Critical Yield Factors

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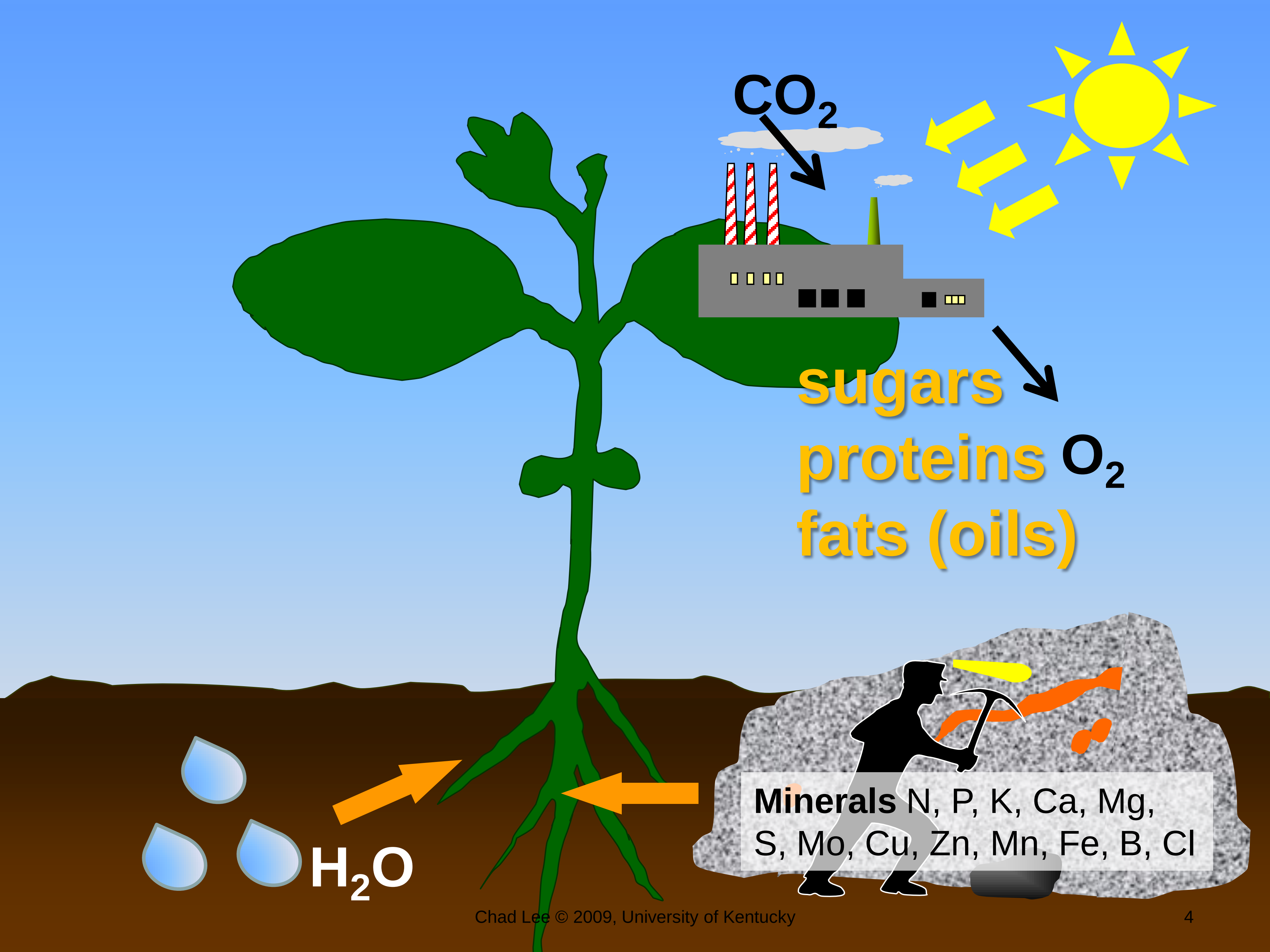
What is your main goal as a farmer?

Where it starts

- Photosynthesis is the fundamental plant process that is responsible for plant growth and the production of yield.
- All of our food supply depends upon photosynthesis.

Source: Dennis Egli


CO2
sugars
proteins
fats (oils)
O2
H2O
Minerals N, P, K, Ca, Mg, S, Mo, Cu, Zn, Mn, Fe, B, Cl

"Practically everything we see about us has involved photosynthesis at some stage or another. The gardener often talks about 'feeding' plants when he applies fertilizers and the notion that plants derive their nourishment from the soil is one that is commonly held. They do not. Plants take up minerals from the soil and they derive their nourishment from the air".

Edwards and Walker (1983) C3, C4: Mechanisms and Cellular Regulation of Photosynthesis. Blackwell Scientific Publications.

Source: Dennis Egli

Photosynthesis

- Chlorophyll – green pigments
- Absorbs light.
- Light powers the process
- Capture C from CO_2 and O_2 from H_2O to form sugars

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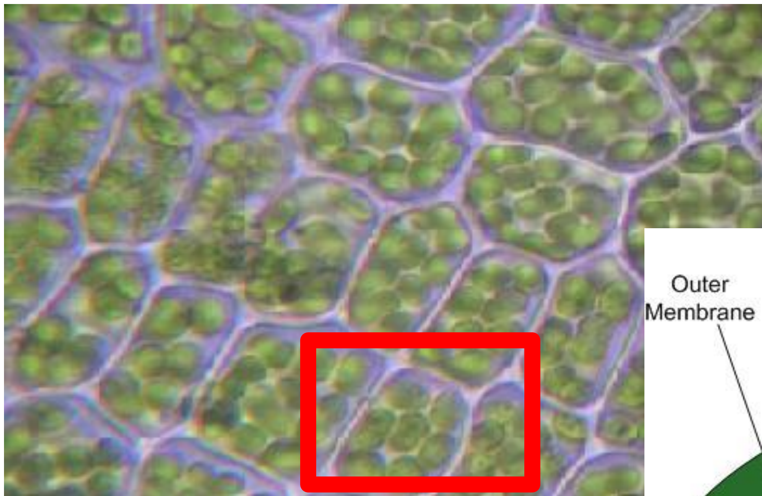
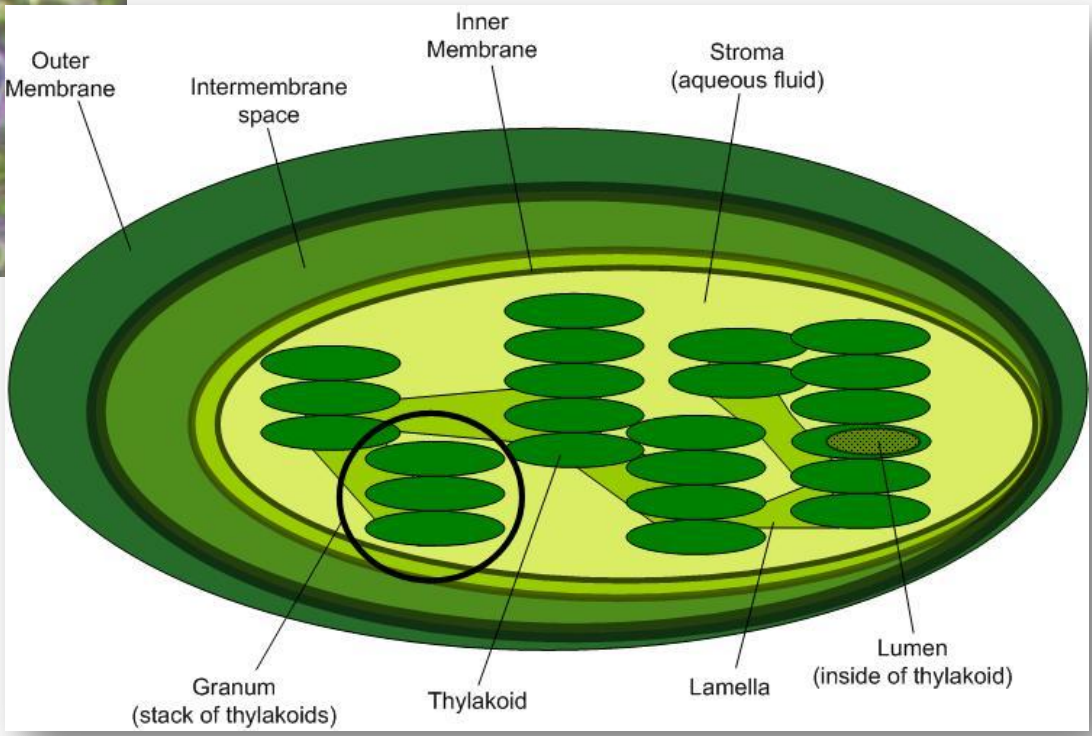
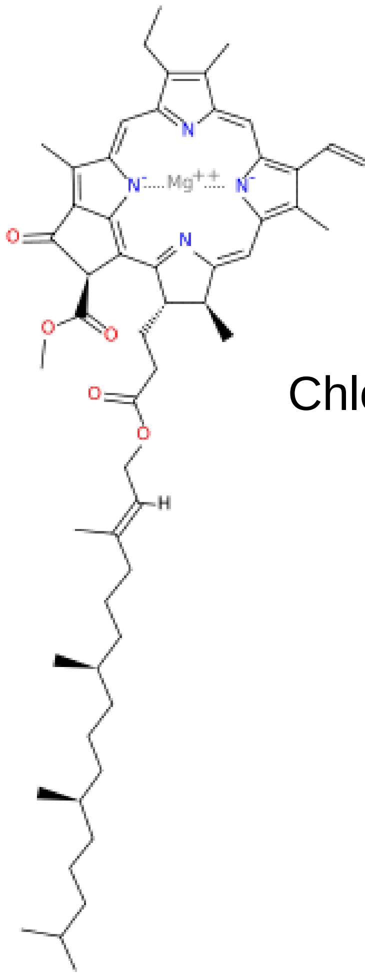
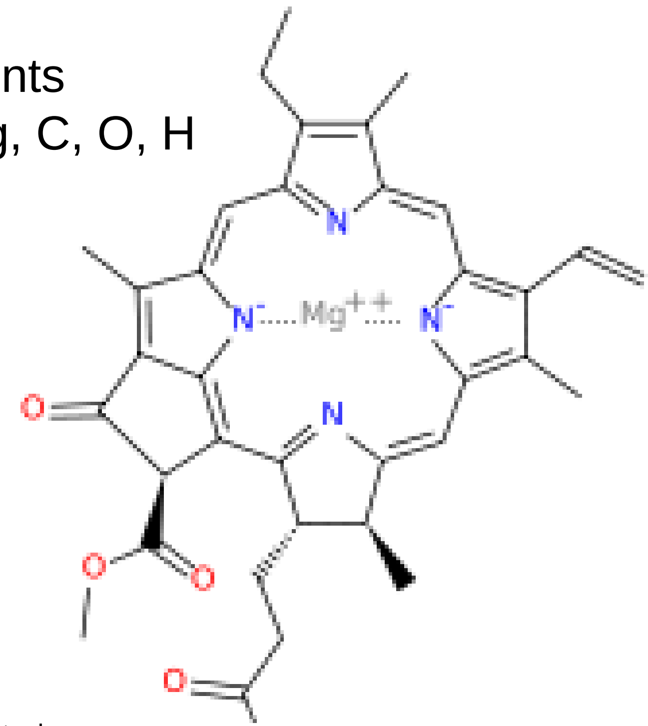



Outer Membrane
Intermembrane space
Inner Membrane
Stroma (aqueous fluid)
Granum (stack of thylakoids)
Thylakoid
Lamella
Lumen (inside of thylakoid)



Chlorophyll – green pigments

Key elements – N, Mg, C, O, H



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Photosynthesis

- Chlorophyll – green pigments
- Absorbs light.
- Light powers the process
- Capture C from CO_2 and O_2 from H_2O to form sugars

Respiration

- Uses some of the C fixed in photosynthesis to carry on maintenance and development of the plant.
- Photosynthesis makes the sugar, respiration does something with it.

