NEBRASKA SOYBEAN & CORN POCKET FIELD GUIDE

— 2019 EDITION —

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ACKNOWLEDGEMENTS:

Funding support for this Nebraska Soybean and Corn Pocket Field Guide was provided by the

Nebraska Soybean Board:

http://nebraskasoybeans.org/.

The mission of the Nebraska Soybean Board (NSB) is to invest checkoff funds towards innovative research and soybean productivity, enhancing consumer and industry education, and creating demand for soybean products. The nine volunteer farmer-leaders who serve on the NSB board of directors invest your checkoff dollars in research to improve soybean production practices to make your farm more profitable and ensure the sustainability of Nebraska soybean production.

United Soybean Board:

http://unitedsoybean.org/.

The 73 farmer-leaders of the United Soybean Board (USB) oversee the investments of the national soy checkoff to maximize profit opportunities for all U.S. soybean farmers by investing and leveraging soybean checkoff resources. Please visit the USB website (above) for more information on how the soy checkoff benefits you and other soybean farmers throughout the U.S.

Nebraska Corn Board:

http://www.nebraskacorn.org/.

Enhancing Demand — Adding Value — Ensuring Sustainability

The Nebraska Corn Board is funded by Nebraska corn farmers through the ½-cent-per-bushel corn checkoff and is managed by a nine-farmer member board of directors. The Nebraska Corn Board works to promote the value of corn by creating opportunities.

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PREFACE:

This guide was designed to provide Nebraska soybean and corn producers with key crop management information (photos, tables, charts, etc.) in an easy-to-carry, pocket-sized format. Thus, the guide can be hand-carried when scouting crop fields, and then used when the producer observes some specific insect or weed, or observes plants exhibiting symptoms of disease, nutrient deficiency, or herbicide injury, and wants to make an initial identification/diagnosis by comparison with photos. Of course, the producer is advised to confirm any initial diagnosis by contacting an Extension Specialist at their local county extension office (see guide page 374), and/or by submitting a plant tissue sample or specimen to the **UNL Plant & Pest Diagnostic Clinic** (see next page).

Comprehensive crop management information cannot be provided in a small pocket guide. For more detailed information, the reader is advised to go to the References and Sources cited at the end of each topic. For reader convenience, Internet URLs are provided for most of these citations.

The first page in the soybean-specific **(guide pages 18-135)** and in the corn-specific **(guide pages 136-245)** management sections of this guide has a list of website URLs that the soy or corn producer can access to read articles/commentary authored by UNL research/ extension specialists about current management issues. Example: http://cropwatch.unl.edu/. Producers can subscribe at no cost to automatically receive the CropWatch eNewsletter emails on a weekly basis during the growing season.

PREFACE:

Nebraska Plant & Pest Diagnostic Clinic

Nebraska producers, as well as county, regional and state research/extension personnel, are provided diagnostic support by the Clinic. After submission of a plant tissue sample or an insect/weed specimen to the Clinic, the submitter will be provided with a report and recommendations from the Clinic.

For detailed Clinic instructions and tips on how to: (a) properly collect a sample, (b) package it before mailing or hand-delivering, (c) download, print, and complete a sample submission form, and (d) get information about the nominal fees applicable for diagnosis, contact the Clinic Coordinator at 402-472-2559 or visit: http://plantpathology.unl.edu/plant-pest-diagnostic-clinic.
For a NebGuide PDF on this topic, visit: http://extensionpublications.unl.edu/assets/pdf/g2226.pdf.
To deliver samples to the UNL office, see: http://cropwatch.unl.edu/plantdisease/unl-diagnostic-clinic-lincoln.

The below websites offer detailed management recommendations for producers after the discovery and confirmation of a disease/insect/nutrient deficiency in a corn or soybean field:

http://extensionpublications.unl.edu/assets/pdf/ec130.pdf.

http://cropwatch.unl.edu/insect/soybeanpestmgt.

http://cropwatch.unl.edu/plantdisease/soybean.

http://cropwatch.unl.edu/soybeans/weedmgt.

http://cropwatch.unl.edu/soybeans/soils.

http://cropwatch.unl.edu/corn/insectmgt.

http://cropwatch.unl.edu/plantdisease/corn.

http://cropwatch.unl.edu/corn/weedmgt.

http://cropwatch.unl.edu/corn/soilmgt.

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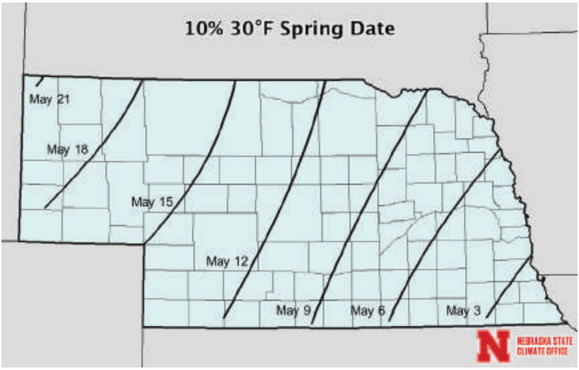
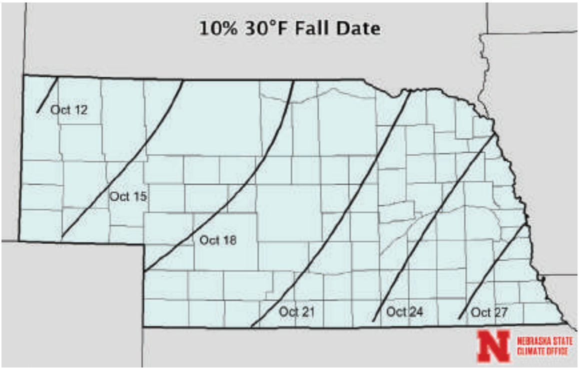
NEBRASKA'S CLIMATE – FREEZE DATES:

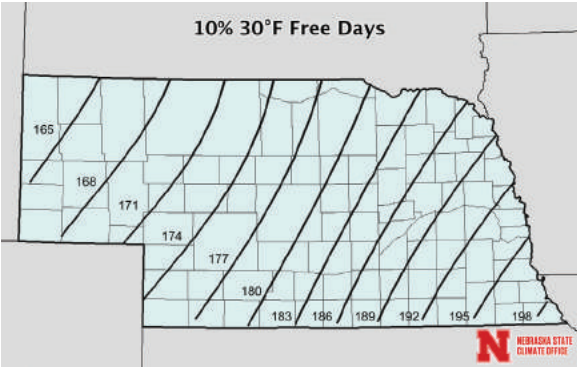
These Nebraska maps show three-day interval boundary line dates relative to a 10% probability of a later spring freeze or earlier fall freeze occurring after the given line date. Note that lines are general and do not reflect locally specific topography. A 30° F temperature was used in the maps because 32° F water can exist in either a liquid or solid (ice) state – a latent energy difference. Also, solutes in the plant cell cytoplasm serve as a mild antifreeze that can depress the freezing point of most plant tissues by 1-2° F.





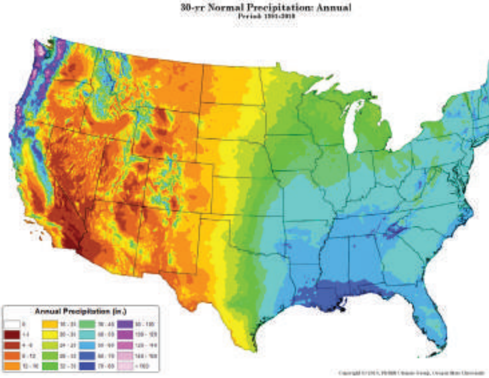
NEBRASKA'S CLIMATE – 30° F FREEZE-FREE DAYS:

Below map shows, with three-day interval boundary lines, the 10% probable number of 30° F freeze-free seasonal days.



NEBRASKA'S CLIMATE – ANNUAL PRECIPITATION:

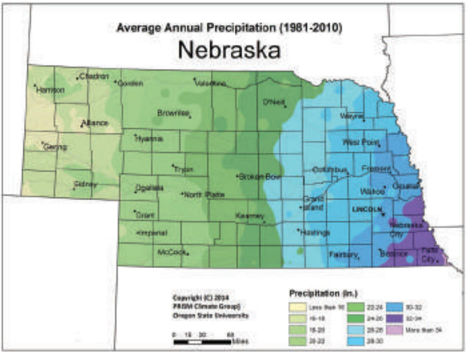
The U.S. east-to-west annual precipitation gradient map (15 zones) shows that Nebraska spans five of those zones.



Map Source: http://www.prism.oregonstate.edu/normals/.

NEBRASKA – ANNUAL PRECIPITATION BY REGION:

Annual precipitation ranges from more than 34 inches (southeastern Nebraska) to less than 16 inches (western Nebraska). The east-to-west gradient is shown below in terms of 11 colored zones (i.e., 2-inch increments). This gradient obviously impacts what crops can be grown on non-irrigated land (as does the freeze-free day gradient shown on the prior page for both rainfed and irrigated land).

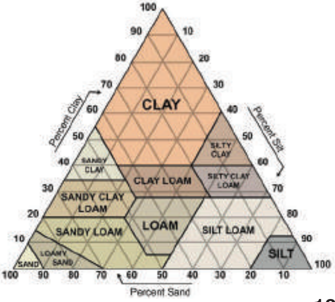


Map Source: http://www.prism.oregonstate.edu/normals/.

