.3

	Grams of Glucose needed per gram of product
Carbohydrate	1.21
Protein (with reduced N)	1.62
Protein (with nitrate N)	2.48
Lipid	2.71
Lignin	1.92
Organic Acids	0.91

Connor, Loomis and Cassman. 2011. Crop Ecology: Productivity and Management in Agricultural Systems. Cambridge University Press. New York. (p. 297-299)

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Sugar Demand of the Crop

Crop	Glucose Needed to produce one Bushel
	lbs of Glucose
Corn	77.9
Soybean	119.3

- **200** bushels of corn requires about 15,580 lbs of glucose
- For a 115-day hybrid, that would be 135 lbs glucose/day.

Connor, Loomis and Cassman. 2011. Crop Ecology: Productivity and Management in Agricultural Systems. Cambridge University Press. New York. (p. 297-299)

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Could sugar help at pollination?

- Plant is most sensitive to stress at this point in time.

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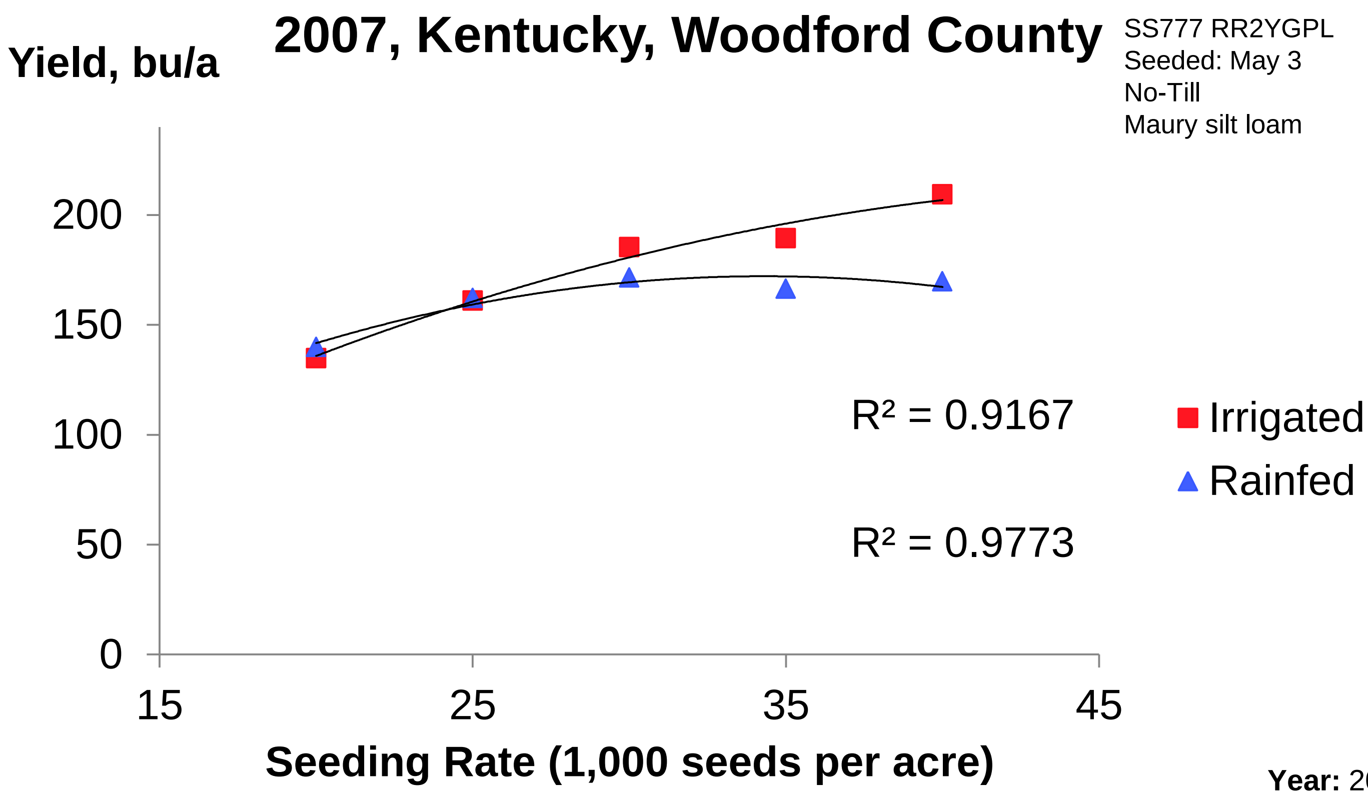
Corn Grain Yields