Photosynthesis:

carbon dioxide + water → sugar + oxygen

$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{Solar energy}} C_6H_{12}O_6 + 6\ O_2$$

Solar energy

Respiration:

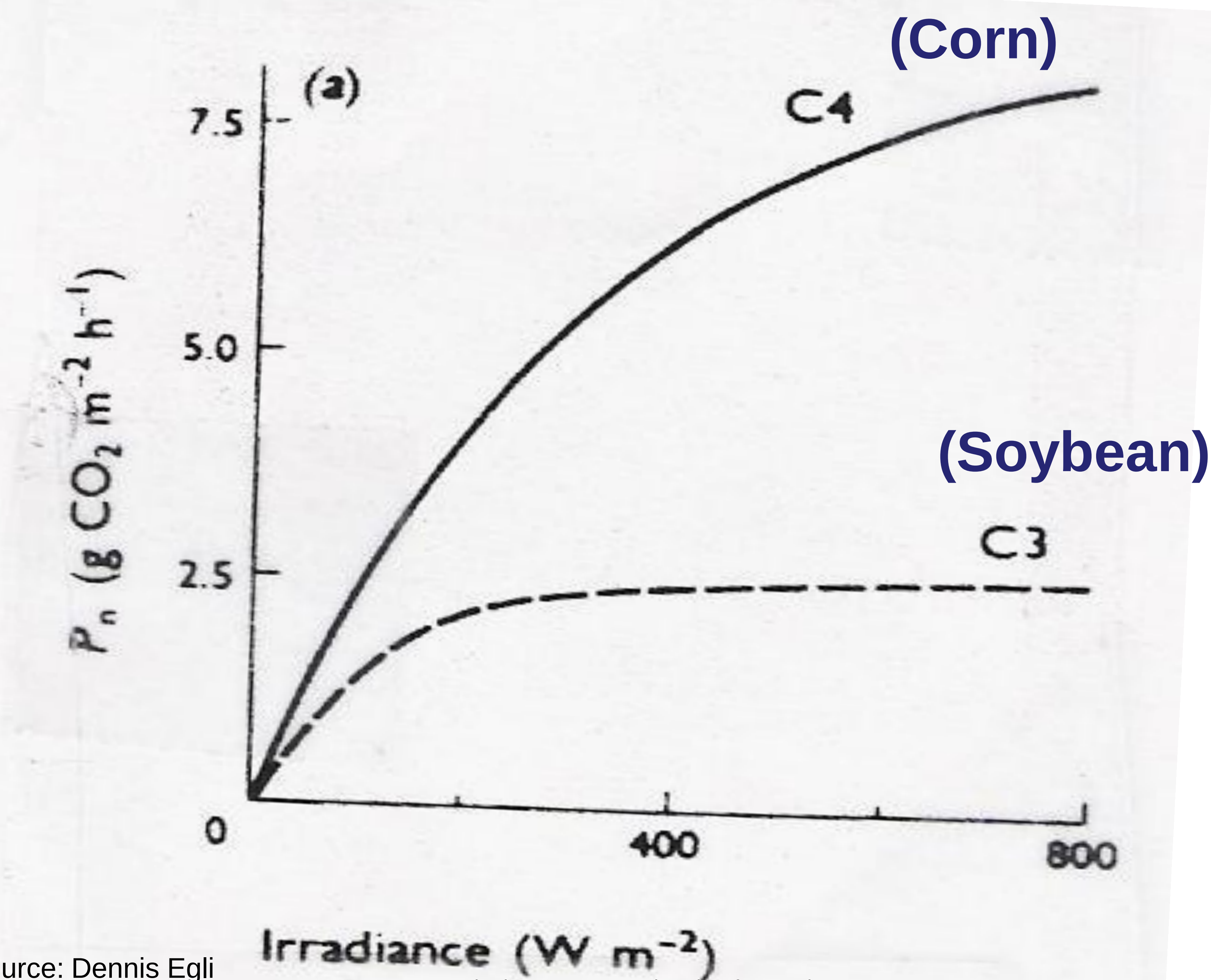
$$C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O \longrightarrow 6\ CO_2 + 12\ H_2O$$

Energy

Source: Dennis Egli

Photosynthesis

- Capture C from CO_2 and O_2 from H_2O to form sugars
  - C_3 plants – 3-carbon sugar
  - C_4 plants – 4-carbon sugar



Source: Dennis Egli

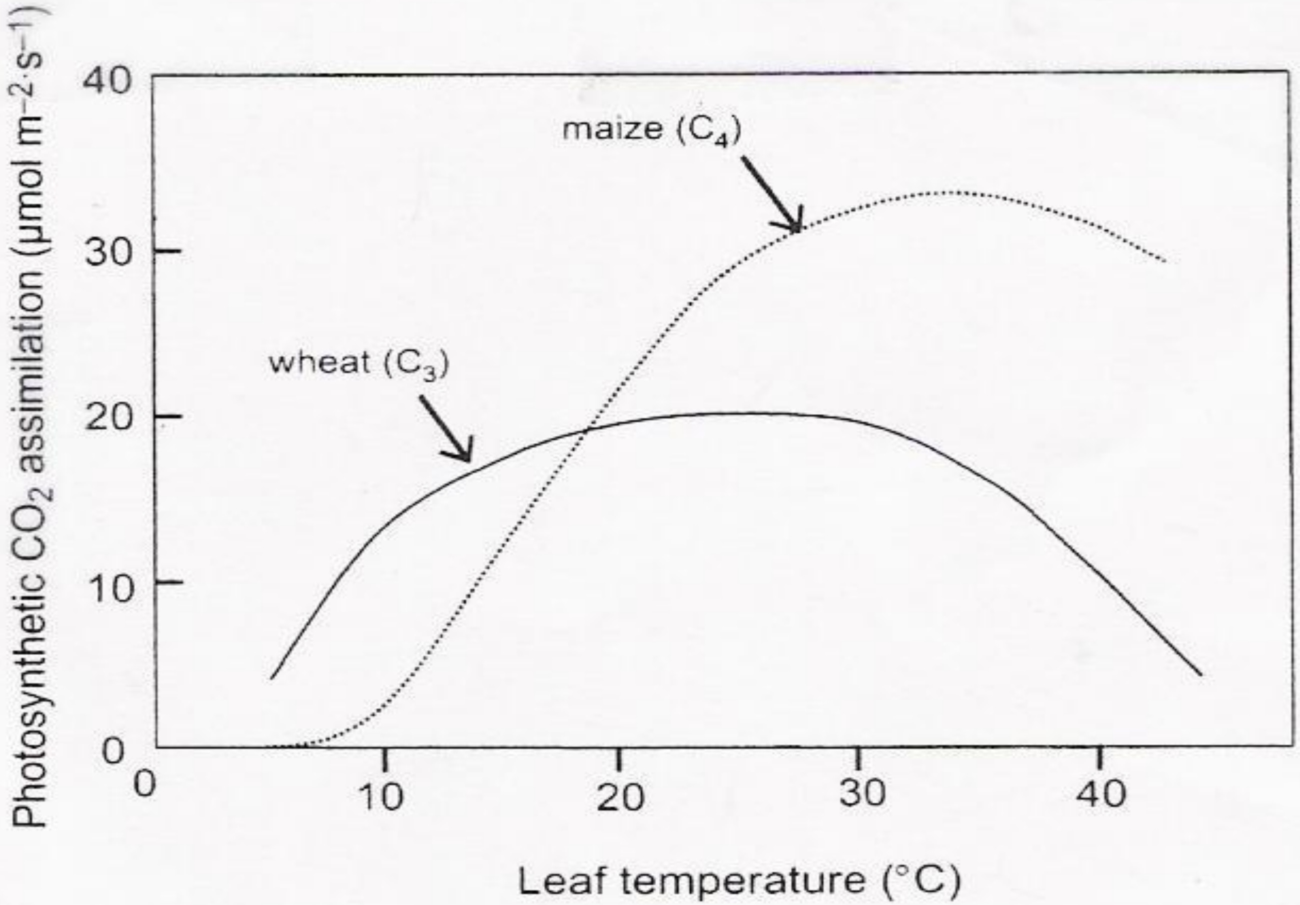


FIGURE 5.6. Leaf photosynthesis of wheat and maize as a function of temperature. *Source:* Adapted from Stone (2001).

UKAg Source: Dennis Egli

Top 10 world grain crops based on total world production (2005-2006).

Species	Total Production (2005/2006)	Rank	Photosynthesis
	Millions of tonnes[1]		
Maize (corn)	*704*	*1*	*C_4*
Rice	634	2	C_3
Wheat	618	3	C_3
Soybean	218	4	C_3
Barley	140	5	C_3
Sorghum	*58*	*6*	*C_4*
Peanut	50	7	C_3
Rapeseed	49	8	C_3
Millet	32	9	C_3
Sunflower	*30*	*10*	*C_4*

[1] 1 tonne = 1000 kg = 2205 pounds. Source: Food and Agriculture Organization of the United Nations (www.FAO.org).

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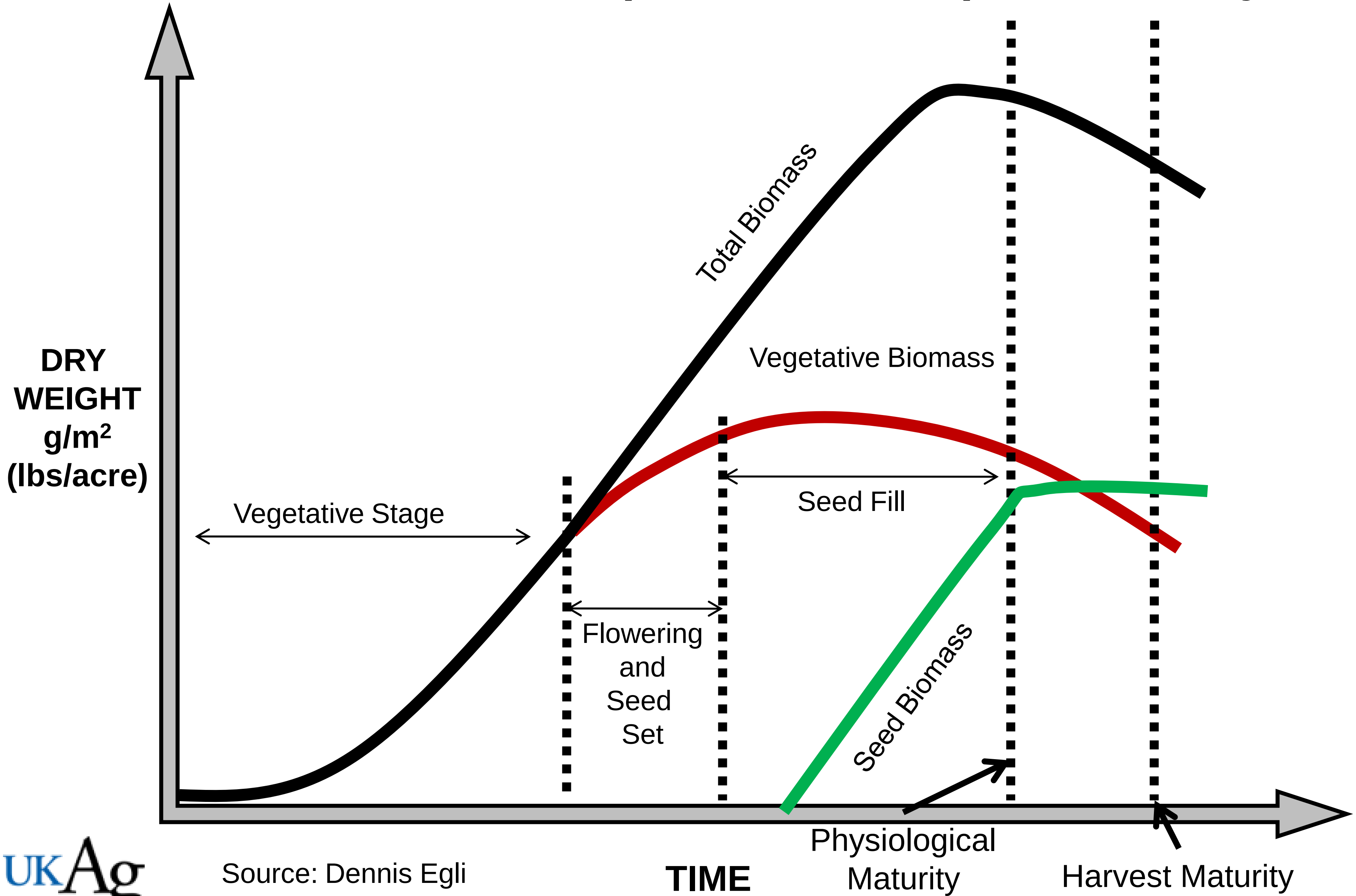
Source: Dennis Egli

Maximize Light and the Use of Light

$$\text{Yield} = \text{LI} \times \text{RUE} \times \text{HI}$$

Growth and Development of a Crop Commodity



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Source: Dennis Egli

Three Stages of Yield Production (Murata,1969)

- **Vegetative Growth:**
  - Formation of organs for nutrient absorption and photosynthesis
- **Flowering and Pod Set:**
  - Formation of flower organs and the yield container.
- **Seed Filling:**
  - Production, accumulation and translocation of yield components

Reproductive Growth

Source: Dennis Egli

Questions

Questions

- What takes more N. Corn or soybean?
- Will early season frost hurt corn or soybean more?
- Will defoliation six weeks after planting hurt corn or soybean more?
- Will early season stand reduction hurt corn or soybean more?

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Corn

Yield Components

- Ears per acre
- Kernels per ear
- Kernel weight (size)

What went wrong?

What went wrong?

What went wrong?

Image 1

What went wrong?

Image 2

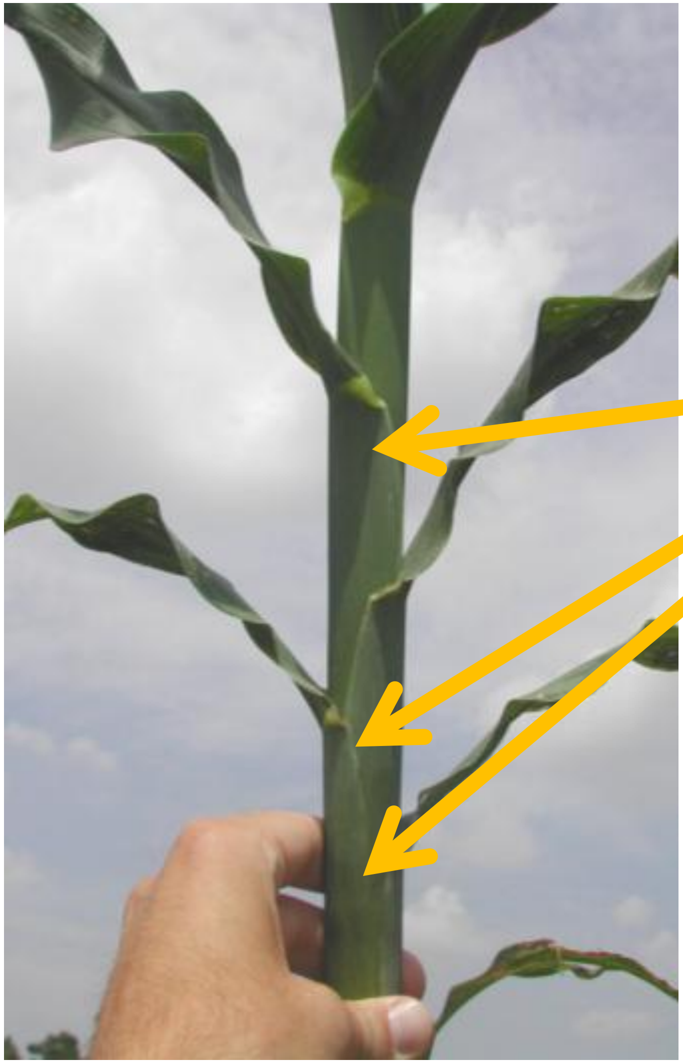
What went wrong?