NEBRASKA'S SOILS:

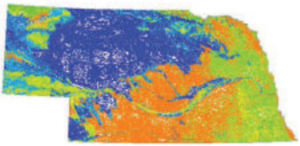
This soils triangle shows the 12 major soil types defined by their clay-silt-sand composition percentages. *Source:* https://www.wcc.nrcs.usda.gov/ftpref/wntsc/H&H/training/soilsOther/soil-USDA-textural-class.pdf. See Fig. 2 therein.

The Nebraska maps on the next page show the distribution of the 12 types across the state. Because of variance by soil depth, a map is provided for each of four soil depths (i.e., 0-4, 4-8, 8-20, and >20 inches).

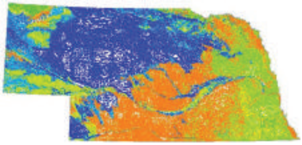


NEBRASKA'S SOIL TYPES (BY DEPTH):

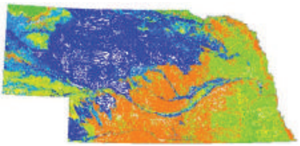
Below Nebraska maps show the 12 major soil types by soil depth.



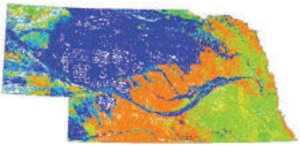
^ Soil depth of 0 to 10-cm (0 to 4-inches)



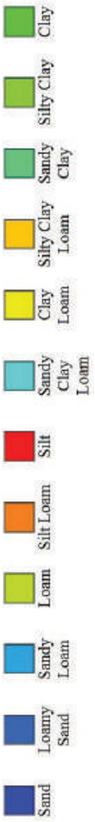
^ Soil depth of 10 to 20-cm (4 to 8-inches)



^ Soil depth of 20 to 50-cm (8 to 20-inches)



^ Soil depth of >50-cm (>20-inches)

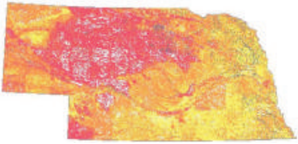


Source:

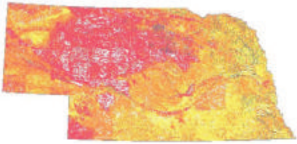
https://beaumont.tamu.edu/SoilData/SoilStateMap.aspx?index=2_14_0_30&name=NEBRASKA.

NEBRASKA MAP – SOIL ORGANIC MATTER:

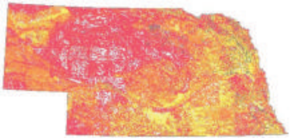
Soil organic matter is a key crop productivity factor. These maps show the range in % soil O.M. (by depth) across Nebraska.



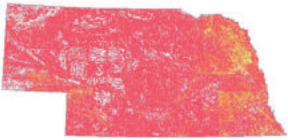
^ Soil depth of 0 to 10-cm (0 to 4-inches)



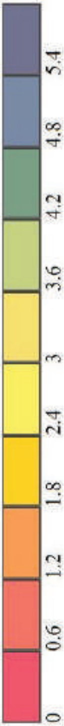
^ Soil depth of 10 to 20-cm (4 to 8-inches)



^ Soil depth of 20 to 50-cm (8 to 20-inches)



^ Soil depth of >50-cm (>20-inches)



Source: See website on prior page of guide.

For more information about soil organic matter and its value, see:

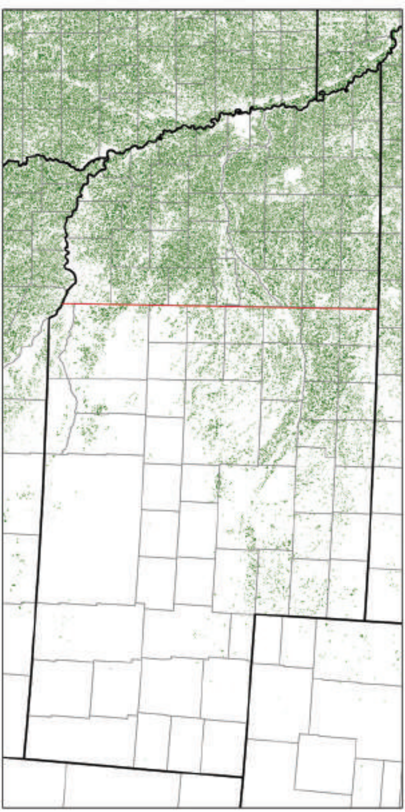
https://passel.unl.edu/pages/printinformationmodule.php?idinformationmodule=1130447040.

Also:

https://www.extension.umn.edu/agriculture/tillage/importance-of-soil-organic-matter/.

NE SOYBEAN PRODUCTION – CROP DENSITY MAP:

Nebraska soybean production density (i.e.,acres per unit of all land area), denoted as pixel density in the below map, is the greatest in counties east of meridian -98.27 (red line), but west of that line, soy crop density decreases due to the east-to-west decline in rainfall needed for profitable yield. See NE precipitation map on guide page 13, and NE soybean irrigated and rainfed acres by county on guide pages 21-22.

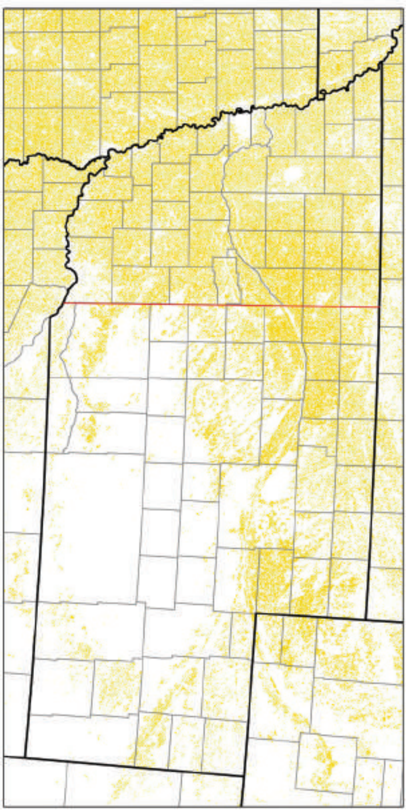


Source: https://nassgeodata.gmu.edu/CropScape/.

Mapping assistance provided to lead authors by J Rattalino Edreira (UNL).

NE CORN PRODUCTION – A CROP DENSITY MAP:

Nebraska corn production is more dense (more pixels) than soybean production (see prior page map) in counties east of meridian -98.27, and also west of that line in central Nebraska along and south of the Platte River, including the North Platte River valley in the panhandle. Nearly all of the western corn production is irrigated. See also the Nebraska County maps of corn irrigated and rainfed acreage on guide pages 139-140.



Source: https://nassgeodata.gmu.edu/CropScape/.

Mapping assistance provided to lead authors by J Rattalino Edreira (UNL).

SOYBEAN MANAGEMENT

In this section, photos, charts, tables, and contextual commentary are provided for a variety of soybean crop management issues. In order to be concise, only the most important management topics have been included. Additional web references have been included at the end of each topic for those who might be interested in obtaining more detailed information. For up-to-date information during the growing season, please visit the websites listed on the next page.

IN-SEASON SOYBEAN MANAGEMENT INFORMATION:

At http://cropwatch.unl.edu (or soybean page therein) http://cropwatch.unl.edu/soybeans, you can find a wealth of soybean-specific management information and links to other useful websites. By subscribing (free) to **CropWatch**, you will be emailed reports that are issued weekly during the growing season. These reports contain articles written by UNL (and other university) experts about current issues of producer concern. You can also search the **CropWatch archive** for past season articles that may be of interest to you.

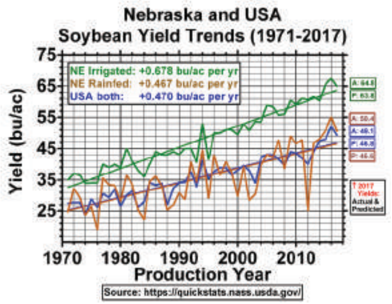
If you are interested in soybean research trials that were conducted on producer farms and targeted at specific crop management questions, you can view past/current results and conclusions at the Nebraska On-Farm Research Network: http://cropwatch.unl.edu/farmresearch.

Several UNL Institute of Agriculture and Natural Resources (IANR) experts operate blogs for reporting issues of local interest. A listing of Nebraska Extension blogs can be found at: http://extension.unl.edu/extension-blogs/. For example, Dr. Nathan Mueller and Jenny Rees, Nebraska Extension educators, have blogs. Both offer commentary and advice on many in-season crop production topics. Go to:

http://croptechcafe.org/ or: https://jenreesources.com/.

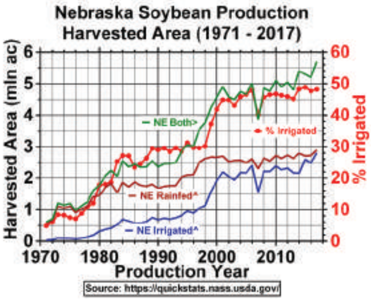
SOYBEAN IRRIGATED AND RAINFED ON-FARM YIELD TRENDS:

Since 1971, the state's irrigated on-farm soybean yields have risen at a **rate of 0.68 bu./acre per year**. The rainfed on-farm yield has also risen, but at a slower **rate of 0.47 bu./acre per year**. Note actual & predicted **2017** yields (boxes).