Woodford County, Kentucky 2007, Dry Weather During Seed Fill



Year: 2007
Location: Woodford County Farm
Hybrid: SS777RR2YGPL
Poncho 1250-treated seed
Planting: May 3, 2007

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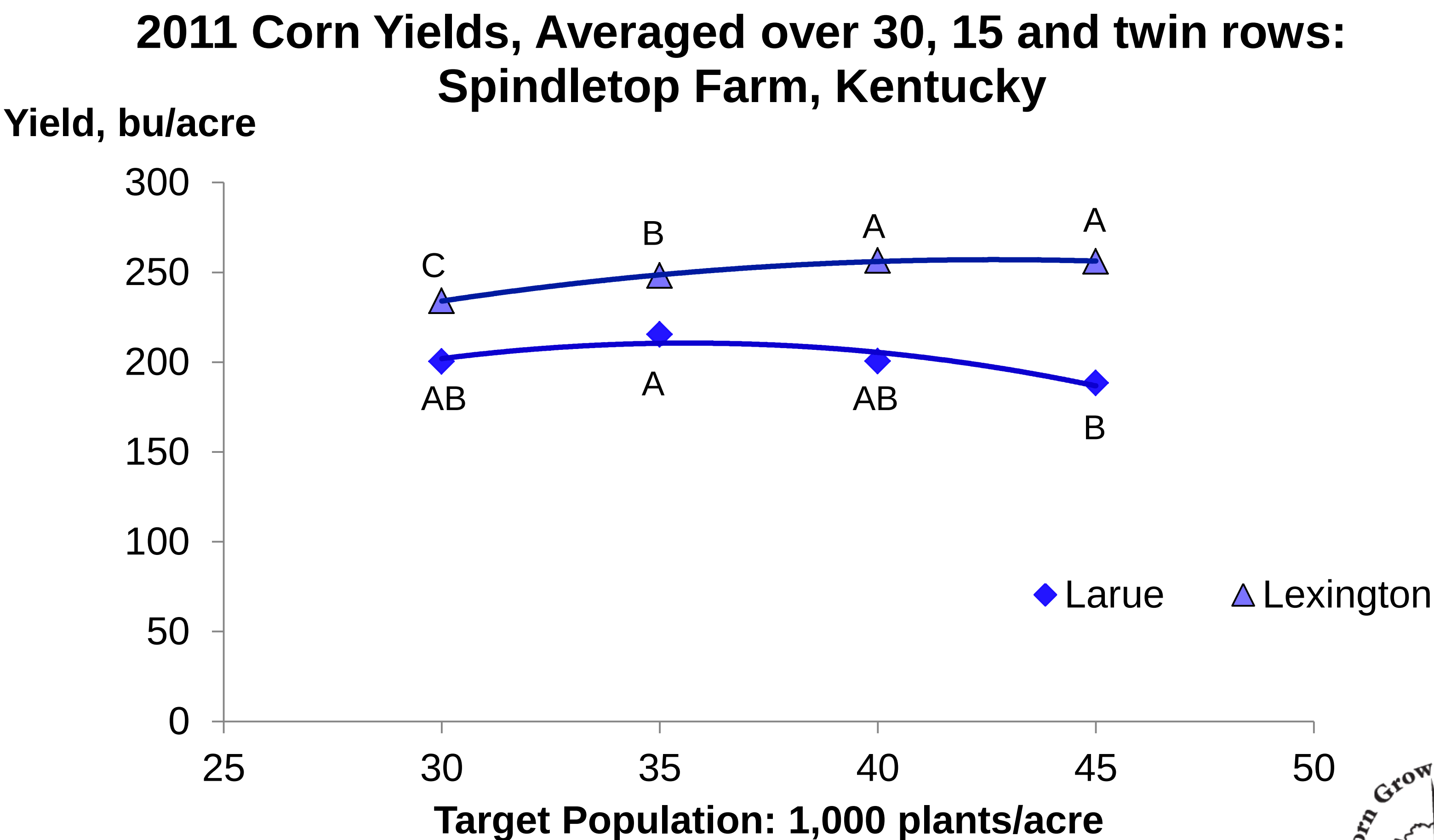
Corn with “adequate” water