Image 3

Corn Emergence (VE)

Corn Growth Stages: Vegetative

V3 3 Collars	
V6 6 collars	
V12 12 collars	
V15 15 collars	
VT tassel	



A V-stage is counted when a the collar is visible on a fully emerged leaf

Corn Growth Stages

V3 3 Collars	Nodal roots active. Growing point below ground
V6 6 collars	Growing point above ground. Tassel and ear development starting.
V12 12 collars	Ear size, kernel size and kernel number being determined. Limits on water and/or nutrients will reduce yields.

V6: Six Visible Collars

Tassel development has started.

Ear shoot formation has also started.

Some herbicide labels limit spraying at V6…don’t want to interfere with tassel and ear shoot development!!

Spray based on growth stage.

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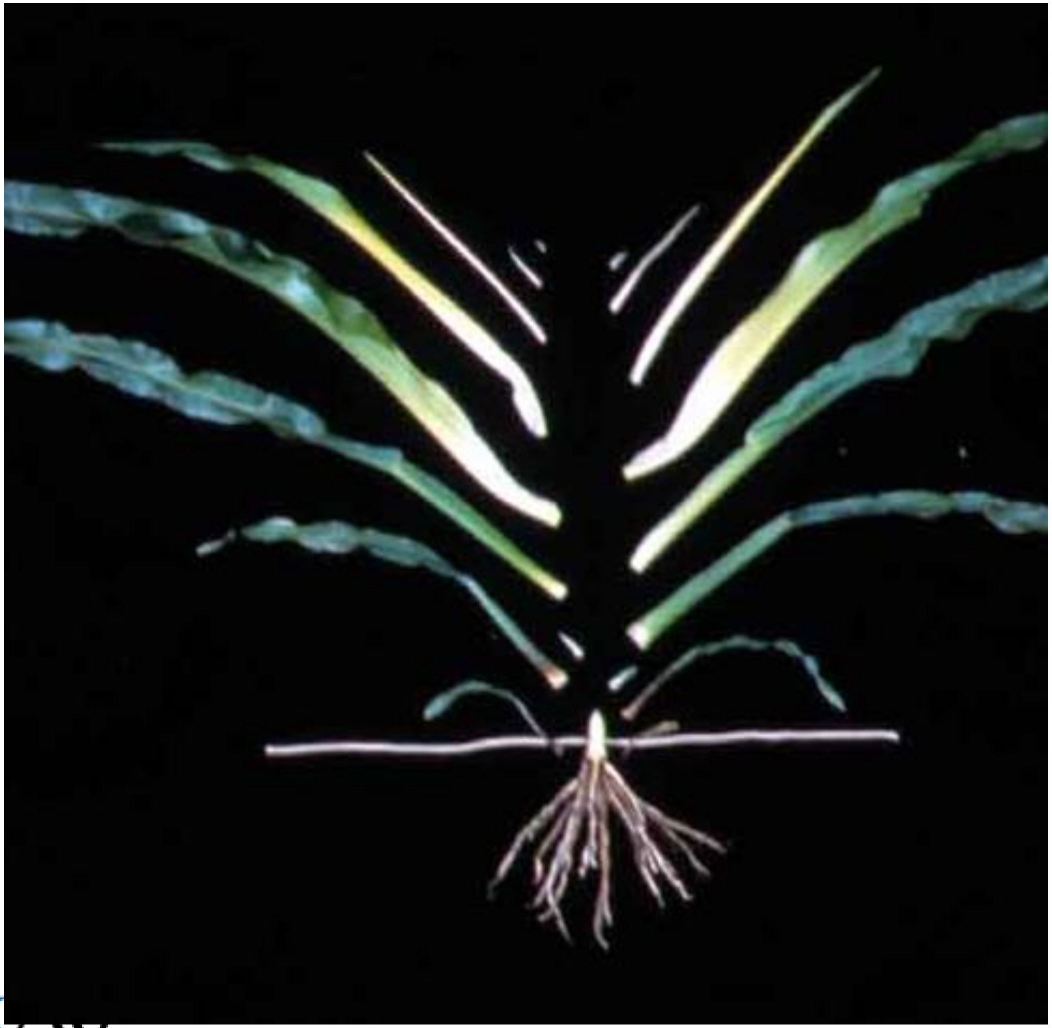
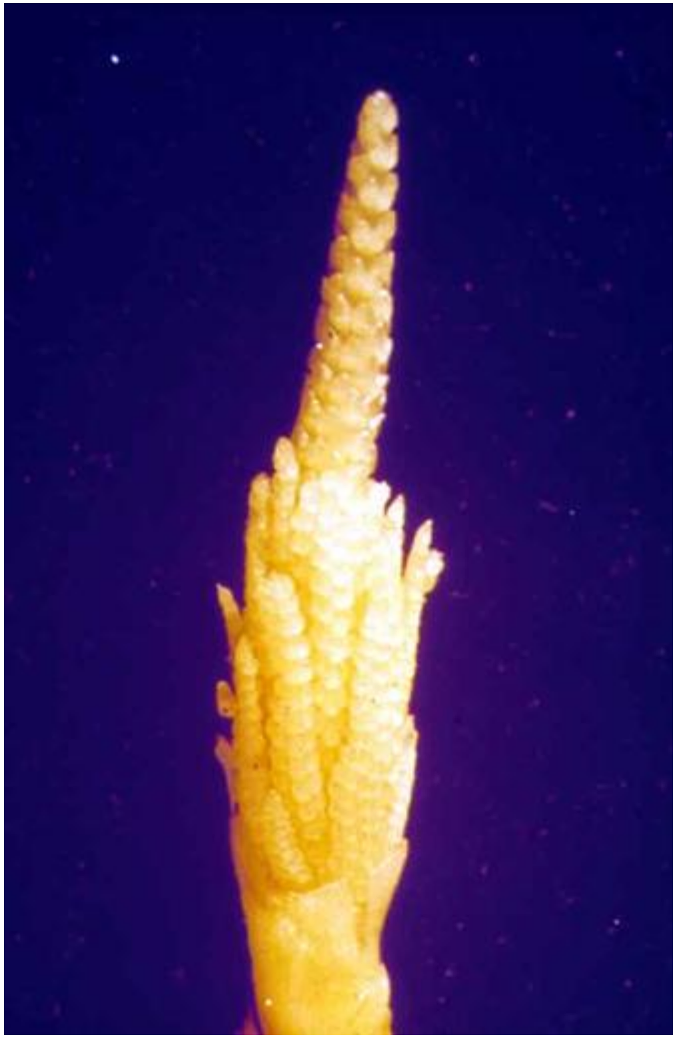
V6

Dissected V6 Plant



Premature Tassel



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Corn Growth Stages

V15 15 collars	Rapid growth, about 10 to 12 days before silking. Most sensitive to stress.
VT tassel	Last tassel branch is visible but prior to silking. Complete leaf loss will cause nearly 100% yield loss.

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Corn Growth Stages

- Comparing visible collars to actual nodes.
- Tassel and ear development start early.

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Corn Growth Stages

R1 Silking	N and P uptake are rapid. About 50% of total N is taken up after R1. K uptake is nearly complete. Water needed for pollination. Pollination occurs.
R2 Blister	Ear size nearly complete. Silks begin to dry out. A miniature corn plant is being formed in each fertilized kernel.

Corn Growth Stages

R4 Dough	Kernels have accumulated ½ of total dry weight. Five leaves have formed in the kernel.
R5 Dent	Most kernels have dented and are near 55% moisture at start. Starch layer has formed and progresses down the kernel.

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Corn Growth Stages

R6 Physiological Maturity	Blacklayer has formed at bottom of kernel. Kernel is about 30 to 35% moisture.

Corn Growing Degree Days

- Corn Growing Degree Day
- Base 50° F
- Max 86° F
- Min 50° F

Example

High: 98

Low: 58

$$\frac{86+58}{2} = 72$$

$$72 - 50 = 22$$

Corn Growing Degree Days

- Corn Growing Degree Day
- Base 50° F
- Max 86° F
- Min 50° F

$$\frac{78+50}{2} = 64$$

$$64 - 50 = 14$$

Example

High: 78

Low: 45

Growing Degree Days

- Online GDD calculator
- Useful when trying to determine a problem
- Ag Weather Center
- Ag/Wx Calc
- http://wwwagwx.ca.uky.edu/cgi-bin/cropdd_www.pl

Corn Growing Degree Days

Corn Maturity (Days)	GDD
85 to 100	2100 – 2400
101 to 130	2400 – 2800
131 to 145	2900 – 3200

From NCH-40 Growing Season Characteristics and Requirements in the Corn Belt. National Corn Handbook.

GDD Requirements of a 2700 GDD Hybrid

Growth Stage	GDD
V2	200
V6	475
V12	870
VT	1135
R1	1400
R6	2700

From NCH-40 Growing Season Characteristics and Requirements in the Corn Belt. National Corn Handbook.

Farmer Problem

Growth Stage	GDD
V2	200
V6	475
V12	870
VT	1135
R1	1400
R6	2700

- A farmer has pinched ears.
- The farmer planted on April 7.
- The farmer sprayed herbicides on May 22 to corn under 30 inches tall.
- Could the herbicides caused the pinched ear?

From NCH-40 Growing Season Characteristics and Requirements in the Corn Belt. National Corn Handbook.

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Corn Growing Degree Day Calculator/Forcaster - Windows Internet Explorer

http://wwwagwx.ca.uky.edu/cgi-bin/cropdd_www.pl

Corn Growing Degree Day Calculator/Forcaster

With this form you can request a listing of daily corn growing degree day accumulations for a number of sites within Kentucky, as well as a few sites from bordering states for 1978 through the current year (2009).

Simply fill out the desired parameters then press the "Submit Choices" button.

Station:	Biofix Date:
Henderson	Apr 01 2008

GDD Accumulations ?

◉ Daily ○ Monthly

Output Destination ?

◉ Screen ○ Save to file ○ E-mail to: [ ]

[Submit Choices] [Reset Form]

Done

http://wwwagwx.ca.uky.edu/cgi-bin/cropdd_www?Crop=Corn&CityName=Henderson&Month=Apr&Day=07&Year - Wi...

Corn Growing Degree Day Totals for Henderson for 2008
Base: 50F   Max cutoff: 86   Min cutoff: 50

Day	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		268	716	1479	2288	3046	3661	4017	4108
2		286	739	1503	2318	3072	3670	4029	4108
3		295	766	1529	2345	3101	3682	4041	4109
4		304	797	1553	2370	3128	3694	4054	4109
5		317	828	1576	2398	3146	3710	4066	4109
6		331	858	1600	2426	3164	3729	4078	4109
7	12	346	888	1627	2455	3184	3746	4082	4109
8	22	360	918	1655	2477	3206	3762	4082	4109
9	32	370	949	1681	2496	3224	3775	4082	4112
10	47	380	976	1706	2518	3242	3790	4082	4112
11	61	386	1000	1734	2540	3267	3812	4082	4112
12	66	395	1028	1762	2560	3294	3832	4084	4112
13	66	404	1056	1790	2580	3323	3854	4089	4112
14	66	416	1080	1812	2602	3351	3877	4095	4115
15	70	427	1104	1836	2624	3364	3900	4096	4115
16	80	436	1130	1861	2646	3380	3908	4096	4115
17	92	450	1150	1886	2666	3394	3916	4096	4115
18	104	466	1168	1912	2686	3412	3922	4096	4115
19	112	479	1188	1939	2708	3434	3930	4096	4122
20	120	490	1211	1966	2733	3454	3940	4096	4122
21	132	502	1235	1992	2758	3476	3950	4096	4122
22	148	514	1258	2020	2788	3498	3956	4096	4122
23	166	532	1280	2046	2814	3521	3964	4096	4122
24	184	548	1303	2067	2842	3542	3968	4097	4124

Farmer Problem

Growth Stage	GDD
V2	200
V6	475
V12	870
VT	1135
R1	1400
R6	2700

- A farmer has poor seed set and ear development.
- The farmer planted on April 7.
- Aerial applicators sprayed a cocktail mix of fungicides, insecticides, adjuvants on June 15 to "fully tasseled" corn .
- Could the timing of the spray be part of the problem?

From NCH-40 Growing Season Characteristics and Requirements in the Corn Belt. National Corn Handbook.

Soybean

Soybean

- When is soybean most susceptible to yield loss?
- Will defoliation hurt yield more when it occurs
  - Before flowering
  - During pod set

Components of Soybean Yield

- Soybean yield is determined by 3 major components.
  - Number of pods per plant.
  - Number of seeds per pod.
  - Weight per seed (seed size).

(plants per acre) x (pods per plant) x (seeds per pod) ÷ (seeds per pound) ÷ (seeds per bushel) = (bushels per acre)

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The stages of yield production (Murata, 1969)

- **Vegetative Growth:**
  - Formation of organs for nutrient absorption and photosynthesis
- **Flowering and Pod Set:**
  - Formation of flower organs and the yield container.
- **Seed Filling:**
  - Production, accumulation and translocation of yield components

Reproductive Growth

Source: Dennis Egli

Soybean Growth Stages

Vegetative Stages

VE – emergence

VC – cotyledon (unrolled unifoliolate leaves)

V1 – first trifoliolate*

V2 – second trifoliolate

V3 – third trifoliolate

V(n) – nth trifoliolate

* A fully developed trifoliolate leaf node has unrolled leaflets.