SOYBEAN IRRIGATED AND RAINFED ACREAGE TRENDS:

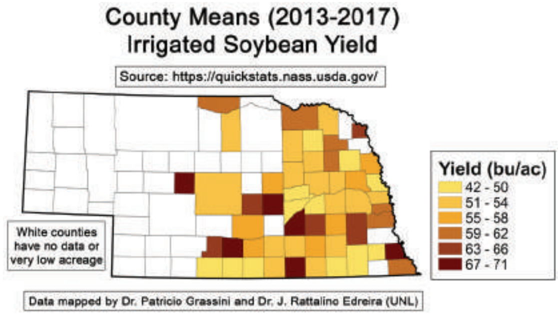
The state's irrigated and rainfed soybean acreages have increased since 1971, but total acreage plateaued in 2000. About 48% of all NE soybean acreage is now irrigated.



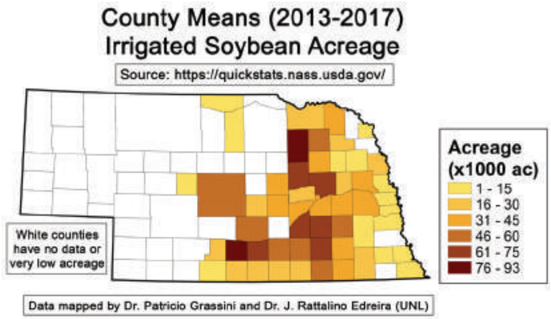
For a NE map of 2017 soybean production density, see guide page 16.

IRRIGATED SOYBEAN YIELDS AND ACREAGES BY COUNTY:

On a county-level basis, irrigated soybean yields tend to be the highest in Central Nebraska. Suitably scheduled irrigation can mitigate water stress, allowing capture of more of the available genetic and agronomic yield potential.

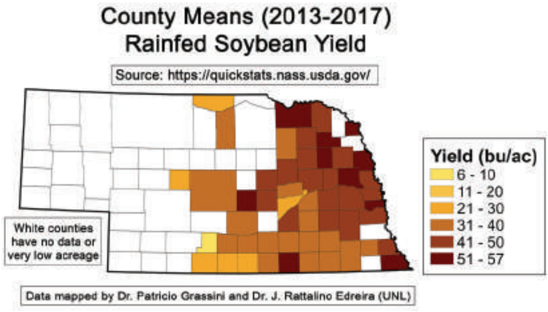


Most of the irrigated soybean acreage is located in the Central Nebraska counties. County acreage is confounded with county size, so for a map of county soybean acreage as a percent of total soybean + corn acreage, see guide page 23.

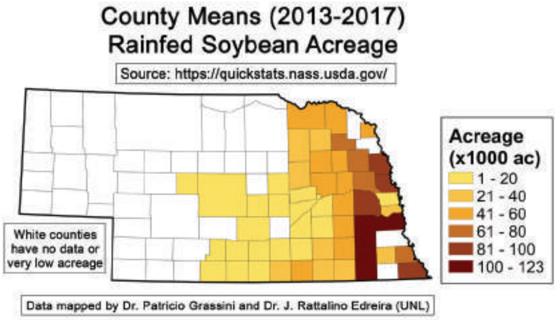


RAINFED SOYBEAN YIELDS AND ACREAGES BY COUNTY:

The east-to-west high-to-low gradient across the state in annual precipitation is clearly evident in the below east-to-west county yield map. However, the highest rainfed soybean yields are produced in the northeast quarter of Nebraska counties.



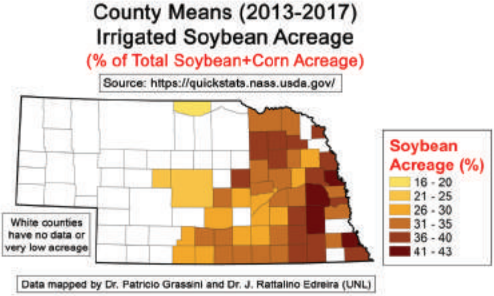
Nebraska rainfed soybean production acreage is limited to just the eastern half of the state, with the gradient from high acreage in eastern counties to low acreage in western counties reflecting the east-to-west precipitation decline pattern.



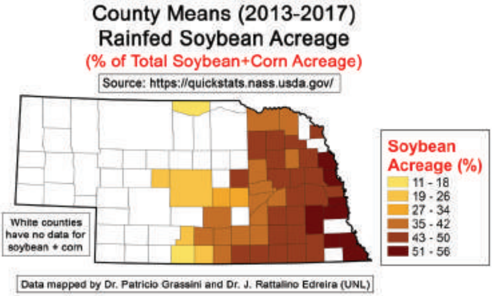
SOYBEAN ACREAGE (% OF SOYBEAN + CORN ACREAGE):

Nebraska producers commonly rotate soybeans with corn on a 2-year basis (50:50 split), or on a 3-year soybean-corn-corn basis (33:67 split). When soybean acreage is expressed as a percent of the total soybean + corn acreage, the soybean:corn percentage split by county is **mostly 33:67** in the below irrigated map, but mostly 50:50 in the below rainfed map – note the 9 eastern NE counties with >50% soybean : <50% corn acreage splits!

Irrigated Map:



Rainfed Map:

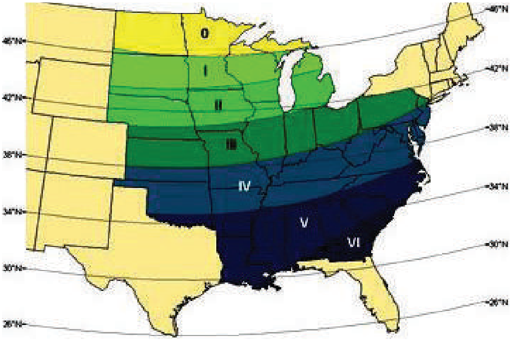


U.S. SOYBEAN MATURITY GROUP (MG) ZONES:

In the U.S., there are seven zones of latitudinal maturity adaptation (MGs 0 to VI). Varieties of MG 000 and 00 are adapted to southern Canada. Varieties of MG VII, VIII, IX, and X are adapted to Florida, Southern Texas, Mexico, and Latin America – all north of the equator in the Northern Hemisphere. In the Southern Hemisphere, the numbered MG zones are inverted below the equator, going from MG X in Brazil to MG 0 in Argentina.

Also note that MG 000 to IV varieties are almost always **indeterminate** (main stem tip node accrual does not cease until stage R5), whereas MGs V to X varieties are almost always **determinate** (stem tip node accrual ceases at R1).

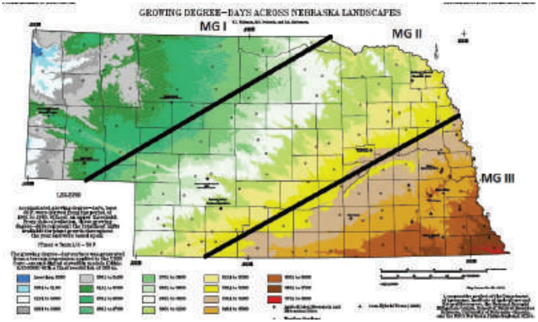
The extension of U.S. MG boundary lines westward (as shown below) is technically <u>inappropriate</u>, because of the gradually increasing altitude and shorter growing season from east-to-west in the High Plains states, where soybean acreage is increasing. See the next page for a <u>more appropriate</u> Nebraska MG boundary zone map.



Reference: Above map is from Zhang et al. (2007).

CHOOSING A VARIETY MG SUITABLE FOR YOUR NE FIELD:

The **MG boundary lines** drawn across the below Nebraska county map are reflective of the Nebraska east-to-west growing-degree-day gradient (the background in the map). **The lines are only suggestive,** and do NOT imply a strictly prescriptive “use this earlier MG on the north side of the line but use this later MG on the south side of the line.”

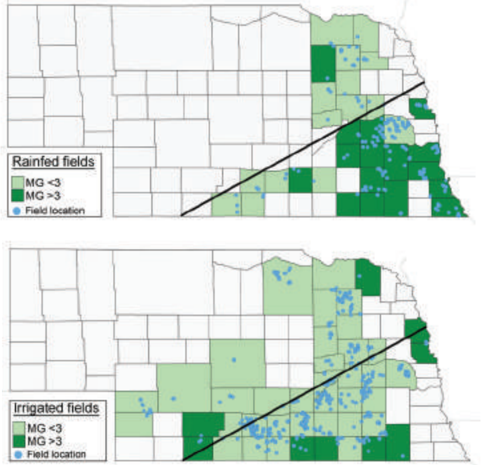


Each variety sold in Nebraska is assigned a 2-digit **Relative Maturity (RM)** number. The MG numbers of **I**, **II** and **III** (in above map) translate into RM numbers of **1**, **2** and **3**, but the **RM has a decimal point and number to provide more maturity specificity.** For example, a **2.5** RM variety can be expected to attain stage R8 maturity (when 95% of the pods are mature) later than a RM **2.0** (MG II) variety, but earlier than a RM **3.0** (MG III) variety.

Within a given Nebraska MG zone, a producer can opt to plant varieties with RMs of 2.0 to 2.9 in the MG II zone, <u>or</u> RMs of 3.0 to 3.9 in the MG III zone, <u>or</u> RMs of 2.5 to 3.5 on each side of the MG II-III boundary line. Depending on the planting date, producers can choose varieties of an RM that offer the greatest yield potential for a given field.