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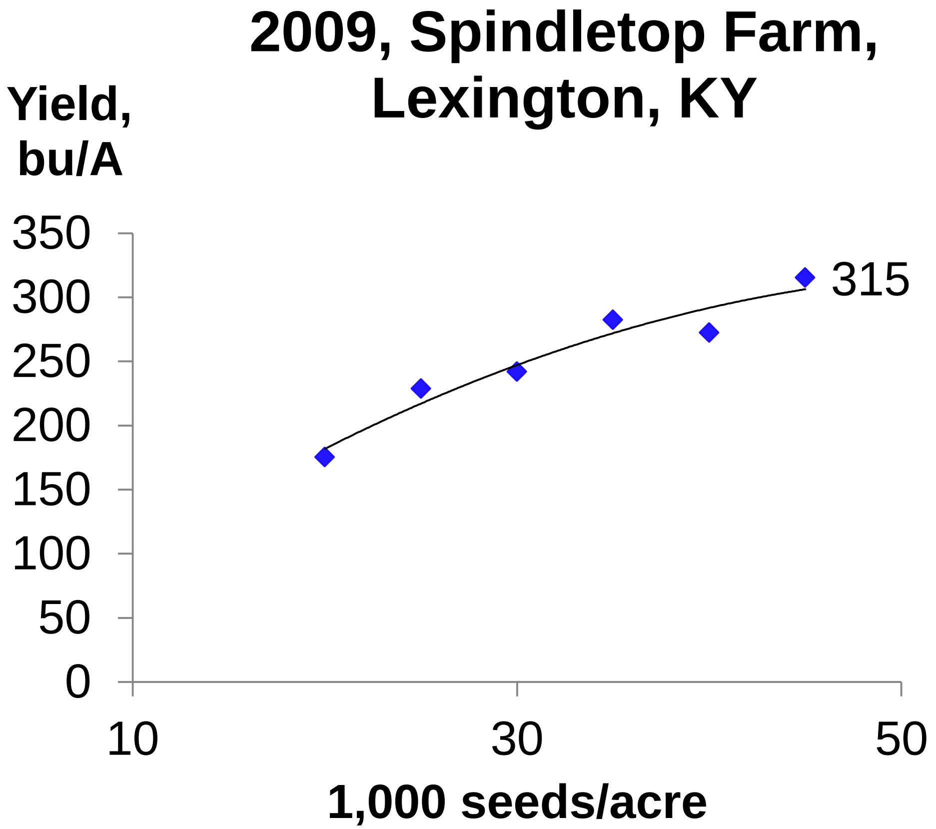
Corn with adequate water



2009, Spindletop Farm
4 hybrids: DKC63-42, DKC63-45, DKC64-44 & DKC65-47
No-Till
Loradale Silt Loam