ISU Extension publication
Soybean Growth and Development (PM 1945)

Reproductive Stages

R1 – beginning bloom

R2 – full bloom

R3 – beginning pod

R4 – full pod

R5 – beginning seed

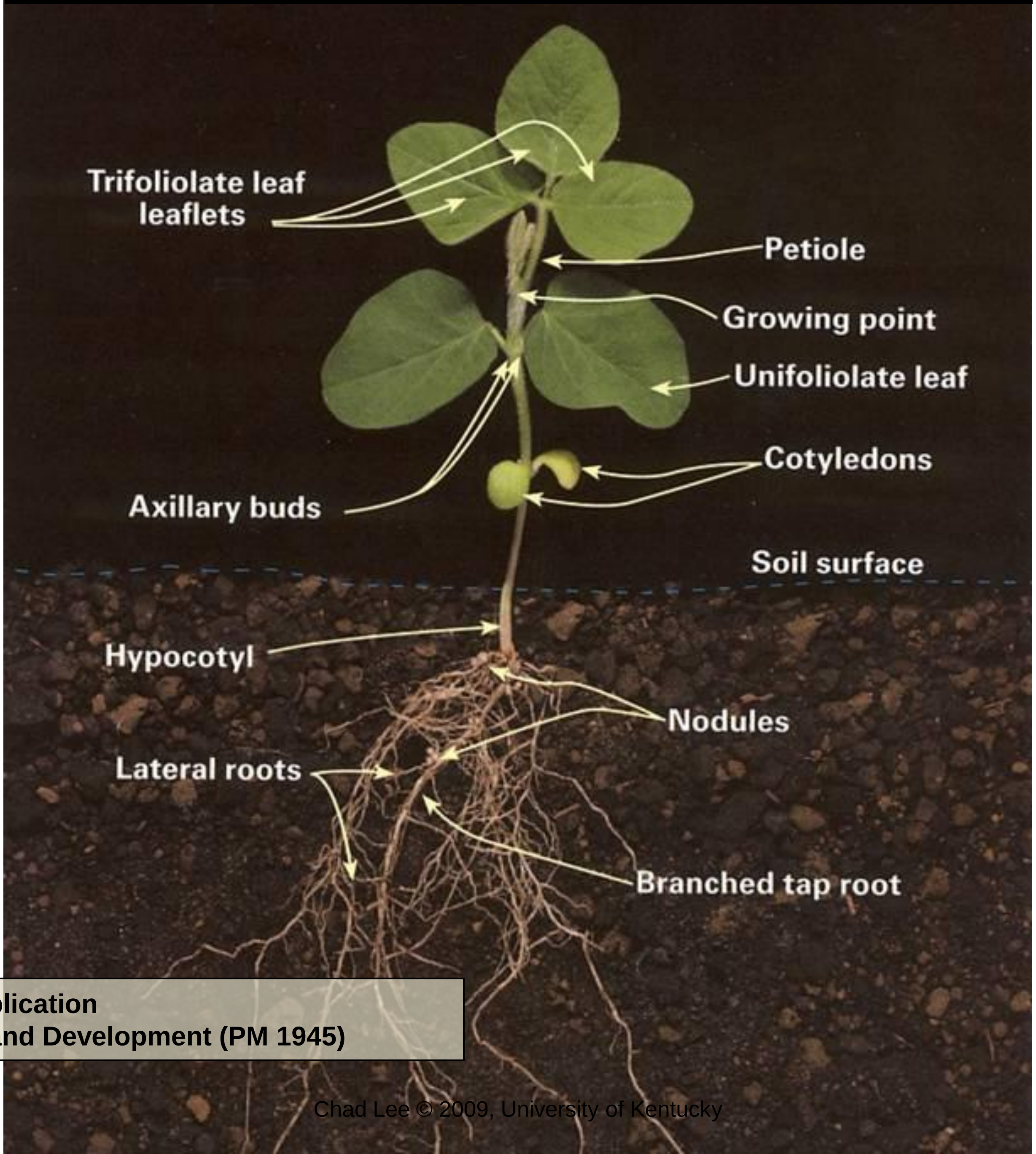
R6 – full seed

R7 – beginning maturity

R8 – full maturity

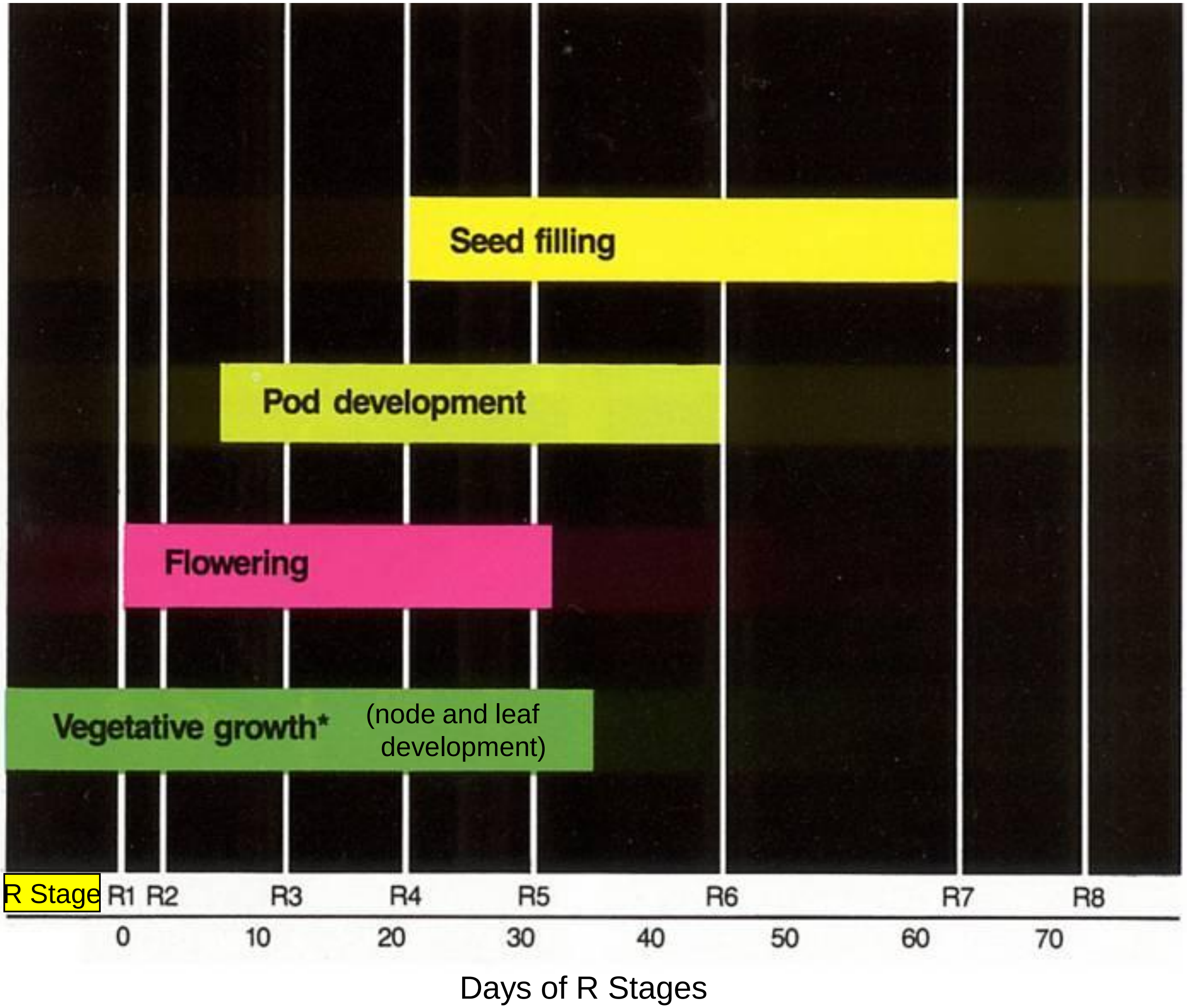
When staging a soybean field , each specific V or R stage is defined only when 50% or more of the plants in the field are in or beyond that stage.

Young Soybean Plant (Seedling)



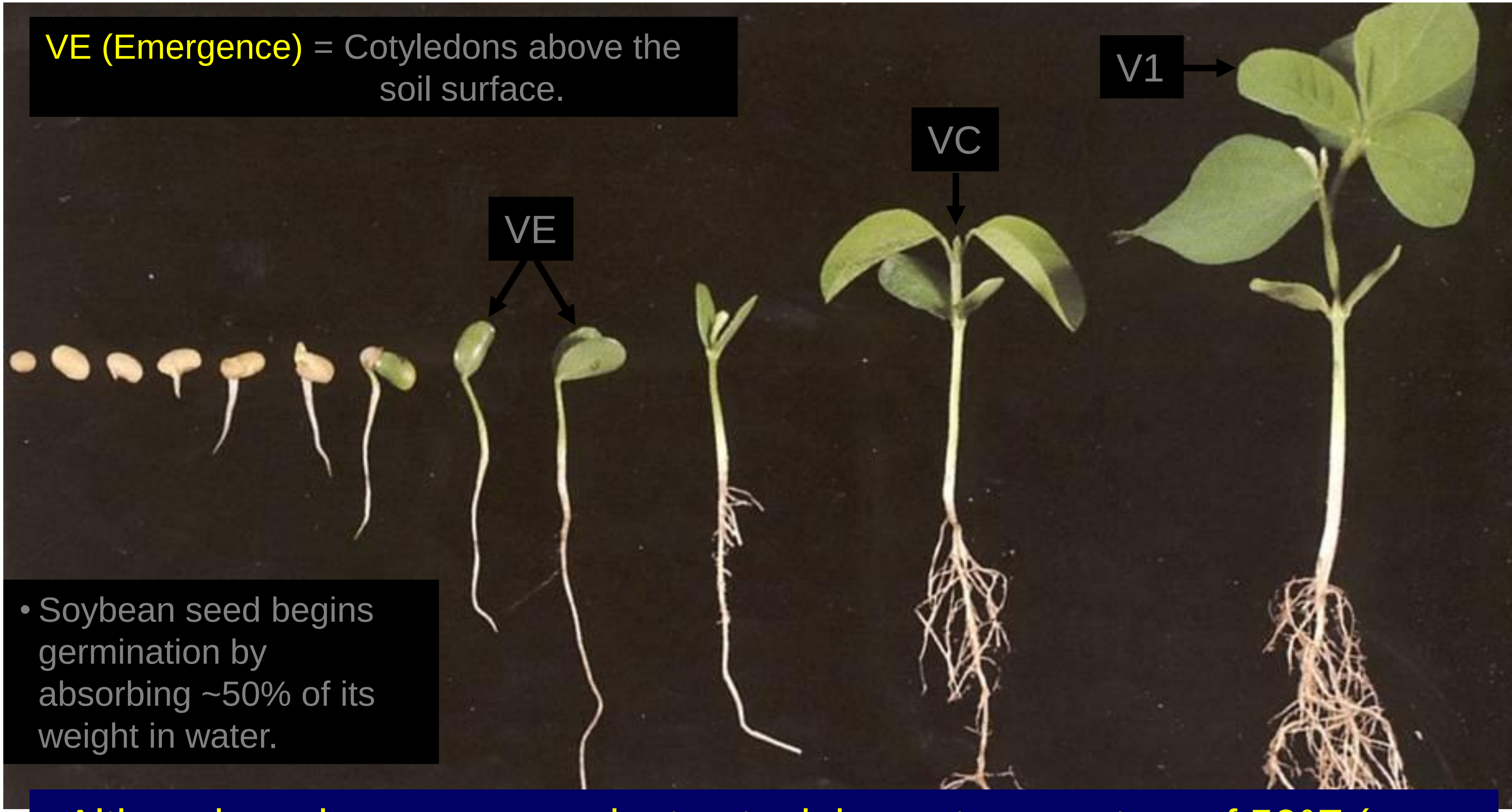
ISU Extension publication
Soybean Growth and Development (PM 1945)

Development and timing of vegetative growth, flowering, pod development, and seed filling.



VE

VE (Emergence) = Cotyledons above the soil surface.

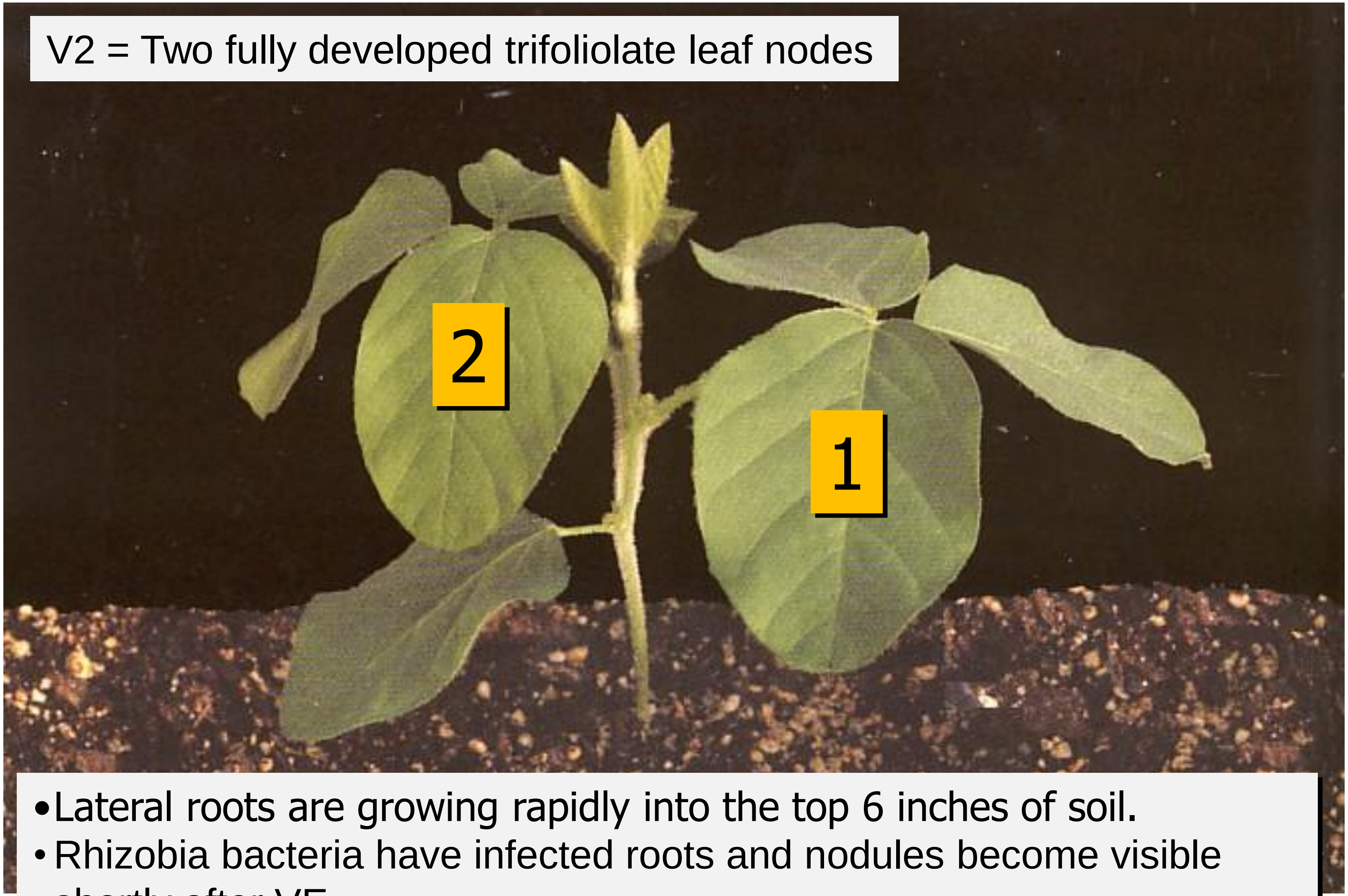


- Soybean seed begins germination by absorbing ~50% of its weight in water.