PRODUCER MG CHOICE – IRRIGATED *VS.* RAINFED FIELDS:

Water stress during the growing season *hastens* soybean maturity (i.e., maturity is sooner than expected). **Maturity can be hastened by as much as 0.6 to 0.9 days per inch of below-normal July-August rainfall.** Moreover, hastening **is 0.2 days more per deficit rainfall inch in earlier vs. later RM varieties**. *[Reference: Specht et al. (1986; 2001)]*. Producers in Northeast Nebraska, on average, plant **MG 2.6 in irrigated (IR) fields**, but **MG 2.8 in rainfed (RF) fields**, whereas in Southeast Nebraska, producers plant **MG 3.1 (IR) and MG 3.3 (RF).** *[Reference: Grassini et al. (2015)]*. Producer survey data (2013-2015; n=909 fields; 89% irrigated; 11% rainfed) in the below maps show the light green and green counties in which either <MG 3 or >MG 3 varieties predominate. Thus, Nebraska soybean producers apparently use earlier MG varieties in their irrigated fields than in their rainfed fields. See prior guide page 25 for reference.



Maps from Dr. J. Rattalino Edreira and Dr. P. Grassini

SEEDING RATE – ADJUSTING THE SOYBEAN PLANTER:

To determine if your planter is set to deliver a desired seed/acre rate, you will need to know the number of seeds dropped by each planter unit per foot of furrow length. For a reliable estimation, count the dropped seed number in several 10-ft. row sections, and then compute **an average seed count/foot value to use in the left column to translate that number into seeds planted per acre value.** Use the second formula below the table to get germination-adjusted seeding rate.

Seed count / foot	Row Width (inches)						
	38	36	30	20	15	10	7.5
	Seeds planted per Acre (thousand)						
1	13.8	14.5	17.4	26.1	34.8	52.3	69.7
2	27.5	29.0	34.8	52.3	69.7	104.5	139.4
3	41.3	43.6	52.3	78.4	104.5	156.8	209.1
4	55.0	58.1	69.7	104.5	139.4	209.1	278.8
5	68.8	72.6	87.1	130.7	174.2	261.4	
6	82.5	87.1	104.5	156.8	209.1		
7	96.3	101.6	122.0	183.0	243.9		
8	110.0	116.2	139.4	209.1	278.8		
9	123.8	130.7	156.8	235.2			
10	137.6	145.2	174.2	261.4			
11	151.3	159.7	191.7	287.5			
12	165.1	174.2	209.1				
13	178.8	188.8	226.5				
14	192.6	203.3	243.9				
15	206.3	217.8	261.4				

Formula – For converting dropped seeds/foot to seeds planted/acre:

Seeds/Acre = [43,560 ÷ (Row Width ÷ 12)] x Seeds/Foot
Example: Average of 7 seeds/foot in 30-inch wide rows:

43,560 ÷ (30 ÷ 12)] x 7 = 121,968 Seeds/Acre.

Formula - Set planter to drop an X number of *viable (live)* seeds/acre based on the Y-percent germination listed on the seed tag:

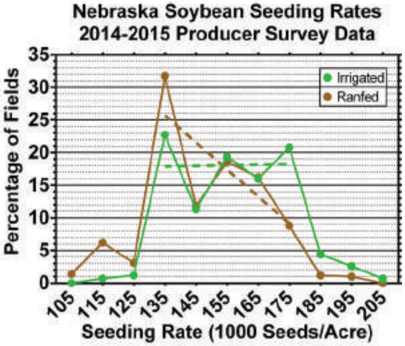
$$\textbf{Viable Seeds/Foot} = \frac{(X \div 43{,}560) \times (\textit{Row Width} \div 12)}{(Y \div 100)}$$

Example: 122,000 *viable* seeds/acre, 30-inch rows, 91% germ

$$\frac{(122{,}000 \div 43{,}560) \times (30 \div 12)}{(91\% \div 100)} = \textbf{7.69 seeds to drop per foot of row in 30" rows}$$

SEEDING RATES – NEBRASKA PRODUCERS SURVEY DATA:

Just over 900 Nebraska soybean producers were recently surveyed to determine what seeding rates they used in their irrigated and rainfed fields. See the below chart.



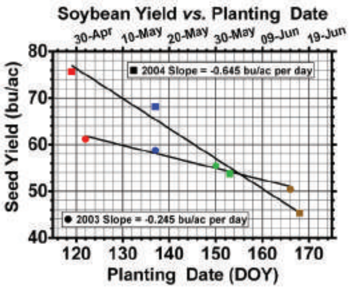
Data Source: Dr. P. Grassini & Dr. J. Rattalino Edreira

Only 5-10% of Nebraska producers use less than 135,000 or more than 175,000 seeding rates in their fields. Within the five 135,000 to 175,000 rate categories, irrigated fields (green) were (roughly) split equally (about 18% each – dashed line) among the five rates. In rainfed fields (brown), the 135,000 rate (32%) was used 3.6x more often than the 175,000 rate (9% - dashed line).

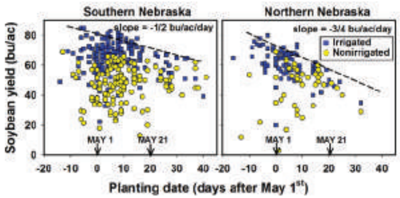
Positive yield responses to seeding rate in field trials have been reported, but most were not statistically significant, or were not sufficient to recover the seed cost. For more information on this topic, see guide pages 33 and 36-37.
http://cropwatch.unl.edu/2016/soybean-seeding-rate-tips.
http://crops.extension.iastate.edu/files/article/OptimumPlantPop_000.pdf.

PLANTING DATE – IMPACT ON SOYBEAN YIELD:

Nebraska experimental data indicate that **soybean yield declines (on average) by one-quarter (0.25) to five-eighths (0.625) bu./acre for each day planting is delayed after May 1**. Note that a **10-day delay** resulted in a total opportunity cost penalty of either **10** x 0.25 = **2.5 bu./acre**, or **10** x 0.625 = **6.25 bu./acre**.



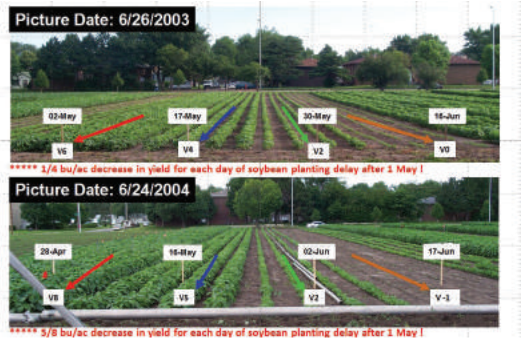
Reference: Bastidas et al. (2008)
http://extensionpublications.unl.edu/assets/pdf/ec145.pdf.
The yield penalty for planting soybeans after May 1 can vary from year to year and field to field, but that penalty is (on average) persistently probable in Nebraska irrigated and rainfed soybean fields, as shown below where the dashed lines reveal a **1/2 or 3/4 bu./acre yield loss per day of planting delay after May 1** in Southern *vs.* Northern Nebraska fields.

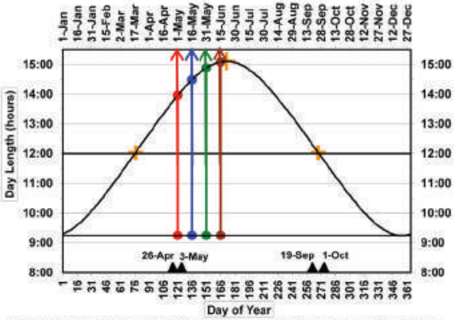


Reference: Grassini et al. (2016)
http://extensionpublications.unl.edu/assets/pdf/ec3000.pdf.

PLANTING DATE – IMPACT ON SOYBEAN CANOPY CLOSURE:

A soybean crop **will yield more when planted early** because it can capture more solar radiation by starting earlier in the spring (the four colored chart lines match the four colored lines in the planting date photos), and it can close its canopy prior to the critical R3 (begin pod) stage. Plant early to get your soybean field **"green to the eye by the 4th of July!"**





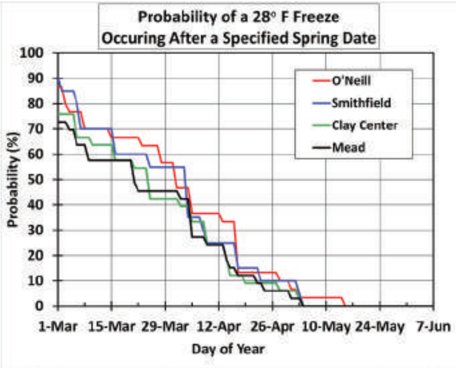
The triangle dates represent 20% & 10% probabilities of < 32 F occurring after the spring dates or before the fall dates. Orange symbols denote the June summer solstice (15-hr day) and spring Mar & fall Sep equinox (12-hr day/night).

See:

http://extensionpublications.unl.edu/assets/pdf/ec145.pdf.
http://cropwatch.unl.edu/data-show-nebraskans-planting-soybeans-earlier-each-year.
https://extension.agron.iastate.edu/soybean-planting-date-can-have-significant-impact-yield.
https://www.cornandsoybeandigest.com/soybeans/soybean-flowering-fallacy.

EARLY PLANTING REWARD *VERSUS* SPRING FREEZE RISK:

Soybean seedlings can be killed by a late spring freeze, *but only after they have emerged.* Late April-planted soybeans can take up to 10 to 14 days to emerge. **Keep this in mind to balance an early-planting high yield reward *vs.* the risk of a killing-freeze replant penalty.** In the below chart, the chance of a freeze occurring after planting on April 26 is about 5-15% at these North, West-South-Central, East-South-Central, and East Nebraska sites. Note that if an April 26 planting was used at each site, the seedlings would likely not emerge until May 6 to 10, for which the last spring freeze probability for these now emerged seedlings would be nearly zero!



Source:
http://cropwatch.unl.edu/2016/early-bird-gets-worm-benefits-early-soybean-planting.