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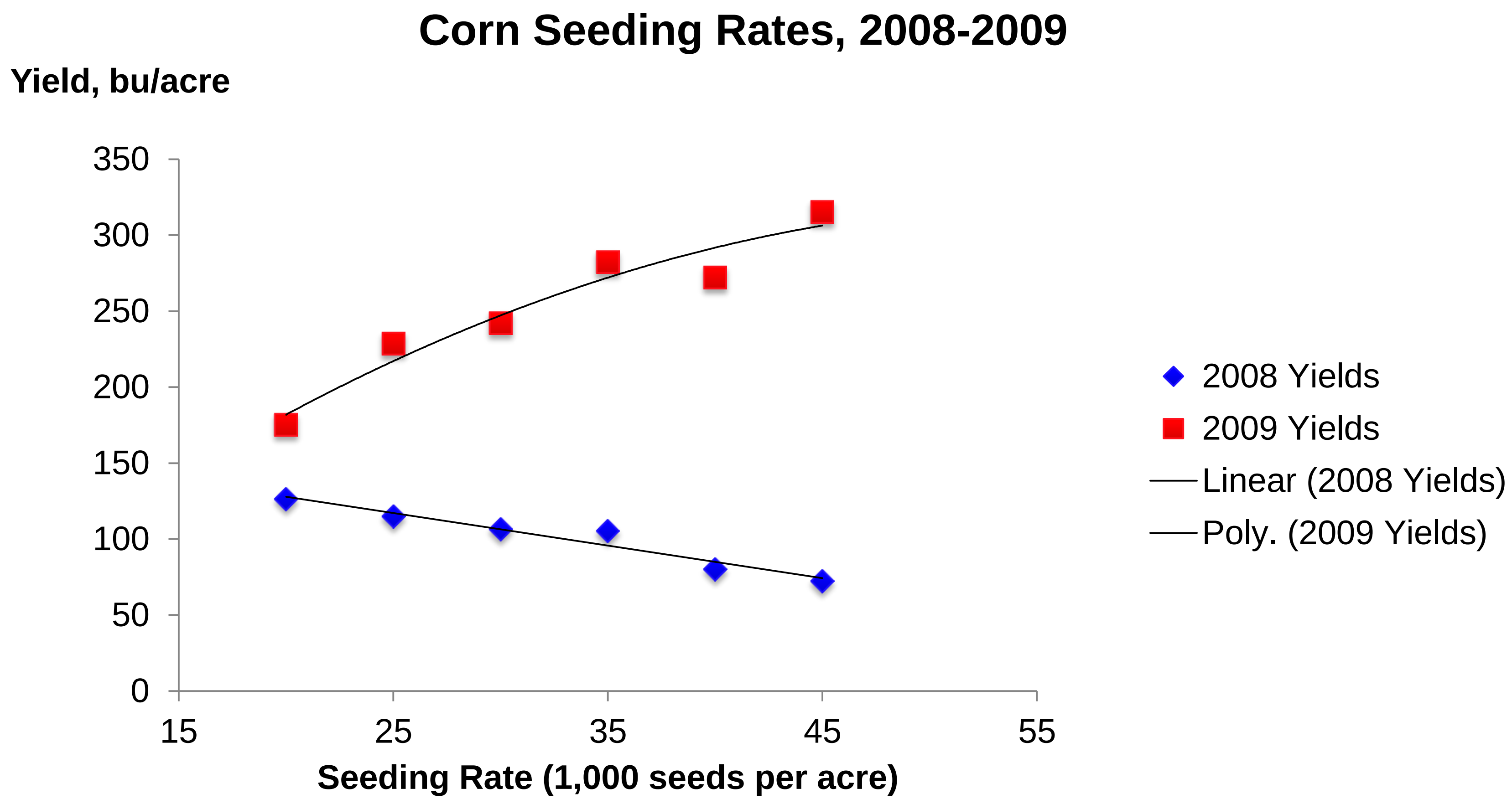
Adequate Water vs. Lack of Water