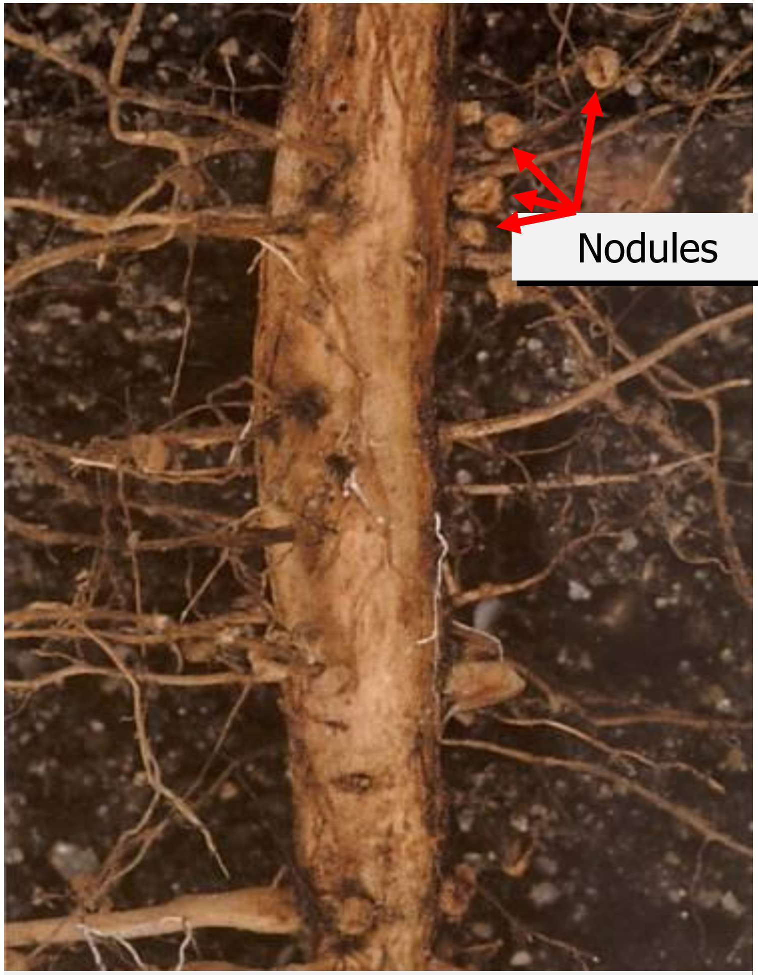
- Although soybean can germinate at minimum temperature of 50°F (or less), field emergence is more rapid (~7 days) and uniform if soil temperature is above 65°F.

V2

V2 = Two fully developed trifoliolate leaf nodes



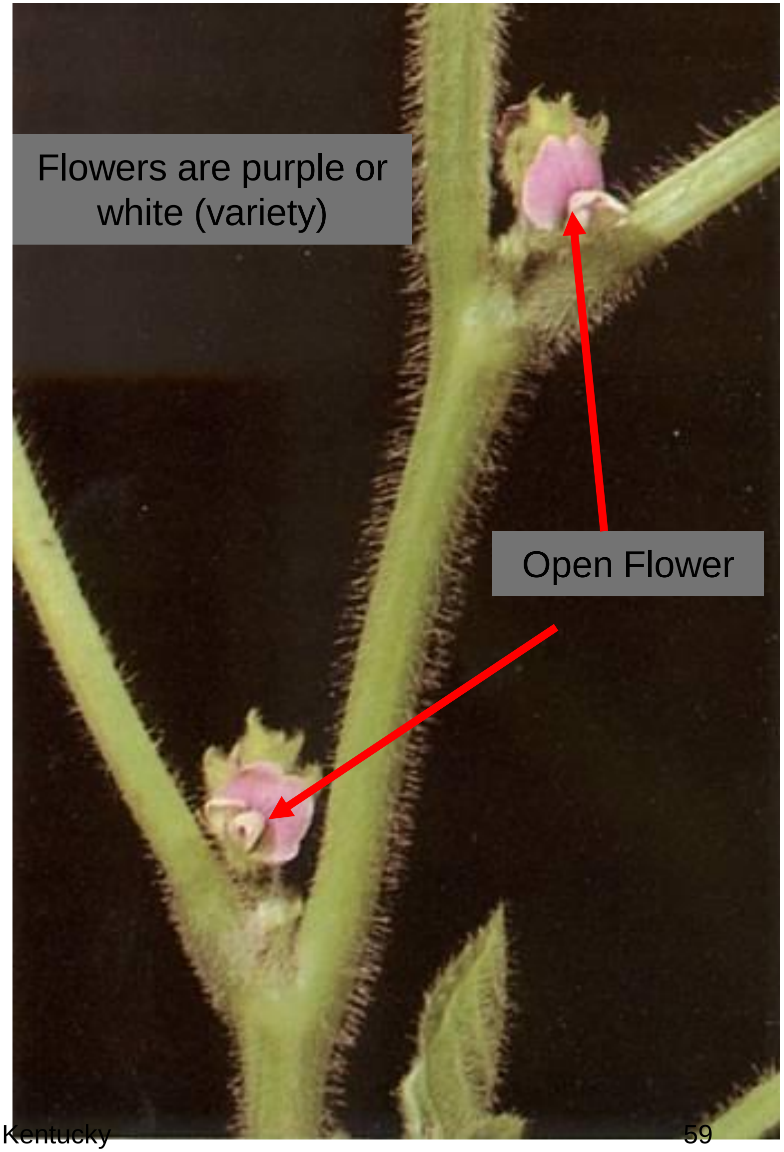
- Lateral roots are growing rapidly into the top 6 inches of soil.
- Rhizobia bacteria have infected roots and nodules become visible shortly after VE.
- N-fixation begins at V2 to V3 stages.



Root showing nodules

R1 – Beginning Bloom

R1 = One open flower at any node on the main stem.



<u>Indeterminate varieties:</u>
At R1, plants are in the V7 to V10 stage. Flowering begins on the third to sixth node (depending on V stage at flowering) and progresses upward and downward.

Vegetative growth continues after flowering begins. At R1, less than half of the nodes on the main stem have developed and plants have achieved less than half their final height.

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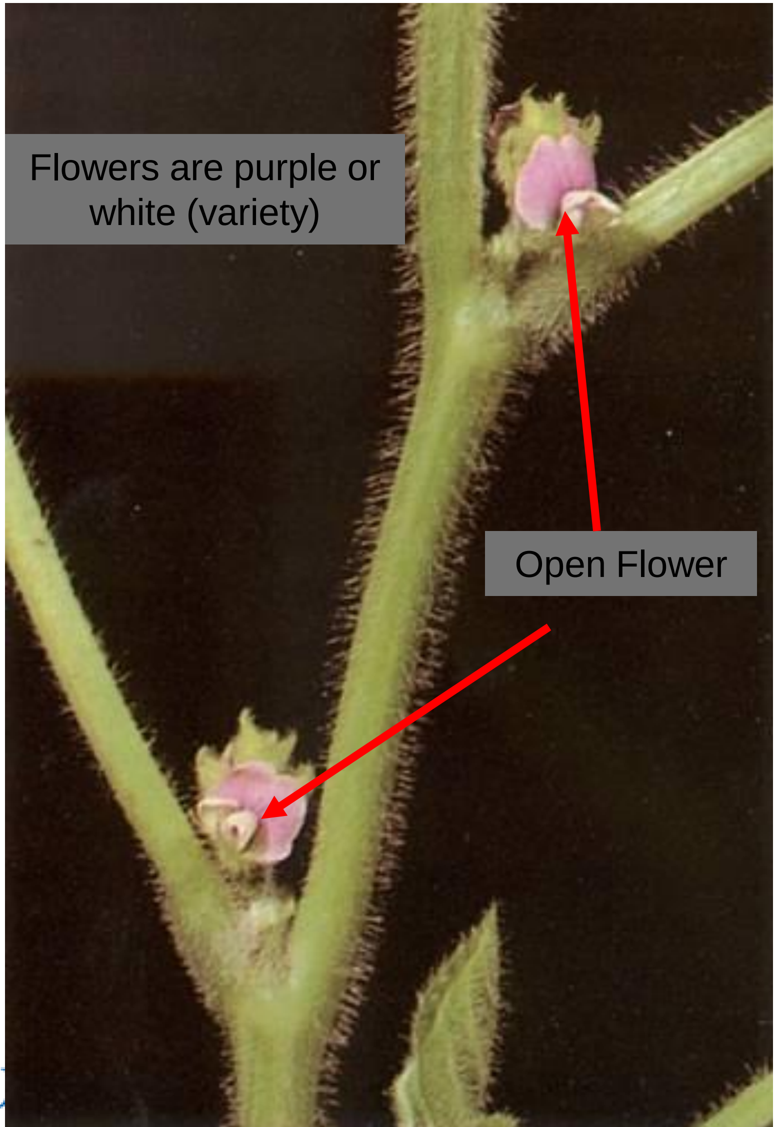
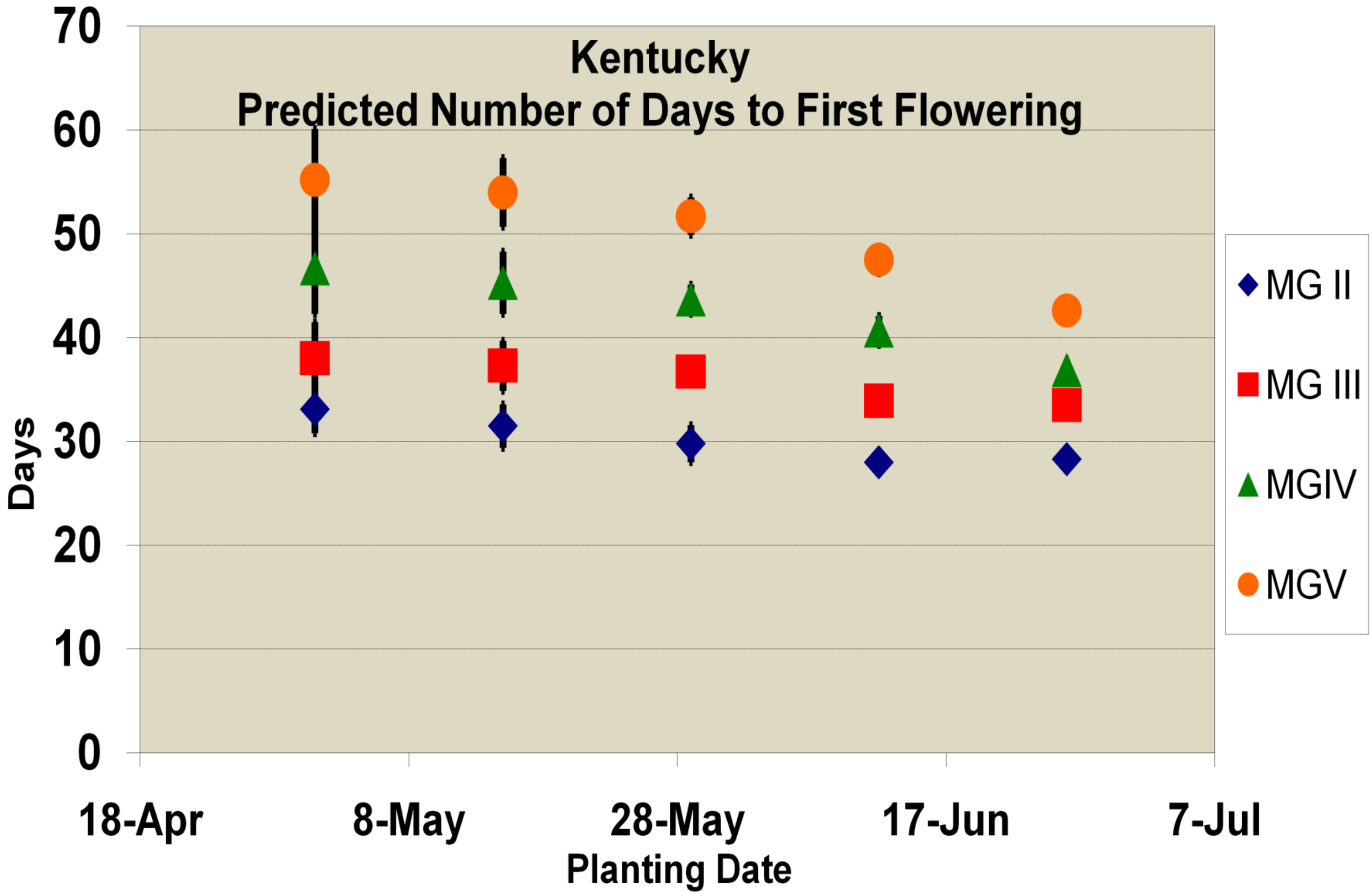
R1 – Beginning Bloom

R1 = One open flower at any node on the main stem.