Note: For spring freeze dates corresponding to 90%, 50%, or 10% probabilities at a Nebraska weather station site closer to your farm field than the four sites in the chart, see:
https://www.ncdc.noaa.gov/climatenormals/clim20supp1/states/NE.pdf.

EARLY SPRING PLANTING – CHILLING INJURY CONSIDERATIONS:

Germinating seedlings are intolerant of soil temperatures of <50° F during the first 36-48 hours of "imbibitional" water uptake. This phase of rapid water uptake rehydrates quiescent cells and membranes, but cold soil temps disrupt this process, leading to "chilling injury" (i.e., germination failure and seedling death). **After the imbibitional water uptake ends, the risk of chilling injury also ends.** Seedlings in the "osmotic" phase of water uptake are quite tolerant of soil temps as low as <35-40° F, though germination will, of course, be slower than germination at 50° F or warmer. To avoid the risk of chilling injury, soil temps below the soil surface should be checked each morning with a sturdy thermometer in each field you want to plant in late April or early May. If the field soil temp is below 50° F on a given day, hold off planting and recheck the next day.

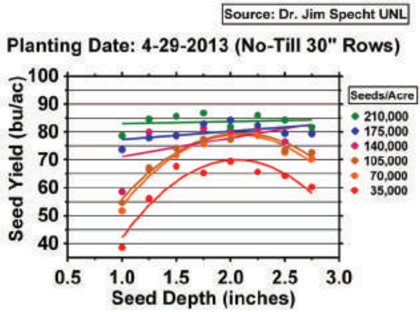
Whenever the soil temp is 50° F (or greater) after April 26, *and you do not expect that soil temp to drop below 50° F during the next 48 hours,* then PLANT to capture the yield potential available with early planting! Note: Over a 48-hr period, a wet soil temp does not change as fast as the air temp does. ***By fine-tuning your soybean planting date management, you can capture the yield reward available with early planting in a way that can completely mitigate to near-zero the risk of chilling injury.***

See:
http://cropwatch.unl.edu/chilling-injury-corn-and-soybeans-0.
http://cropwatch.unl.edu/tracking-air-and-soil-temperatures-soybeans-planted-april-29-unl-cropwatch-may-2013.

SOYBEAN SEEDING RATE AND DEPTH – IMPACT ON YIELD:

Relative to final seed yield in early-planted no-till, irrigated fields, a recent UNL study indicated that the **optimum seed depth was 1.5 to 1.75 inches.** At shallower depths, pieces of soil surface residue were frequently introduced into the seed furrow, which precluded full closure of the furrow by the press wheels, thus resulting in poorer germination and emergence. Seeding depth impacted yield only at seeding rates of <140,000 seeds/acre. Your no-till planter should be equipped to keep residue from falling into furrows.

Six seeding rates were also evaluated in this UNL study. **For the optimum no-till seeding depths of 1.50 to 1.75 inches, a 210,000 seeds/acre rate resulted in the highest yield,** but a **70,000 seeds/acre** rate did not lead to significantly lower yields. The recommended goal is to have **100,000 plants/acre at maturity,** but to attain that goal, producers will need to use a higher seeding rate (e.g., 125,000 seeds/acre) to serve as a buffer against unexpected post-sowing germination, emergence, and seasonal plant loss.

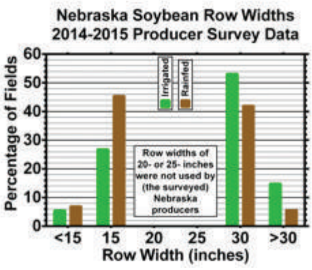


Go to:
http://cropwatch.unl.edu/soybean-planting-depth-consider-planting-deeper.
http://cropwatch.unl.edu/2016/soybean-seeding-rate-tips.

SOYBEAN ROW SPACING – IMPACT ON YIELD:

Canopy closure must be attained by at least the R3 stage (begin pod) to optimize yield. This is doable in 30-inch rows if planting occurs prior to May 5. **Narrowing the row width to 15 inches results in a 10- to 15-day earlier canopy closure, thereby *lessening the yield penalty arising from delayed planting impact on canopy closure in wider rows*** (see guide page 30), thus yields rise with narrower rows: https://crops.extension.iastate.edu/files/article/OptimumPlantPop_000.pdf.

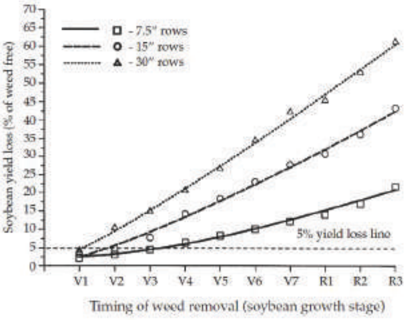
Narrow rows (NR) can also offer faster shade suppression of weeds (see next page). However, **(1) Pre-R1 canopy closure can amplify the risk of white mold** due to cooler, moister conditions in NR canopies. The more equidistant-spaced plant stems and leaves impede air movement. White mold risk is even greater in irrigated NR fields, if irrigation must be commenced during the R1-R2 flowering stage. **(2) Reproductive stage fungicide and/or insecticide application results in sprayer wheel track plant damage in NRs.** A 1.5% to 3.5% yield loss may be incurred, depending on sprayer boom width. **(3) Reducing row width to <15 inches will require a drill planter** that (1) cannot be used to plant corn, and (2) may not be easy to use in high-residue no-till corn fields. Note that <7% of Nebraska's soybean acreage is drill planted.



Data source: Dr. P. Grassini and Dr. J. Rattalino Edreira

EARLY-SEASON WEED INFESTATION – IMPACT ON YIELD:

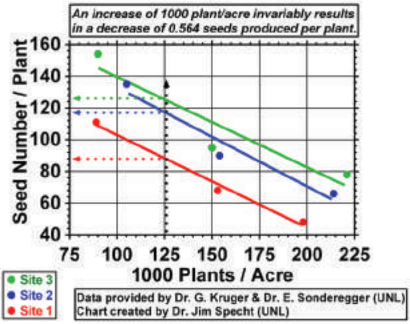
Weeds compete with crops for sunlight, water and mineral nutrients. If weed suppression or removal is not timely, the yield loss arising from competing weeds will rise with each incremental advance of soybean leaf stage from Vn to Vn+1 (see below chart). For perspective, there is a 3.7-day interval between Vn stages *[Reference: Bastidas et al. (2008)]*. Note that the cumulative yield loss is smaller as the row width is narrowed, because more equidistant soybean plants and leaves will result in earlier shade suppression of weed seed germination and weed seedling growth.



Source: Knezevic et al. EC130 (2017)
http://extensionpublications.unl.edu/assets/pdf/ec130.pdf.

SOYBEAN PLANT DENSITY – IMPACT ON SEEDS/PLANT:

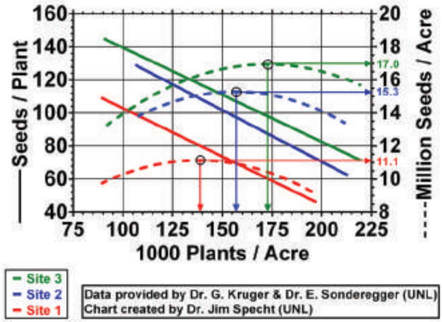
The **two major soybean yield components** are ***seeds/acre*** (= seeds/plant x plants/acre), and ***seed/pound*** (average seed weight). In a recent UNL study, the average number of seeds produced by each mature plant was measured in plant densities of 100,000, 150,000, and 200,000 at each of three field sites. The charted data indicated that ***for each <u>incremental increase of 1000 plants/acre</u> there was an <u>incremental decrease of 0.56 seeds/plant</u>.*** The three *trend line slopes* were not significantly different (i.e., were parallel), so this **560**



seeds/1000 plants number may be a useable rule-of-thumb value. However, the three parallel trend line slopes were located at significantly different "elevations" in the chart. If you draw a vertical line <u>upward</u> from say, 125,000 plants/acre value, that line <u>intersects</u> the site 3, 2, and 1 trend lines at values of **125**, **117**, and **88** seeds/plant, revealing sites **3** and **2** to be *intrinsically more "productive"* than site **1**. The "elevational productivity position" of *<u>your</u>* field's **0.56 seeds/plant** trend line in this chart will depend on <u>how much of the genetic and agronomic yield potential you can create and then capture</u> *by a rational fine-tuning of the best cost-effective management tools <u>you</u> can use in <u>your</u> field.*

SOYBEAN PLANT DENSITY – IMPACT ON SEEDS/ACRE:

The number of seeds/acre produced at each site changed as the plant density changed. Note the curvature in the seeds/acre response (dashed lines in chart), and response peaks of **17.0**, **15.3**, and **11.1** million seeds per acre at sites **3**, **2**, and **1** (ordered by productivity). **This finding (inferentially) suggests that increasing the seeds/acre yield component in productive fields may require higher plant densities.** This finding is interesting in view of the fact that Nebraska producers use seeding rates in the range of 135,000 to 185,000 per acre (see guide page 28), even though Nebraska on-farm trials



do not show statistically significant yield response to high seeding rates, which in turn has suggested that such rates are not economic. *See:* https://cropwatch.unl.edu/drop-soybean-seeding-rate-and-save-10-18-acre. *Also see:* https://cropwatch.unl.edu/2016/soybean-seeding-rate-tips. At low-plant densities, more branches and pods will be present at the lower stem nodes, necessitating a lower combine cutter height to mitigate pods left on the stem and branch stubble (see guide page 78 about harvest losses). The lowering of the cutter bar height will be restricted if the field ground surface is uneven, undulated or has rocks.