Lexington, 2008-2009, 4 Hybrids, VT3 Hybrids and RRCB Hybrids



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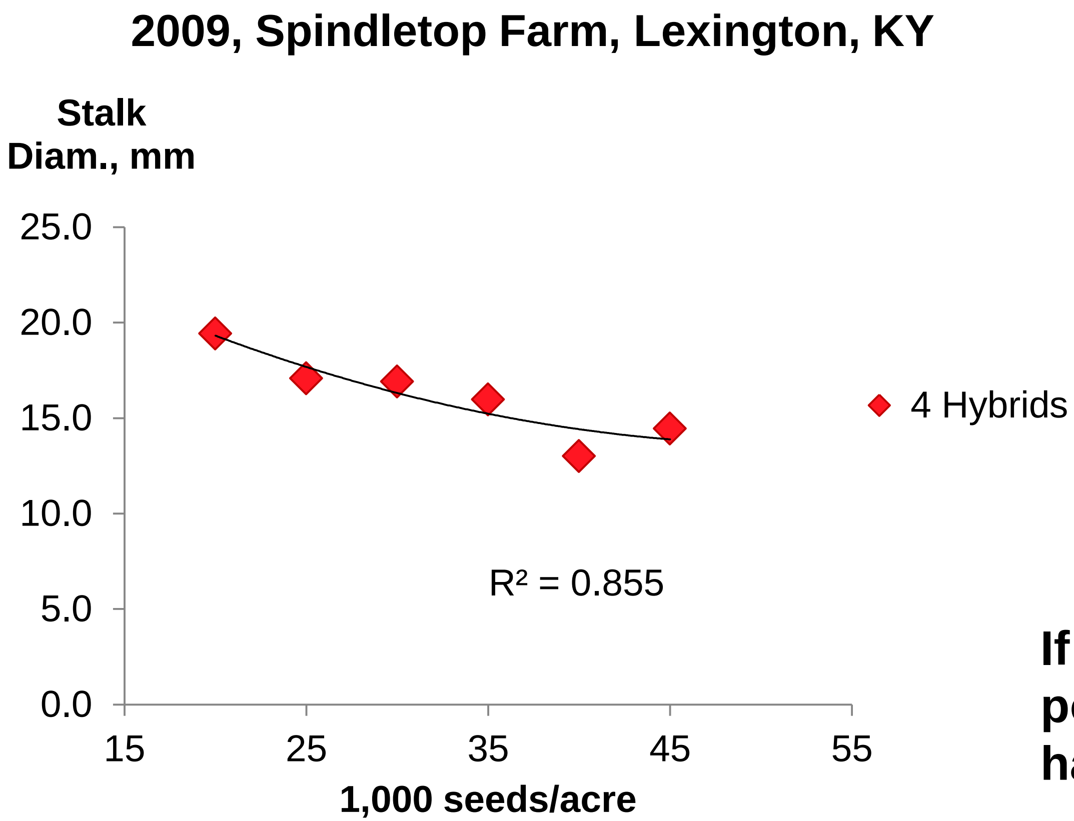
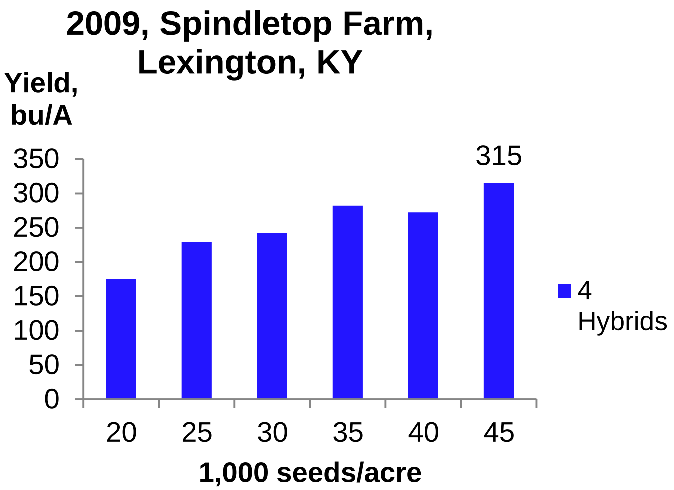
Higher Populations = Smaller Plants = More Yields?





If you are going to push populations, you better have good stalk strength.