<u>Determinate varieties:</u>
Vegetative growth is complete before flowering begins. Most or all of the nodes on the main stem have developed and plants grow very little in height after R1.

Flowering occurs at the same time in the top and bottom of the plant. R1 and R2 may occur simultaneously.



Average of 29 years of weather data, Spindletop Farm, Lexington, KY.
Standard deviation: measurement of variation, expressed by bars.
Flowering dates generated from CROPGRO and verified from field data by Dr. Dennis Egli.

Row Width Effect on Canopy Closure (Kentucky)

Row Spacing	Time from Planting to Full Canopy	
	Average	Range
Inches	Days After Planting	
≤ 10	32	25-40
15-20	50	45-55
30	65	60-70

Growing conditions will affect the amount of time needed for canopy closure.
Poor growing conditions increase the length of time to canopy.
Later planting dates decrease the length of time to canopy.

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R2 – Full Bloom

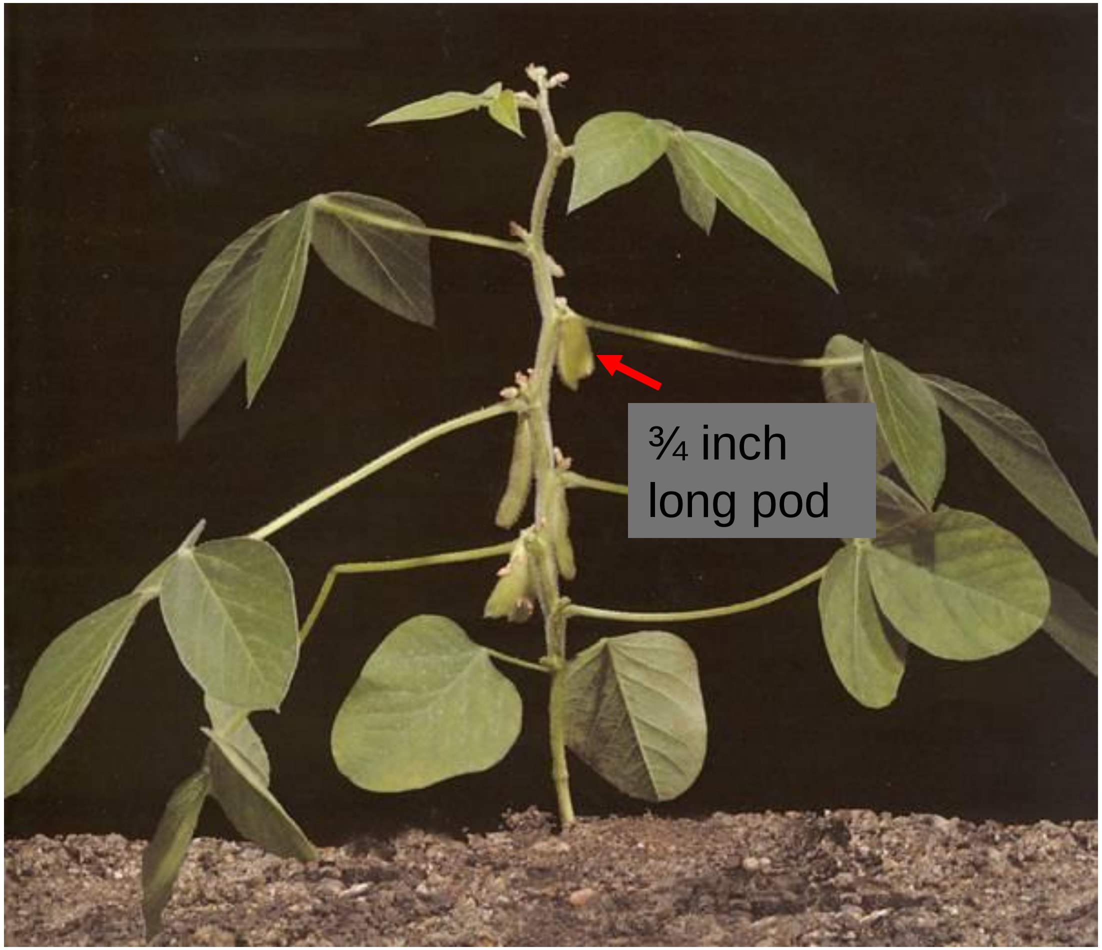
R2 = Open flower at one of the two uppermost nodes on the main stem with a fully developed trifoliolate leaf node.

The rapid dry weight accumulation initially starts in the vegetative plant parts but then gradually shifts to the pods and seeds between R3 and R6.

50% defoliation at R2 reduces yield about 6 percent.

R2 marks the beginning of a period of rapid and constant (linear) dry weight accumulation by the whole plant which continues until shortly after the R6 stage.

R4 – Full Pod



- Pod is 2 cm (¾ inches) long at one of the four uppermost nodes on the main stem with a fully developed trifoliolate leaf node.

Period of rapid dry weight accumulation by the pods (R4 to middle of R5).

R4 – Full Pod

R4 is start of the most critical period for yield determination.

From R4 through R6, stress (moisture, light, nutrients, frost, lodging, defoliation) reduces yield more than any other period.

Yield reductions at R4 result mainly from fewer pods per plant.

Stress can cause pods to abort.

Period of rapid dry weight accumulation by the pods (R4 to middle of R5).

R6 – Full Seed

R6 = Pod containing a green seed that fills the pod cavity at one of the four uppermost nodes on the main stem with a fully developed trifoliolate leaf node.

"green bean" stage

Stress reduces seed size (weight)

Dry weight accumulation still rapid in seeds, but begins to slow shortly after R6.

Sequence of Seed Development (R5 → R6)

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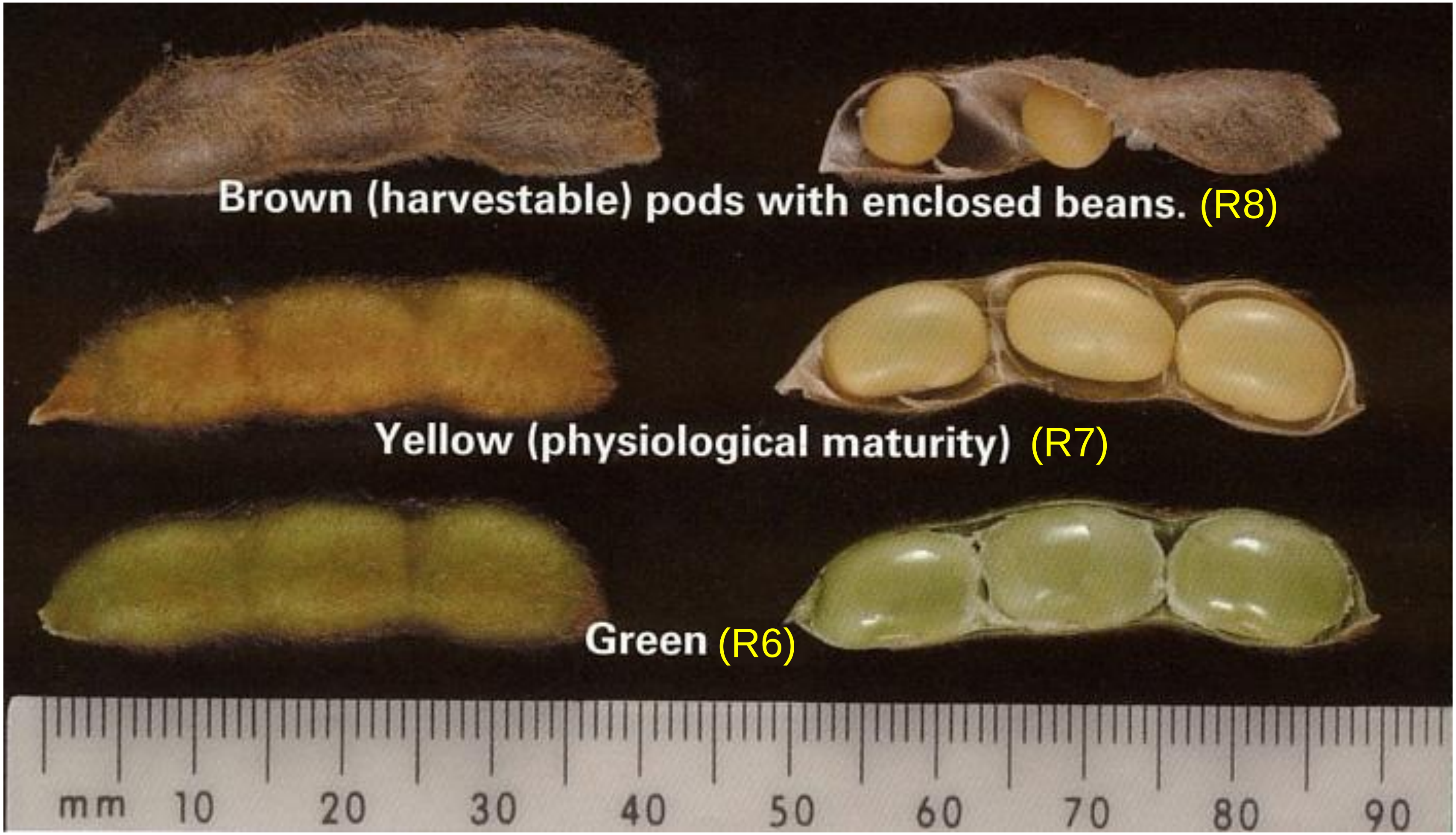
Soybean Pods and Seeds (R6 → R8)



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Components of Soybean Yield

- Soybean yield is determined by 3 major components.
  - Number of pods per plant.
  - Number of seeds per pod.
  - Weight per seed (seed size).

(plants per acre) x (pods per plant) x (seeds per pod) ÷ (seeds per pound) ÷ (seeds per bushel) = (bushels per acre)

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Yield Components

Yield Components

Increase Plant Population

Pods per Plant

Seeds per Pod

Seed Size

Yield Components

Ideal Temperatures During Pod Set

Yield Components

Ideal Temperatures During Pod Set And Seed Fill

Yield Components

Hot Temperatures During Pod Set, Ideal During Seed Fill

Yield Components

Ideal Temperatures During Pod Set,
Hot & Dry During Seed Fill

Pods per Plant

Seeds per Pod

Seed Size

Yield Components

Stink Bug Infestation Injures 40 pods per 5 plants

Pods per Plant (▲)	Seeds per Pod (▼)	Seed Size (▼)

University of Kentucky Entomology Website:
http://www.ca.uky.edu/entomology/entfacts/ef131.asp

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Components of Soybean Yield

- Soybean yield is determined by 3 major components.
  - Number of pods per plant.
  - Number of seeds per pod.
  - Weight per seed (seed size).
- (plants per acre) x (pods per plant) x (seeds per pod) / (seeds per pound) / (pounds per bushel) = (bushels per acre)

- (plants per acre) x (pods per plant) x (seeds per pod) / (seeds per pound) / (pound per bushel) = (bushels per acre)
- (120,000) x (32) x (2.5) / (2,500) / (60) = 64 bu/a
- (120,000) x (32) x (2.5) / (3,500) / (60) = 45.7 bu/a

Wheat (*Triticum aestivum* L.)

- Originated in the area that is now modern Turkey, Syria and Jordan
- Bread from wheat found in the Nile valley around 5,000 BC

Wheat: Key Numbers

Crop Stage	Number	
Emergence	25	plants/sq.ft.
Tillering	70 to 100	tillers/sq.ft.
Heading	60 to 70	heads/sq.ft.
Heading	35	kernels/head

Scouting Stands

Drill Row Width	Linear Length of Row Needed to Equal 1 ft^2
(inches)	(inches)
6	**24.0**
7	**20.6**
7.5	**19.2**
8	**18.0**

Wheat Yield Contest Year	Top Yields Tilled bu/a	No-Till bu/a
1997	**110.89**	96.94
1998	**81.85**	80.96
1999	**116.4**	109.9
2000	117.51	**120.94**
2001	**121.27**	98.01
2002	92.26	**105.93**
2003	**109.53**	105.89
2004	98.54	**102.02**
2005	**123.71**	112.04
2006	108.36	**119.71**
2007	**98.90**	91.23
2008	124.56	**130.61**
Average	108.65	106.18

Wheat Yield	Top Yields		Difference	
Contest	Tilled	No-Till	Tilled minus No-Tilled	
Year	bu/a	bu/a	bu/a	%
1997	**110.89**	96.94	13.95	13%
1998	**81.85**	80.96	0.89	1%
1999	**116.4**	109.9	6.50	6%
2000	117.51	**120.94**	-3.43	-3%
2001	**121.27**	98.01	23.26	19%
2002	92.26	**105.93**	-13.67	-15%
2003	**109.53**	105.89	3.64	3%
2004	98.54	**102.02**	-3.48	-4%
2005	**123.71**	112.04	11.67	9%
2006	108.36	**119.71**	-11.35	-10%
2007	**98.90**	91.23	7.67	8%
2008	124.56	**130.61**	-6.05	-5%
Average	108.65	106.18	2.47	2%

Wheat Yield Contest Year	Top Yields Tilled bu/a	No-Till bu/a	Difference Tilled minus No-Tilled bu/a	%
1997	**110.89**	96.94	13.95	13%
1998	**81.85**	80.96	0.89	1%
1999	**116.4**	109.9	6.50	6%
2000	117.51	**120.94**	-3.43	-3%
2001	**121.27**	98.01	23.26	19%
2002	92.26	**105.93**	-13.67	-15%
2003	**109.53**	105.89	3.64	3%
2004	98.54	**102.02**	-3.48	-4%
2005	**123.71**	112.04	11.67	9%
2006	108.36	**119.71**	-11.35	-10%
2007	**98.90**	91.23	7.67	8%
2008	124.56	**130.61**	-6.05	-5%
Average	108.65	106.18	2.47	2%
1st Five Years (1997 to 2002)	109.58	101.35	8.23	7%
Last Five Years (2004 to 2008)	110.81	111.12	-0.31	-0.3%