SOYBEAN REPLANT DECISIONS – FACTORS TO CONSIDER:

On occasion, a soybean plant population may be reduced by a weather-related event. In such cases, the soybean producer may need to evaluate the pros and cons of replanting. Two questions are relevant:

(1) **What percentage of the original yield potential (before the stand reduction event) can still be captured if the field is not replanted?** First, estimate the number of surviving plants/acre (you can use the table on guide page 27 or on guide page 65). Then use the table below to estimate the yield loss likely to result from a less than ideal (now-reduced) plant density.

Live Plants ------- 1000/ acre	Seeding Depth (inches)						
	1.0	1.25	1.5	1.75	2.0	2.25	2.5
	Percentage of Yield Potential still available when plant populations are reduced – The % values are based on yield estimates derived from non-linear regression trend lines in the chart on page 16.						
210	98	98	99	99	99	99	
175	91	92	93	94	95	96	97
140	84	86	88	90	92	94	96
105	66	77	86	91	94	93	90
70	63	76	85	91	93	93	89
35	50	63	73	80	83	82	77

(2) **If your field were to be replanted now (at a less than ideal planting date), what percentage of the original yield potential is then available?** Depending on the year and location, the yield penalty per day of planting delay can range from **0.25 - 0.75 bushels/acre per day** (see charts on guide page 29). After making your choice of a bushels/acre per day yield loss penalty, multiply that value by the number of days between the field's original planting date and the planting date that would apply if you were to replant this field.

See next page for a Yes or No replant decision worksheet.

SOYBEAN REPLANT DECISION CALCULATION WORKSHEET:

1. Using the field's original planting date, record here your best estimate of expected yield for *this* field in a "normal year":_______ **bu./acre**
2. Estimate the current *likely-to-survive* number of plants/acre to then estimate the percentage of yield loss that arises from a less than ideal plant stand (see table on previous page):_______ **%**
3. Calculate a yield now more likely after the loss of plants [(line 1 x line 2)/100)]:_______ **bu./acre**
4. Calculate a now more likely gross income/acre (line 3 x market price):_______ **$/acre**
5. Estimate extra weed control cost needed for this less than ideal plant stand:_______ **$/acre**
6. **Calculate a gross return per acre for a NO REPLANT Decision** (line 4 - line 5):_______ **$/acre**

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7. Estimate the percentage reduction in yield that is likely by replanting the field on a less than ideal date (see previous page table):_______ **%**
8. Calculate the yield that would be likely for a late replanting [(line 1 x line 7)/100)]:_______ **bu./acre**
9. Calculate the likely gross income/acre from replanting (line 8 x market price) _______ **$/acre**
10. Estimate the additional costs of replanting (seed, chemicals, fuel, labor, etc.):_______ **$/acre**
11. **Calculate a gross return per acre for a YES REPLANT Decision** (line 9 - line 10):_______ **$/acre**

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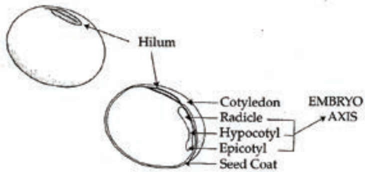
12. ***Compare the gross return per acre values*** *computed in* ***items 6 and 11*** *to compare the financial impacts of a* ***NO or YES REPLANT DECISION****.*

SOYBEAN SEED STRUCTURE:

The key components of the soybean seed are highlighted in the drawing below. After maturing on the parent plant, the soybean seed becomes quiescent and freeze-hardy until planted into moist soil. Handle the seeds carefully after harvest to avoid cracking the seed coat or splitting the seed in half.



The seed coat is actually female parent tissue. The two large **cotyledons** that comprise most of the seed are attached to opposite sides of the embryonic axis at the top of the **hypocotyl** at a node which is **designated as zero (0)**. Look closely at a soybean seed and you will see the hypocotyl outlined just under the (near-transparent) seed coat.

The **radicle**, which becomes the seedling/plant tap root, is located at the bottom of the hypocotyl.

Located above the cotyledons, on the embryonic axis, is the **epicotyl**, to which are attached two tiny **unifoliolate** leaflets on opposite sides **of node one (1)**. The epicotyl apex has, at its tip, **node two (2)**, at which there is a tiny primordial 1st **trifoliolate** that was formed late in seed development. Thus, **the dormant seed embryo already possesses three nodes – 0, 1, and 2,** each of which will become visible nodes on the seedling stem at emergence. Low soil temperatures during germination, often encountered in early planted, heavy residue, no-till fields, will shorten the internode length between each of these three beginning main stem nodes.

SOYBEAN GERMINATION:

Soybean seeds require 50 percent more water uptake than corn seeds do to germinate and are thus more vulnerable to germination failure, particularly if the soil at the furrow bottom is moist enough to germinate, but is not moist enough to complete germination (seedling death occurs).

The seed swells during the first 36 to 48 hours of imbibitional water uptake. The radicle grows quickly, bursts through the seed coat and, after sensing gravity, points its root tip downward, and begins extending through the soil.

Coincidently, the hypocotyl forms a "crook" and extends upward, pulling the cotyledons to the soil surface. The seed coat slips off the cotyledons during this process. The hypocotyl stops growing after pulling the cotyledons from the sowing depth (yellow line in next page photo) to the soil surface. **NOTE: The seedling tap root will not penetrate a sub-surface dry soil layer if such a layer exists at planting time.** Depending on spring rainfall event timing and rainfall amounts, a spring cover crop not killed in a timely manner could result in dry soil layers just below what might appear to be a moist soil surface zone. Thus you should always **check the one-foot soil zone moisture below a cover crop that is killed only a few days BEFORE soybean planting!**

SOYBEAN ROOT DEVELOPMENT DURING GERMINATION:

The downward extension of the radicle that begins after the first 48 hours of germination will have positioned, just before emergence, the radicle root tip to a depth of about 4 inches below the 1.75-inch sowing depth (depicted by 2nd yellow line in the photo, which is about 6 inches below the soil surface). **Lateral roots will begin to emerge from the tap root, but only about 3 to 4 inches behind its tip.** As the tap root tip heads relentlessly downward at about 0.5 inches per day, new lateral roots will continuously emerge in that roughly 3- to 4-inch zone just behind the tap root tip. *[Reference: Torrion et al. (2012)]*. See guide page 62 for more details on soybean root development.

STAGES OF SOYBEAN VEGETATIVE DEVELOPMENT:

When you are scouting soybean fields, **the ability to identify Vn or Rn stages is a critical skill you want to learn, practice and utilize,** particularly in view of the fact that **many crop management practices are effective ONLY if applied at some prescribed Vn or Rn stage**. Examples: post-planting herbicide applications, canopy applications of fungicide or pesticide, stage R3 irrigation scheduling, and the best Vn or Rn stages to begin scouting to ensure early detection of soybean insects and diseases.

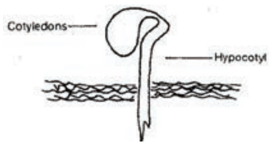
The Fehr and Caviness soybean vegetative and reproductive staging system is universally used by university research faculty, extension educators, and crop consultants. On the following pages you will find photos of the key stages. **The Vn stage characteristics are summarized in the below table. NOTE that the 1st trifoliolate appears at stage V2, NOT V1!** Soybean vegetative development is continuous, but a Vn stage is "called" when a leaf at **node n** is "fully expanded," a "status" attained when leaflets at **node n+1** have just **unrolled** so that their leaflet edges no longer touch. **Note: The Vn stages in a specific soybean field can be forecast using the UNL SoyWater website (see guide page 90).**

V-Stage	Stem Node	Stage Description
VE	--	Emergence
V0	0	Cotyledons (fully expanded)
V1	1	Unifoliolate (fully expanded)
V2	2	1st Trifoliolate (f. expanded)
V3	3	2nd Trifoliolate (f. expanded)
V4	4	3rd Trifoliolate (f. expanded)
V5	5	4th Trifoliolate (f. expanded)
V6	6	5th Trifoliolate (f. expanded)
Vn	n	nth Trifoliolate (f. expanded)

Source: Fehr and Caviness (1977)

EMERGENCE (VE) STAGE:

The seedling hypocotyl has pulled its main stem node **zero (0)** pair of cotyledons free of the soil surface.

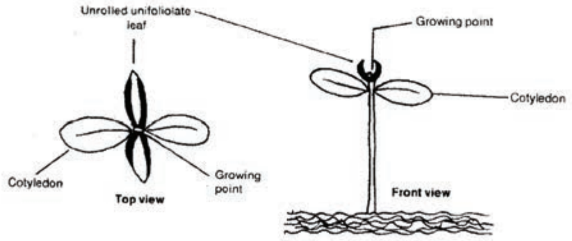


A seedling broken below the cotyledon node always dies. *The cotyledons provide the developing seedling with the carbon and nitrogen it needs to grow before the seedling (1) generates a sufficient number of leaves to support photosynthetic capture of carbon dioxide, and (2) generates a root system sufficiently capable of acquiring from the soil the nitrate (nitrogen) it needs.*

The loss at emergence of both cotyledons, but not the seedling's epicotyl, *due to soil crusting (above right photo), or hail damage, will severely delay vegetative development and reduce yield by 5-10%. If one undamaged cotyledon remains, the delay and yield loss is usually minimal. A replant decision (see guide page 38) will require estimation of the number of likely surviving seedlings, so be sure to get* ***three*** *separate counts of (living) seedlings that have* ***2***, ***1*** *or* ***0*** *cotyledons still attached for making a sound replant decision.*

VC (V0) – FULLY EXPANDED COTYLEDON STAGE:

Located above the **node 0** cotyledons are two young unifoliolate leaflets developing at **node 1**. When those two unifoliolate leaflets have just unfolded and no longer touch each other, the cotyledons at node 0 have attained a fully expanded state. **Note that VC and V0 are equivalent terms for the stage depicted in the below drawing.**



There is a **90° offset** between the **unifoliolates** on each side of **node 1** and the **cotyledons** on each side of **node 0. In the below photos, the unifoliolate leaflets have gone from a VE folded state (left) to a V0/VC unfolded state (right).**

All plant leaves are capable of "sensing" the night length in a 24-hour day. **The unifoliolate leaflets are the first plant leaves available to do that.** A night-length-sensing mechanism is part of a "biological clock" that enables flowering to commence at a seasonally appropriate time *[Reference: Wilkerson et al. (1989)]*.