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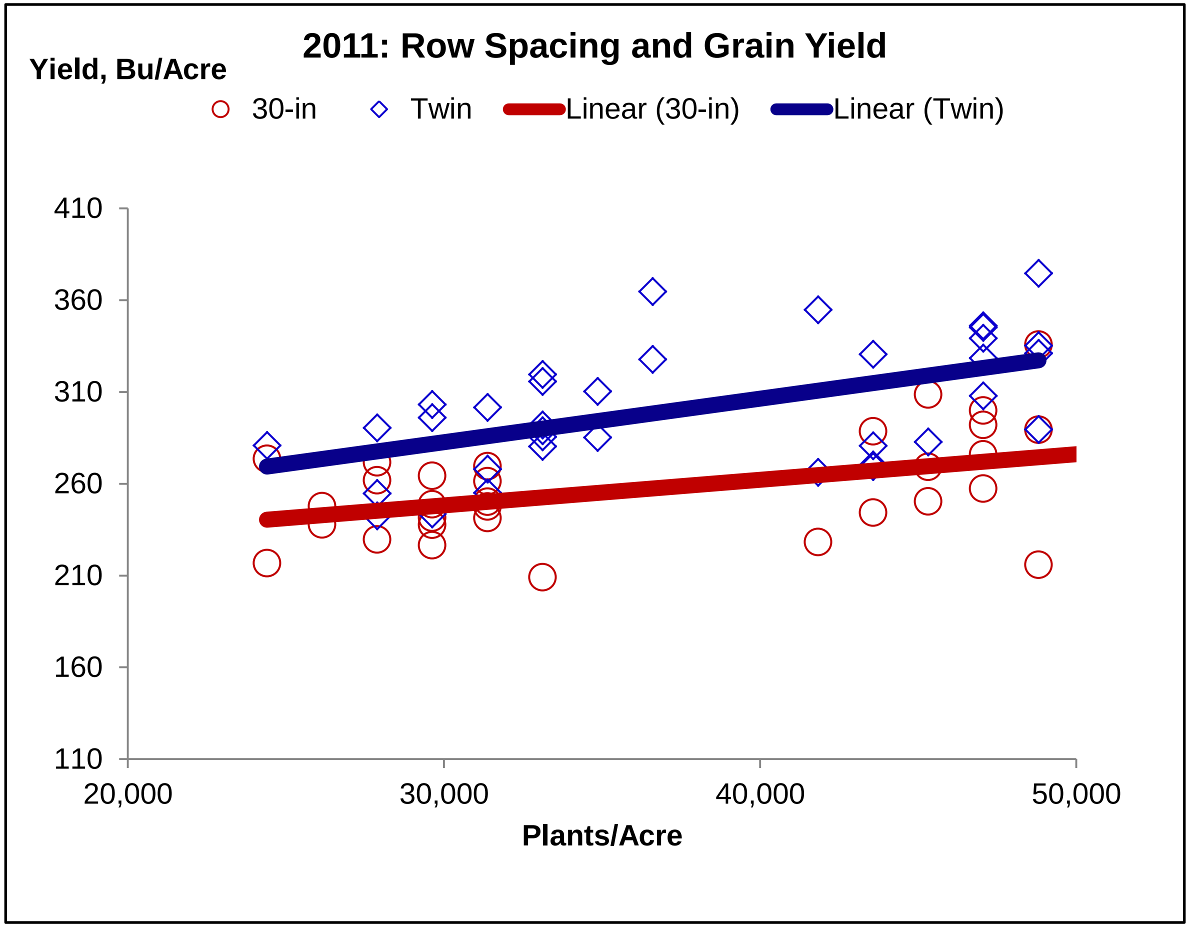
Comparing Twins to 30-inch rows

Hand Harvest of 20 Consecutive Plants



- As plant population increased
  - stalk diameter decreased
  - plant height decreased
  - light interception increased
  - kernels per ear decreased
- Twin rows
  - increased yield
  - did not affect light interception
  - did not affect plant height

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Name	Spindletop Farm, 2009
Yield, Bu/A	**315.00**
Hybrid	DeKalb DKC63-24, DKC63-45, DKC65-44, DKC65-47
County	Fayette County
Planting Date	4/27
Row Width, inches	30
Seeding Rate	About 47,000
Final Stand	47,000
Prev. Crop	Soybean
P_2O_5	0 (adequate soil test)
K_2O	0 (adequate soil test)
N	160 lbs/A
Split N	No, Sidedress Only (V5)

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Name	Spindletop Farm, 2009
Yield, Bu/A	**315.00**
Other	none
Seed Treatment	Poncho 250
Herbicides	Lexar + glyphosate fb glyphosate
Insecticides	None
Fungicides	None
Tillage	No-Till
Planter	John Deere 7200
Harvester	Hege Wintersteiger

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Name	Spindletop Farm, 2009
Yield, Bu/A	**315.00**
H	, DKC63-45, DKC65-44, DKC65-47
C	
F	
F	
S	
Final Stand	47,000
Pr	
P_2	oil t
K_2	oil t
N	
Split N	No, Sidedress Only (V5)
Other	
Seed T	
Herbic	fb glyphosate
Insecti	
Fungic	
Tillage	No-Till
Planter	John Deere 7200
Harvester	Hege Wintersteiger

160.00 lbs N/A

315.00 Bu/A

0.51 lbs fertilizer N/bu

N Uptake, grain

0.7 lbs N/bu

221 lbs N/acre

160 + 82 = 142 lbs N
142 – 221 = 21 lbs N remaining
What happened to the other 21 lbs?