Kentucky Wheat Contest

2008 Wheat Contest	**Kentucky Champion, No-Till**	**Kentucky Champion, Tillage**	**Area 1 Champion**	**Area 2 Champion**	**Area 3 Champion**	**Area 4 Champion**
Name	Elkin Farms	Chris Kummer	Abe & Joe Miller	Pasture Belt Farms	Corn Silks Farms	Reding Farms
Wheat Yield (Bu/A)	**130.61**	**124.56**	120.07	114.70	**128.58**	118.75
County	Warren	Simpson	Todd	Daviess	Logan	Larue
Tillage	No-Till	Disked twice	No-Till	Disked twice	No-Till	No-Till

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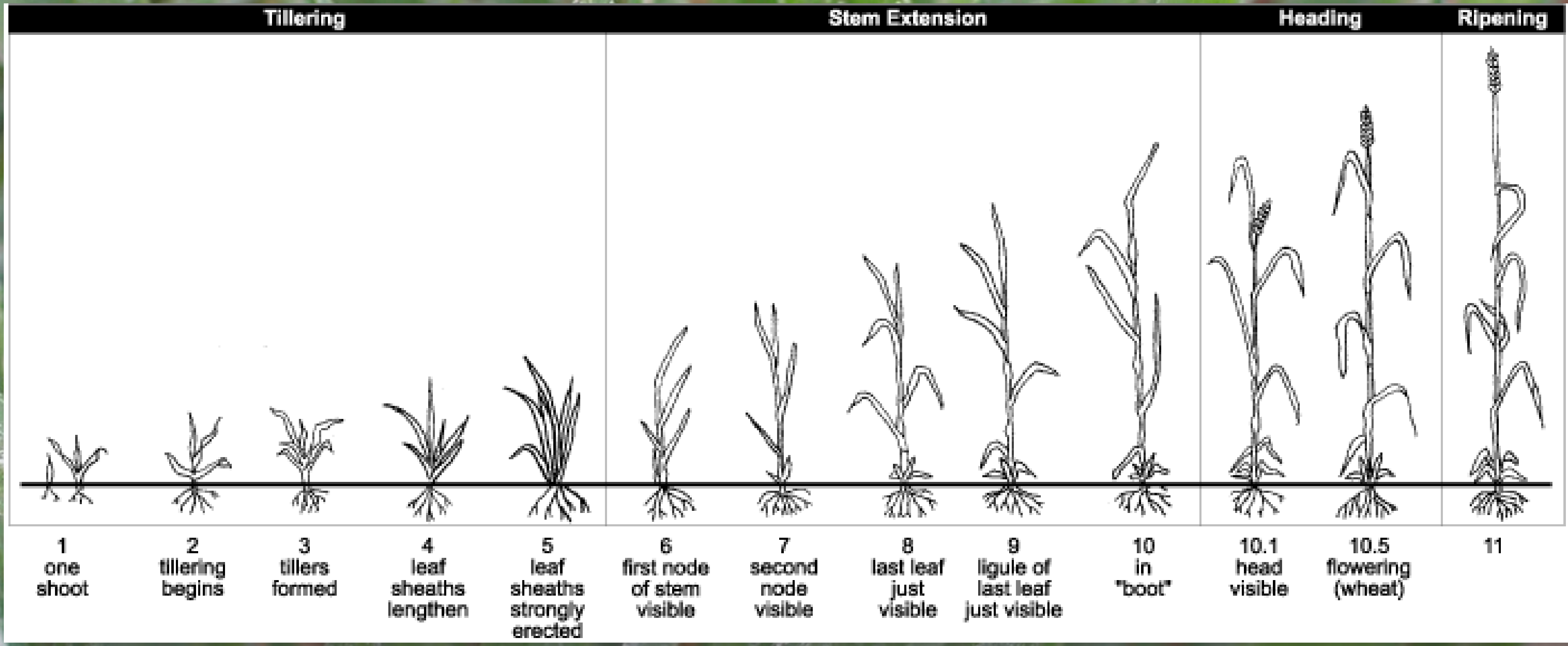
Feekes Scale



General Description	Feekes Scale	Zadoks Scale	Additional Comments
Germination			
Dry seed		00	
Start of imbibition		01	
Imbibition complete		03	Seed typically at 35 to 40% moisture.
Radicle emerged from seed (caryopsis)		05	
Coleoptile emerged from seed (caryopsis)		07	
Leaf just at coleoptile tip		09	
Seedling Growth			
First leaf through coleoptile	1	10	
First leaf unfolded		11	
2 leaves unfolded		12	
3 leaves unfolded		13	
4 leaves unfolded		14	
5 leaves unfolded		15	
6 leaves unfolded		16	
7 leaves unfolded		17	
8 leaves unfolded		18	
9 or more leaves unfolded		19	

General Description	Feekes Scale	Zadoks Scale	Additional Comments
Stem Elongation			
Pseudostem erection	4-5	30	
1st detectable node	6	31	Jointing stage
2nd detectable node	7	32	
3rd detectable node		33	
4th detectable node		34	Only 4 nodes may develop in modern varieties.
5th detectable node		35	
6th detectable node		36	
Flag leaf visible	8	37	
Flag leaf ligule and collar visible	9	39	
Booting			
Flag leaf sheath extending		41	Early boot stage.
Boot swollen	10	45	
Flag leaf sheath opening		47	
First visible awns		49	In awned varieties only.

General Description	Feekes Scale	Zadoks Scale	Additional Comments
Head (Inflorescence) Emergence			
First spikelet of head visible	10.1	50	
¼ of head visible	10.2	52	
½ of head visible	10.3	54	
¾ of head visible	10.4	56	
Head completely emerged	10.5	58	
Pollination (Anthesis)			
Beginning of flowering	10.51	60	Flowering usually begins in middle of head.
	10.52		Flowering completed at top of head.
	10.53		Flowering completed at bottom of head.
½ of flowering complete		64	
Flowering completed		68	
Milk Development			
Kernel (caryopsis) watery ripe	10.54	71	
Early milk		73	
Medium Milk	11.1	75	Milky ripe.
Late Milk		77	Noticeable increase in solids of liquid endosperm when crushing the kernel between fingers

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General Description	Feekes Scale	Zadoks Scale	Additional Comments
Dough Development			
Early dough		83	
Soft dough	11.2	85	Mealy ripe: kernels soft but dry.
Hard dough		87	
Ripening			
Kernel hard (hard to split by thumbnail)	11.3	91	Physiological maturity. No more dry matter accumulation.
Kernel hard (cannot split by thumbnail)	11.4	92	Ripe for harvest. Straw dead.
Kernel loosening in daytime		93	
Overripe		94	
Seed dormant		95	
Viable seed has 50% germination		96	
Seed not dormant		97	
Secondary dormancy		98	
Secondary dormancy lost		99	

Wheat: Key Numbers

Crop Stage	Number	
Emergence	25	plants/sq.ft.
Tillering	70 to 100	tillers/sq.ft.
Heading	60 to 70	heads/sq.ft.
Heading	35	kernels/head

Corn Yield Improvement

- Hybrids
- N fertilizer
- Herbicides
- Higher plant populations
- Narrow rows (from 40 down to 30 inches)
- Earlier planting

Corn Yield Increases

- 60% to genetics
- 40% to agronomics

Lee and Tollenaar, 2007

Corn Harvest Index

- Ear: 50% of dry matter
- Stalk and leaves: 50% of dry matter
- Harvest Index:
  - Ear Weight : Total Above Ground Biomass
- HI has not changed in the hybrid era

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Seed Yield Components

- Kernel number
- Kernel size
- Kernel weight

Lee and Tollenaar, 2007

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Corn Grain Yield

Dry Matter Accumulation

Pre-Silking
- Leaf area/angle
- Flowering Date
- Photosynthesis

Post-Silking
- Leaf area/angle
- Number of Days
- Functional Stay Green
- Visual Stay Green

Silk Establishment

Potential Kernel Number

Threshold plant growth rate at silking (PGRs)

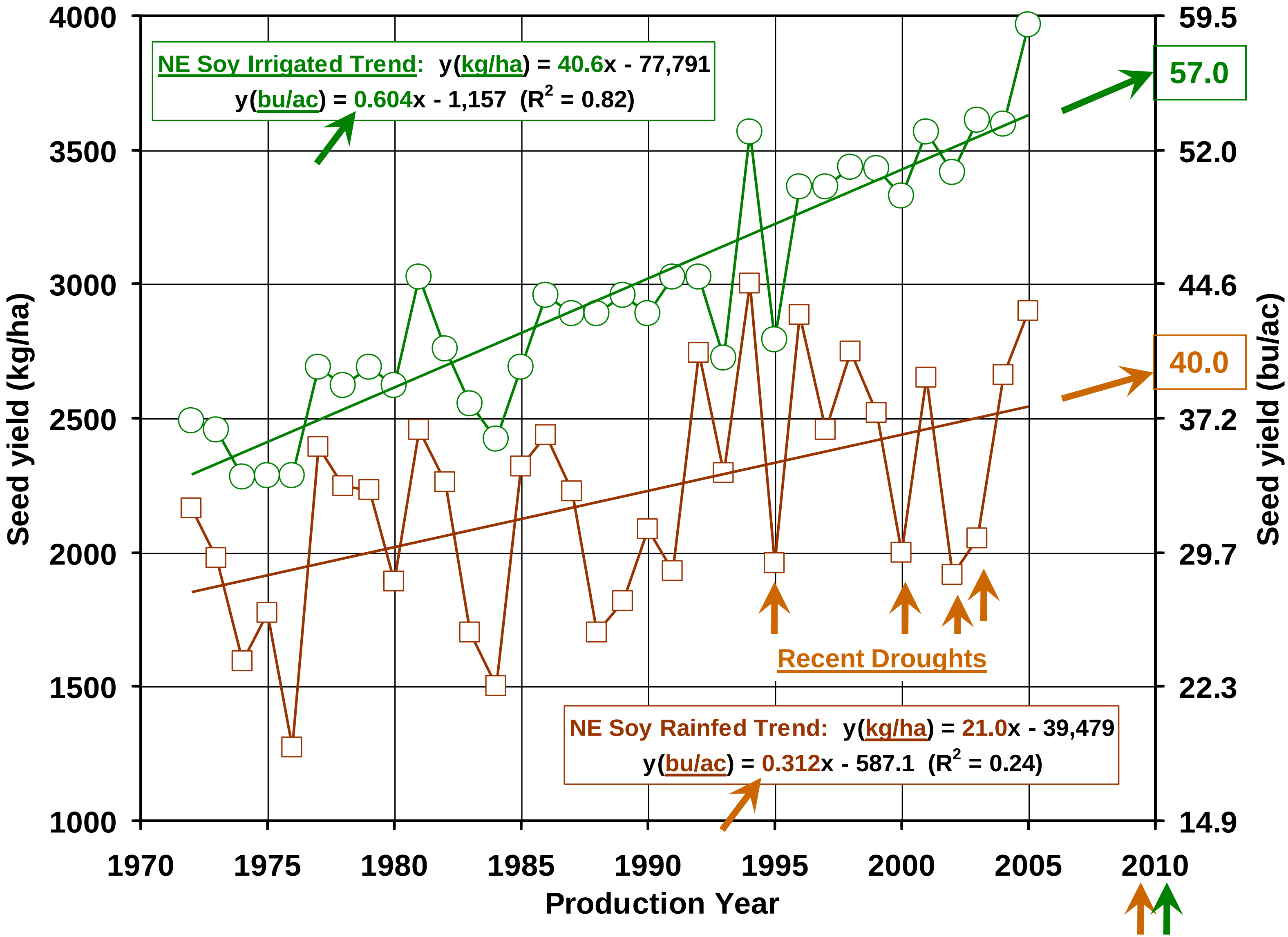
Kernel set efficiency
(# of kernels/unit PGRs)

Lee and Tollenaar, 2007

$Yield = LI \times RUE \times HI$

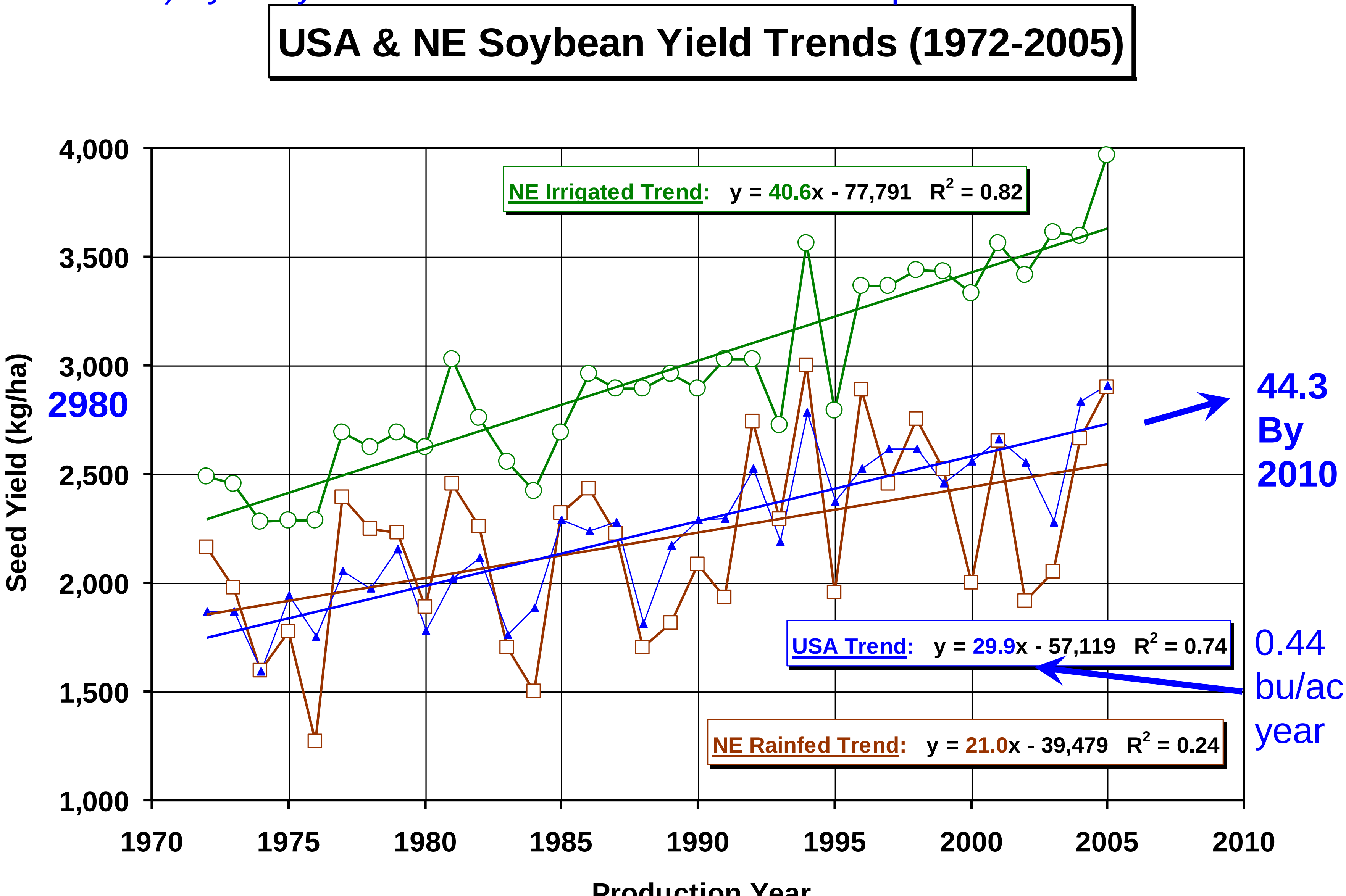
Soybean

- Yield Trends, etc.