To learn more about floral induction during stage V0-V1, see: https://www.cornandsoybeandigest.com/soybeans/soybean-flowering-fallacy.

MAIN STEM TIP LOSS – IMPACT ON PLANT V-STAGING:

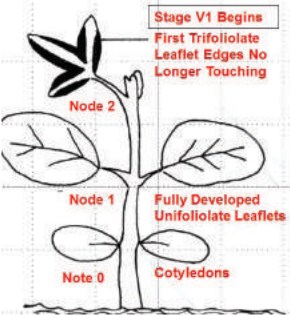
When you are examining soybean plants to determine their current Vn stage, be aware that the main stem tip may have been lost prior to your examination. **Rabbits and deer** visiting your field can nibble down developing stems to the base at cotyledonary node. **This pruning results in the loss of (main stem) apical dominance.** If the seedling still has healthy cotyledons, branches will quickly emerge from lateral vegetative meristems at each cotyledonary axil, as shown in the left photo.

These two branches quickly become vertically oriented and serve as twin stem-like replacements – see right photo. In most cases, one of the two stem-like branches eventually predominates by out-competing the other one for carbon and nitrogen in the cotyledon, leading to that branch becoming the sole apically dominant replacement stem.

When you examine a later stage plant and find its two cotyledonary node axil scars, but cannot find the two unifoliolate node axil scars, it is likely that the examined plant lost its original stem just above cotyledon node. Stem tip loss just above the unifoliolate node will also lead to two stem-like branches developing at those two axils. For even higher main stem tip loss, just one branch generally forms at axils located at **node 2** and higher. See guide pages 76-77 for additional information about soybean branches.

V1 – FULLY EXPANDED UNIFOLIOLATE STAGE:

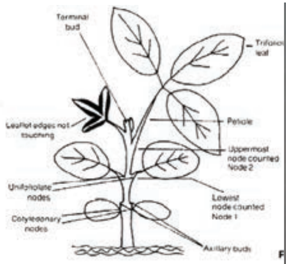
Located above the unifoliolate leaflet pair at main stem **node 1** is a young 1st trifoliolate leaf developing at main stem **node 2**. When the edges of the three leaflets are no longer touching each other (as some are in the below photo), the unifoliolate leaflets at **node 1** are considered to be fully expanded. **Such seedlings have just attained the critical stage of V1.**



If the hours of night length sensed by the unifoliolate leaves from **VO-V1** are of a "critical" duration (which depends on varietal MG), then the "sensing" leaf transmits a photo-inductive signal to the rest of the plant. That signal results in the conversion of all primordial vegetative meristems (not yet committed to become branches) to become what are called inflorescence meristems (IM). The single floral meristems that form on the flanks of the IM go on to produce observable flowers in a process known as floral evocation *[References: Benlloch et al. (2015); Weller and Ortega, (2015)]*. **When varieties of MG 3.0 to 3.9 are grown at Nebraska latitudes, the first observable soybean flower (R1) can be expected around 28-32 days after stage V1 (shown in the above right photo)** - see guide page 64 *[Reference: Bastidas et al. (2008)].* **The number of V1 to R1 days will be fewer for variety MGs > 2.9, but greater for variety MGs > 4.0.** For floral induction details, see: https://www.cornandsoybeandigest.com/soybeans/soybean-flowering-fallacy.

V2 – FULLY EXPANDED FIRST TRIFOLIOLATE STAGE:

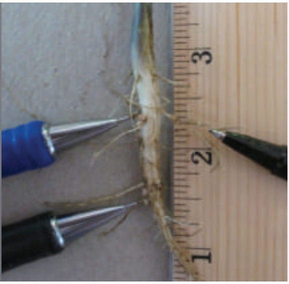
Located above the 1st trifoliolate leaf at main stem **node 2** is a young 2nd trifoliolate leaf developing at main stem **node 3**. When the leaflet edges of this 2nd trifoliolate leaf are no longer touching each other, the 1st trifoliolate leaf at main stem **node 2** is considered to have fully expanded leaflets and the seedling is now at **V2**.



By **V2**, soybean seedlings will have used most of the cotyledonary nitrogen reserves and must soon acquire nitrate from the soil in order to continue synthesizing plant proteins – notably Rubisco – the CO_2 carboxylation enzyme in the leaf chloroplasts. However, heavy spring rainfall may have leached the surface soil zone nitrate to a zone deeper than the secondary root hair zone located 3 to 4 inches above the tap root tip. Heavy residue in no-till corn fields may have immobilized surface zone soil nitrate. Water-saturated soil conditions early in the spring may result in soil microbes breaking down the residue to use NO_3 if O_2 is unavailable. Note that soybean root nodules capable of nitrogen fixation (N-fixation) do not become fully functional until stage **V3**. **Thus, in the foregoing scenarios, soybean seedlings may display yellow leaf nitrogen deficiency symptoms prior to the start of N-fixation.** If this occurs frequently in a particular field, consider using a starter nitrogen fertilizer at planting.

V3 – FULLY EXPANDED SECOND TRIFOLIOLATE STAGE:

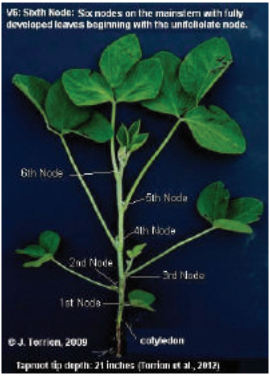
Located above the 2nd trifoliolate leaf at main stem **node 3** is a young 3rd trifoliolate leaf developing at main stem **node 4**. When the leaflet edges of this 3rd trifoliolate leaf are no longer touching each other, **the 2nd trifoliolate leaf at main stem node 3 is considered to have fully expanded leaflets**. A **V2** plant drawing (see prior page) and **V3** plant drawing (not presented below) would be nearly the same, except that **at V3 the plant would have two fully expanded trifoliolates** (see below left photo).



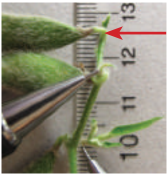
Small root nodules will be evident at V3 (see above right photo). However, nodule initiation/formation may be suppressed or delayed by high soil nitrate in the soil zone where nodulation ordinarily occurs. **The first nodules will typically begin to provide nitrogen to the plant about four weeks after infection of the root hairs by rhizobia bacteria.** New nodules form on a continuous basis, replacing old nodules that degenerate about 60 days after infection.

HOW TO STAGE SOYBEAN VEGETATIVE DEVELOPMENT:

To determine the Vn stage when scouting fields, pull up 5 to 10 “representative” plants. Cotyledons and unifoliolates may be gone, so use your fingers to locate the 90° offset “cot” node (node 0) and “uni” node (node 1) at the stem base, where two opposing scars will be found on each side of the stem. Then rotate the stem 90° to look for the 1st “tri” node (node 2). It will have a single scar, as will higher “tri” nodes that you will observe with a 180° alternating offset rotation. Count the main stem nodes up to the highest node that has a “fully expanded” leaf (as defined on guide page 43 and 50).

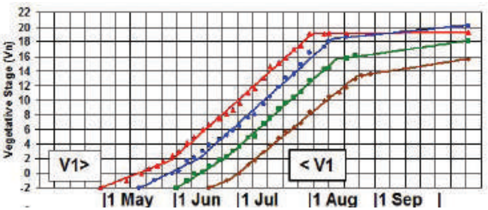


<u>< Left photo:</u> *V6 plant – note the unrolled leaflets at stem node 7. A branch is present at nodes 2 and 3.* ***<u>Right photo: ></u>*** *The bottom 5 nodes of a V21 R5.5 plant are node-number ink labeled from the bottom, starting with the pair of cotyledons at node 0, pair of unifoliolates at node 1, and the 1st to nth trifoliolate nodes 2, 3, 4, on up. For a staging sample of <u>five</u> plants, an <u>average</u> Vn call can be computed:* ***V21+V21+V21+V20+V20 = 20.6 (i.e., about V21).*** Close examination of the stem apex will reveal the small nodal leaves (tips of pencils in photo) that formed after R5 (guide page 58). The arrow shows the last *(indeterminate)* stem node to count as the final Vn.

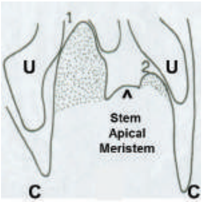


SOYBEAN – PHYLLOCHRON *VERSUS* PLASTOCHRON:

Vegetative main stem node accrual **after V1** occurs at a **rate of about one new Vn node every 3.7 days**, or a node accrual rate of **0.27 nodes per day**, irrespective of planting dates of early May, mid-May, late May, or mid-June (see guide page 30 and below chart). **Late planting leads to a later V1 start of node accrual** (thus fewer nodes will be present on any given day – see chart). Note: The dry quiescent seed already has three nodes.