2009, 0 N "check"

117 bu/acre

82 lbs N/acre

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Where do you focus, first?

- Seeding uniformity
- Seeding rates
- Row width
- Hybrid selection
- N management
- Foliar Products

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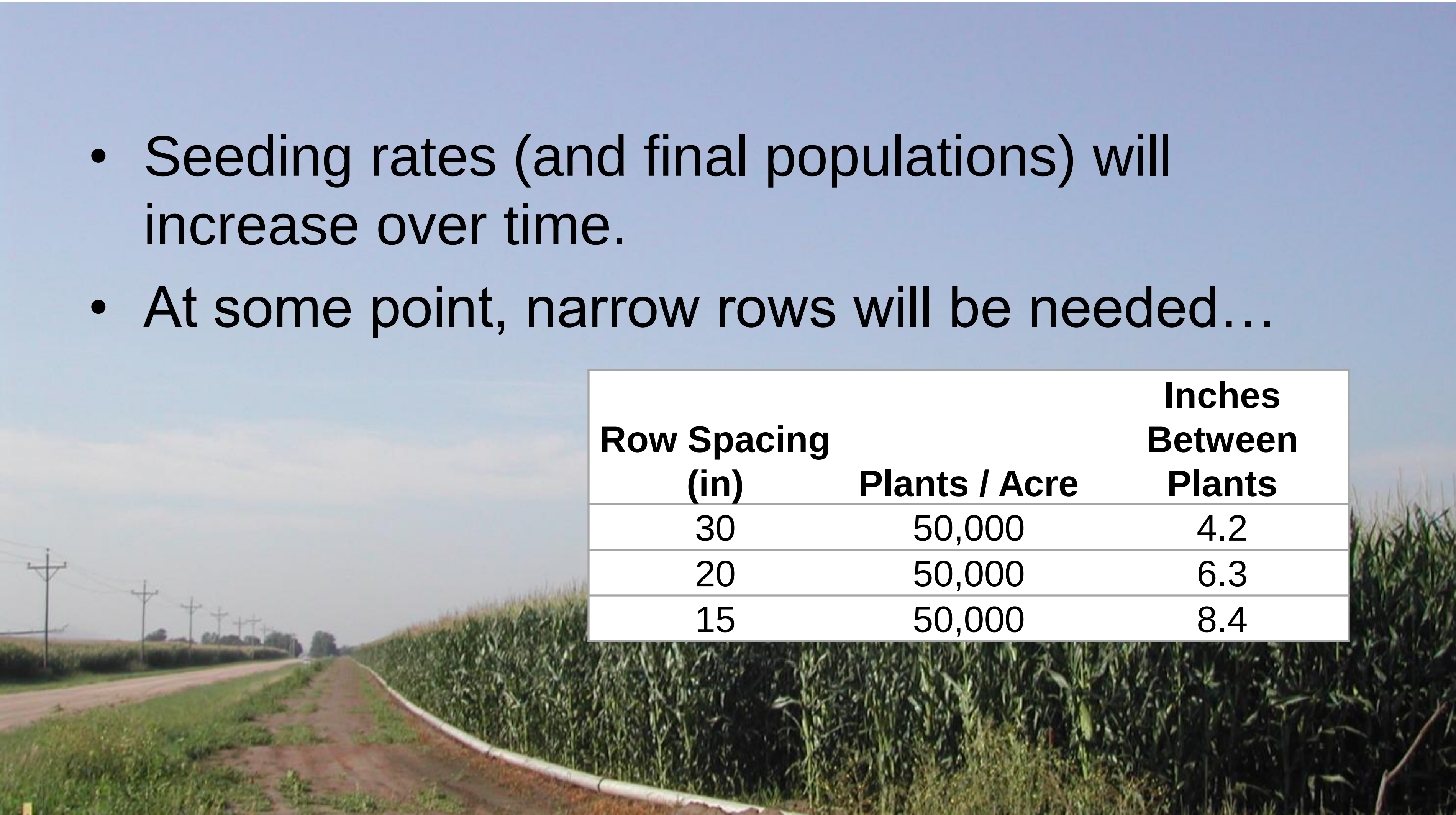
Down the Road