Jim Specht, Nebraska

USA Soy Yield trend line at 29.9 kg/ha yr (0.44 bu/ac yr) rate goes to 4000 kg/ha (ca. 60 bu/ac) by the year 2044. See next slide for what I predicted back in 1999.



Jim Specht, Nebraska

Conversion Factors: 67.25 kg/ha = 1 bu /ac; 1000 kg/ha = 14.7 bu/ac

Annual Improvement in Yield

- **Technological Innovation**
  - **Genetic Technology** – continual release & rapid adoption of the newest, ever-higher-yielding hybrids (corn) or varieties (soybeans).
  - **Agronomic Technology** – periodic development and adoption of more effective crop management practices (with skill & timing!) and equipment.
  - **Genetic x Agronomic Tech Synergism** – yield advantage of modern hybrids & varieties is larger in more productive, highly managed environments.

Jim Specht, Nebraska

Annual Improvement in Yield

- **<u>Other Considerations</u>**
  - **Atmospheric CO_2** (316 ppm in 1959 to 376 ppm in 2003) – i.e., a rise in "carbon fertilization" of 1.5 ppm yr^{-1} = ~5 kg ha^{-1} yr^{-1} (about 1/12 bu ac^{-1} yr^{-1}).

Jim Specht, Nebraska

Genetic Improvement - Goals

- **Productivity –** increase yield potential *per se* by optimizing yield response to abiotic factors (i.e., water) in the targeted production environments.
- **Protection –** minimize the impact of biotic factors via rapid deployment of disease/pest resistance genes to existing and newly developed varieties.
- **Quality –** enhance the constituent or intrinsic marketplace value of the harvested raw product.
- **Other –** Transgenics may be used solve the insoluble, or to unlock (un)foreseen opportunities.

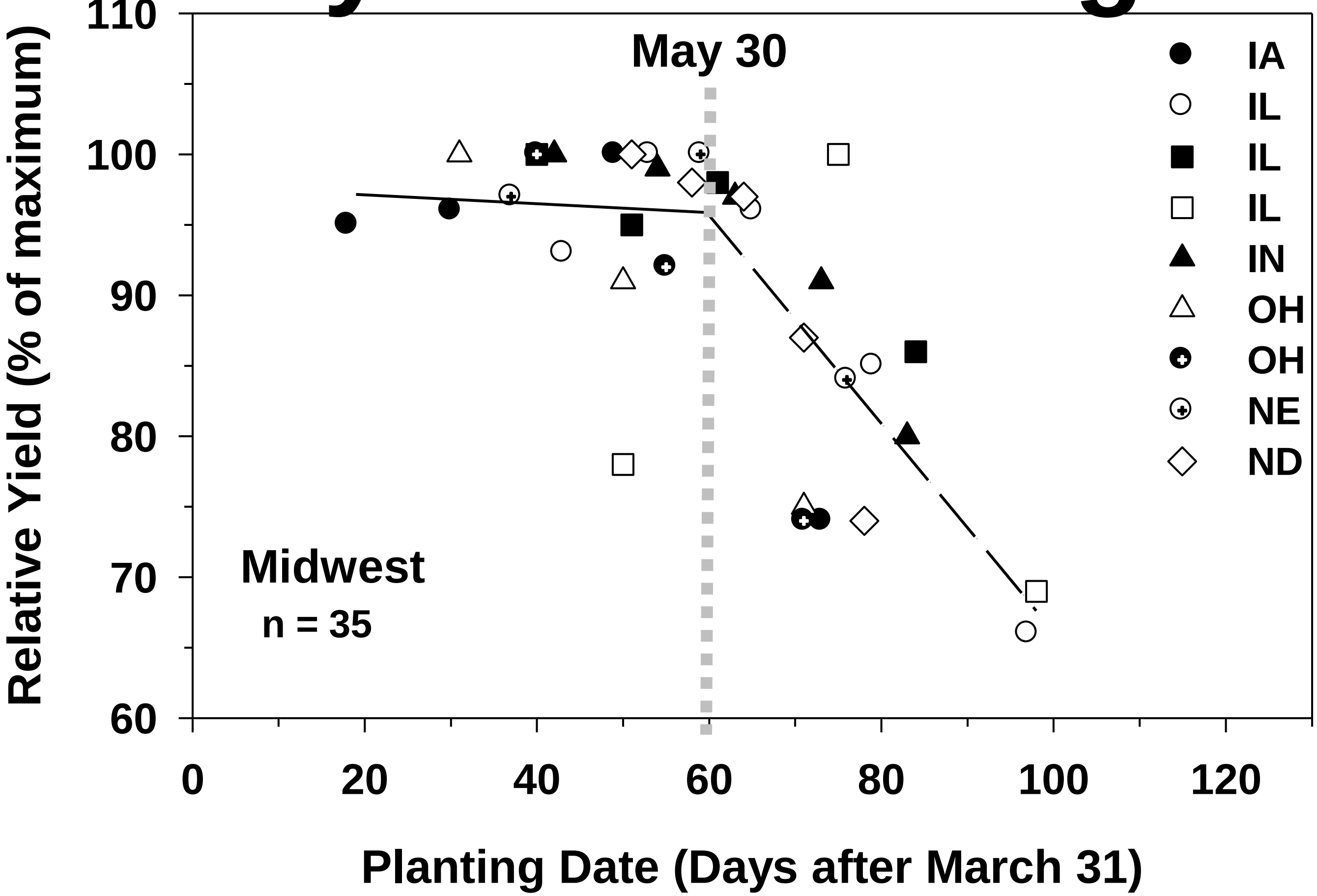
Jim Specht, Nebraska

Soybean - Agronomic Improvements

- Earlier planting
- Narrower rows
- Better weed control
- Lower harvest losses

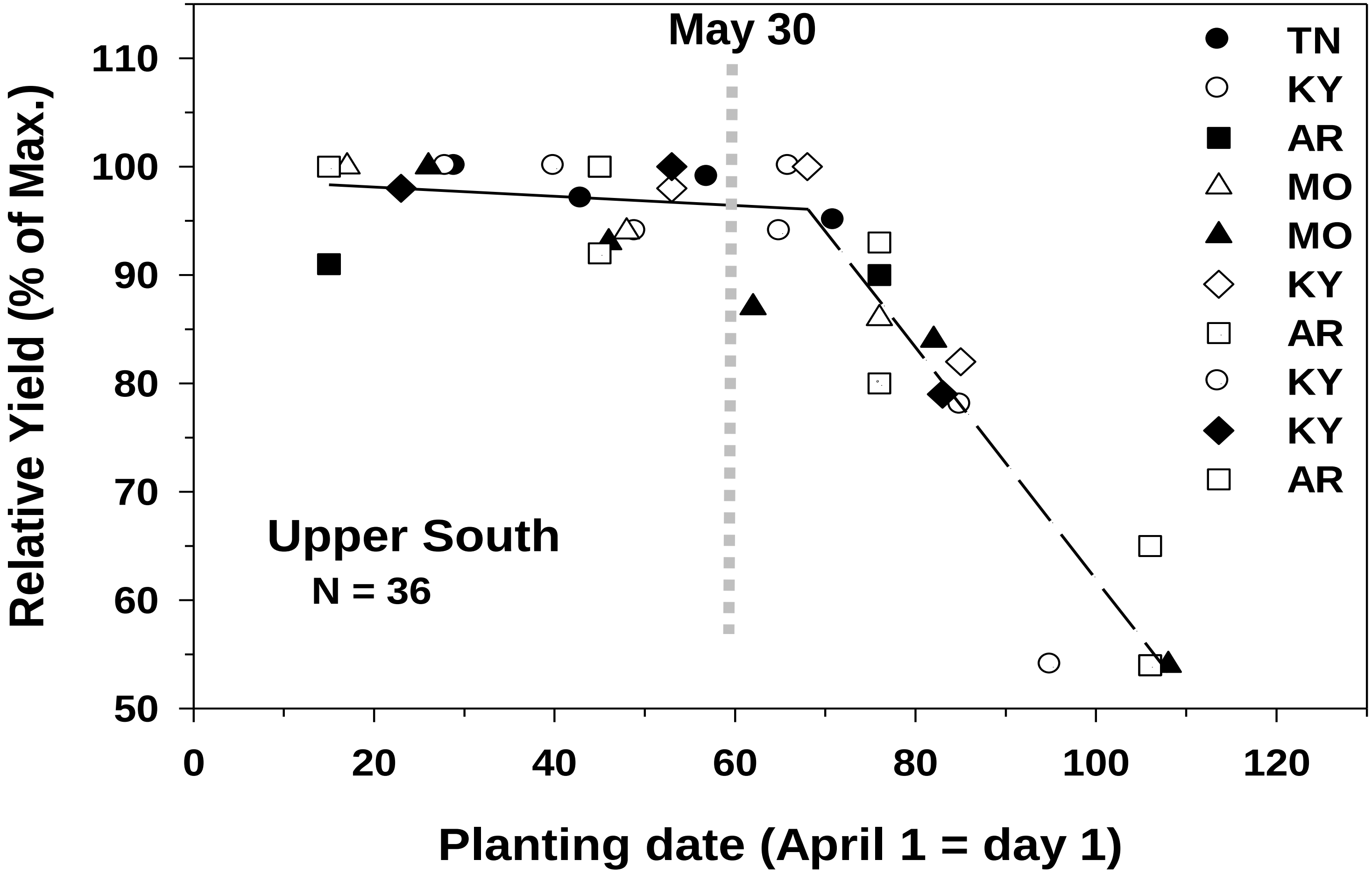
Specht et al., 1999

Soybean Planting Date



Egli. 2009. Agron. J. in press

Soybean Planting Date



Egli. 2009. Agron. J. in press

Wheat Yield Improvements


50% - genetic improvement
50% - improved management

Major Accomplishments in Wheat Breeding

- Incorporation of semi-dwarfing genes
- Day-length insensitivity
- Green Revolution and Int'l. Nurseries (CIMMYT)
- Adult Plant Resistance (rusts, mildew)
- Incorporation of 1B/1R or 1A/1R (pest resistance, adaptation, drought tolerance).
- Rapid response to new pests: Russian wheat aphid, Hessian fly, eyespot, FHB
- Increased grain yield and quality

D. Van Sanford, Kentucky

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Technological Advances

- Improved technology - increased program size
- Rapid information turnaround - more precision choosing parents, testing lines
- Enhanced cooperation - excellent access to germplasm

D. Van Sanford, Kentucky

Increased Number of Varieties

- Number of entries in USDA Uniform nurseries has increased greatly
- Number of entries in KY variety trial -
  - 1982: 32
  - 2004: 72

D. Van Sanford, Kentucky

Wheat Breeding Impact

$$\Delta G = S \cdot h^2$$

- More varieties, bigger populations - **increased selection intensity**
- Yet the rate of yield increase has actually dropped off in the last 20 years

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Genetic Context

- Markers are being used
- Short to mid term infrastructure being developed
- What about the long term?

D. Van Sanford, Kentucky

Long Term Progress in Wheat Improvement

- Have likely accumulated most or all of the major favorable alleles
- Need to be able to identify minor alleles
- Need to work on the difficult traits

D. Van Sanford, Kentucky

Questions

Questions

- What takes more N. Corn or soybean?
- Will early season frost hurt corn more or soybean?
- Will defoliation six weeks after planting hurt corn or soybean more?
- Will early season stand reduction hurt corn or soybean more?

Nutrients used

Crop	Yield	N required	N required
	Bu/A	lb/bu	lbs/A
Corn	150	0.7	105
Soybean	50	3	150

Crop	Yield	P_2O_5 required	P_2O_5 required
	Bu/A	lb/bu	lbs/A
Corn	150	0.4	60
Soybean	50	0.7	35

Crop	Yield	K_2O required	K_2O required
	Bu/A	lb/bu	lbs/A
Corn	150	0.35	52.5
Soybean	50	1.1	55

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Nutrient removals from AGR-1, Table 5.