- Seeding rates (and final populations) will increase over time.
- At some point, narrow rows will be needed…

Row Spacing (in)	Plants / Acre	Inches Between Plants
30	50,000	4.2
20	50,000	6.3
15	50,000	8.4



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Hybrid Development

- Corn hybrid development in the U.S. still occurs in 30-inch rows.
- Companies use high populations to induce stress.

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Corn Irrigation: The Main Points

- Corn needs about 20 to 25 inches (maybe more) of water (in Kentucky).
- Many Kentucky soils will only hold 5 inches of water at field capacity.
- Corn is most sensitive to water stress around tasseling.
- Water stress at many stages of corn growth can reduce yield.

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% Nutrient Uptake

Growth Stage	N	P	K
	% Cumulative Uptake		
VE	0	0	0
V3	1	1	2
V6	8	7	10
V9	24	13	30
VT/R1	58	40	75
R2	74	58	90
R3	80	70	91
R5	91	80	98
R5.5	100	97	100
R6	94	100	90

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Table 1. Normal Range of CEC Values for Common Color/Texture Soil Groups.

CEC in Soil Groups	Examples	meg/100g
Light colored sands	Plainfield Bloomfield	3 to 5
Dark colored sands	Maumee Gilford	10 to 20
Light colored loams and silt loams	Clermont-Miami Miami	10 to 20
Dark Colored loams and silt loams	Sidell Gennessee	15 to 25
Dark Colored silty clay loams and silty clays	Pewamo Hoytville	30 to 40
Organic soils	Carlisle muck	50 to 100

Source: David Mengel. 1993. AY-238: Fundamentals of Soil Cation Exchange Capacity (CEC). Purdue Univ.

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Corn Removal Rates

Crop		N	P_2O_5	K_2O	Yield		N	P_2O_5	K_2O
		lbs/unit					lbs/acre		
corn grain	bu	0.7	0.4	0.35	100	bu	70	40	35
					200	bu	140	80	70
					300	bu	210	120	105
corn stalks	ton	14	7	29	2.8	ton	39	20	81
					5.6	ton	78	39	162
					8.4	ton	118	59	244

AGR-1: Lime and Fertilizer Recommendations

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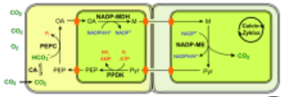
Photosynthesis:

carbon dioxide + water $\longrightarrow$ sugar + oxygen



$$6\ CO_2 + 6\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2$$

Solar energy

Respiration:

sugar + oxygen + water $\xrightarrow{\text{30 steps}}$ carbon dioxide + water + 637 kcal

$$C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O \longrightarrow 6\ CO_2 + 12\ H_2O$$

Energy

Source: Dennis Gardner et al., Physiology of Crop Plants. 1985. The Iowa State University Press. Ames.

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Chemical Composition of Air

Element/Compound	Chemical Formula	Percentage of Composition by Volume
Nitrogen	N_2	78.1 %
Oxygen	O_2	20.9%
Argon	Ar	0.9%
Carbon dioxide	CO_2	0.039% (390 ppm)
Neon	Ne	0.002%
Helium	He	0.0005%
Methane	CH_4	0.0002%
Krypton	Kr	0.0001%
Hydrogen	H_2	0.00005%
Xenon	Xe	0.000009%

http://www.chemicalformula.org/air

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Photosynthesis and Respiration

- An acre of 100-bushel corn manufactures on average 200 lbs of sugar a day
- About ¼ of the sugars are used in respiration
- Respiration uses about 23% of the energy absorbed in photosynthesis
  - (more recent estimates put that number somewhere between 30 to 60%, depending on environment)
- At maturity, the grain contains about ¼ the total energy used in photosynthesis

Transeau, E.N. 1926. The accumulation of energy in plants. The Ohio Journal of Science. 26: 1-10.

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