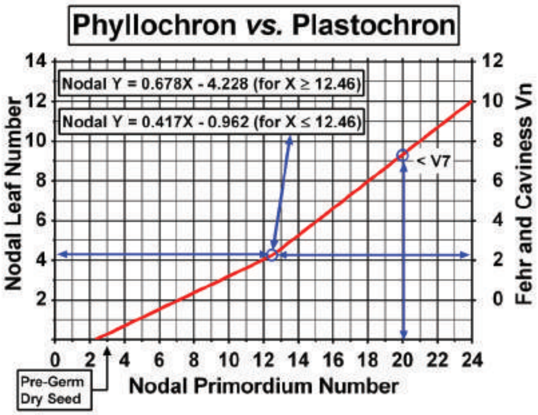


Reference: Bastidas et al. (2008)



<u>Above diagram:</u> Nodes for the "cot" (C), "uni" (U), and the 1st "tri" (#1 above drawing), which were already present in the dry seed, and newly formed 2nd "tri" (#2) are observable 92 hours after germination. **<u>Right diagram:</u>** By day 13 after germination, <u>seven</u> (1-7) trifoliolate nodes are present *[Reference: Miksche (1961)]*. **By day 35 (V7), all subsequently formed nodes thereafter (up to nodes 19-20) will have been created at the stem tip. See V7 in the next page chart.**

Recent research by Fatima Tenorio and Dr. Patricio Grassini at UNL has revealed the relationship **between the rate of (microscopic) nodal leaf primordia "initiation" at the stem apex (plastochron) *and* the rate at which leaves become (macroscopically) "visible" at the stem apex (phyllochron).** The Fehr and Caviness **Vn** phyllochron (guide page 43) differs from the Tenorio and Grassini-defined "visible" leaflet phyllochron by 2 nodes, wherein the cot node is 1 and the unfolded leaf node is counted. At the stem tip, a new nodal leaf primordium is initiated every 2 to 3 days, whereas a new nodal leaf appears at the stem tip every 3.3 to 3.8 days, depending on the coincident air temperature.Visible leaf nodes at the stem tip cease appearing at stage **R5 (begin seed)**. In early May plantings, **R5 occurs *around* V17 or V18**, which limits the final mature stem node number to about 19 to 20 nodes (see guide page 51). *Note that the 20 final nodes were already initiated and thus already present by soybean stage* ***V7****.*



Reference: Tenorio et al. (2017)

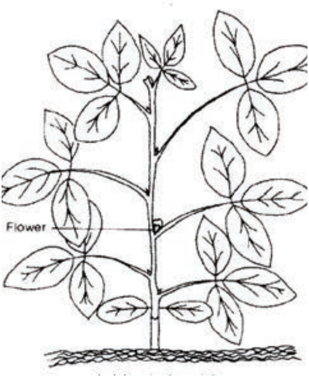
STAGES OF SOYBEAN REPRODUCTIVE DEVELOPMENT:

Unlike Vn stages (3.7 days between Vn nodes), **Rn** stages are more qualitatively characterized *[Source: Fehr and Caviness (1977)]*. **Rn stages in a specific soybean field can be forecast using UNL SoyWater (see guide page 90).**

R-Stage	Stage Name	Stage Description
R1	Beginning Bloom	One open flower at any main stem node
R2	Full Bloom	One open flower at any of the top two nodes with leaves that have been classed as "fully expanded"
R3	Beginning Pod	A pod 3/16" long at any of the top four nodes with leaves that are "fully expanded"
R4	Full Pod	A pod 3/4" long located at any of the top four nodes with leaves that are "fully expanded"
R5	Beginning Seed	A seed of 1/8" diameter present in a cavity of a pod located at any of the top four nodes with leaves that are "fully expanded"
R6	Full Seed	A seed of a diameter that fully fills a cavity "suture to suture" in a pod located at any of the top four nodes with leaves that have are "fully expanded"
R7	Beginning Maturity	One normal pod anywhere on the plant that has attained a fully mature brown or tan color. Stage R7 is more commonly known as "physiological maturity"
R8	Full Maturity	At this stage, 95% of all pods in a given row of plants have attained a final maturity and those pods will display a brown or tan color

R1 – BEGINNING BLOOM:

An open flower will be visible at a main stem node, which in May 1 plantings will be node 6 or 7 in MG III varieties.

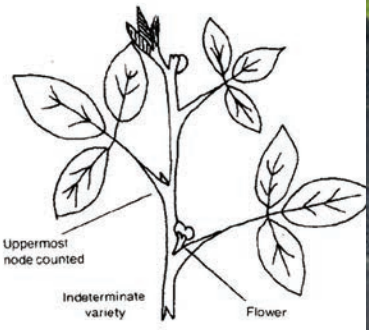


The first open flower (R1)can be expected to be observed about 28 to 32 days after V1 in indeterminate varieties of MG 3.0-4.0 (see guide pages 47 and 64). Flowering will continue to occur thereafter, peaking at **R2**, but not really stopping until around **R5** (see guide page 58). In later planting dates, the first flower will be generally found at a lower stem node. Soybean plants typically abort many flowers (sometimes as many as 70 to 80 percent).

The simple reason for this high abortion rate is that the amount of dry matter (DM) the plant invests in forming a flower is small compared to the amount of DM it must subsequently invest in pods or seeds. Plants abort flowers if current conditions do not favor the creation of pod or seeds from a given flower. However, with a long flowering period from R1 to R5, soybean plants can continually base DM investment into pod formation in coincident favorable or unfavorable environmental conditions that the plants encounter during stages **R3** (begin pod)and **R4** (full pod).

R2 – FULL BLOOM:

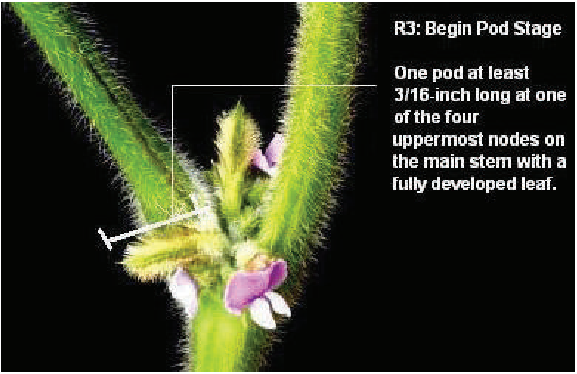
One open flower will be visible at one of the top two nodes with "fully expanded" leaves. Many flowers will be visible at lower nodes.



Indeterminate MG III varieties (used in the North-Central U.S.) will continue to successively produce, not only a new node every 3.7 days at the main stem apex *[Reference: Bastidas et al. 2008]*, **but also produce up to three new floral buds in the axils in those newest nodes.** It may thus seem to an observer that newly open flowers near the stem tip are just barely keeping up with the new Vn nodes forming there (see the R2 horizontal line intersection with the Rn seasonal trend line shown in the upper chart of guide page 62). Irrigation applied during R1-R2 will result in **(a)** excessive elongation of late-forming stem internodes and thus tall, more lodging-prone plants, **(b)** little irrigation yield response (see guide page 90), and **(c)** amplification of the risk of a white mold infection (see guide page 128). By **R2**, the plant has accumulated about 25% of the final dry weight. A 50% defoliation event at **R2** could lead to a yield loss of 50-60%.

R3 – BEGINNING POD:

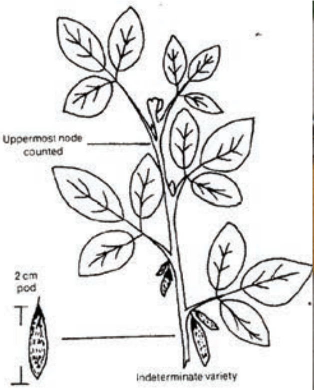
At least **one pod 5 mm (3/16 inch) in length** is present at any of the top four nodes with “fully expanded” leaves.



Flowers will still be forming at the R3 stage, continuing up to the end of flowering at R5 (begin seed) stage [Reference: Bastidas et al. (2008)]. The sensitivity of soybean plants to water stress increases significantly at the **R3** stage, because stress can lead **to young pods not forming, or to the abortion of newly developed pods. In fact, irrigation scheduled to commence at R3 (and continued thereafter as needed) almost invariably generates a substantial yield response, compared to low or zero yield responses to irrigation commenced at any earlier stage (i.e., pre-R1, or during R1 and R2) (see guide page 91) [Reference: Torrion et al. (2014)].** Note also that the tap root tip depth is more than 2.5 feet deep at the **R3** stage. **For details on seasonal soybean root development, see guide page 62.**

R4 – FULL POD:

At least **one pod 2 cm (3/4 inch) in length** is present at any of the top four nodes with “fully expanded” leaves.



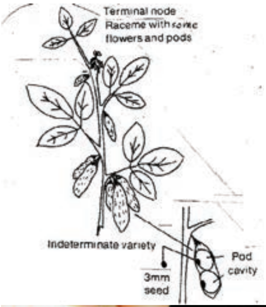
Flowering continues during the R4 stage (see top of right photo). As previously noted, the number of pods per plant will be impacted by water stress during the **R3** (begin pod) to **R4** (full pod) period of reproductive development. The **number of pods per plant** is one of four major components governing seed yield:

Yield (bu./acre) =
Plants/Acre x **Pods/Plant** x 2.5 **Seeds/Pod** ÷ Seeds/Pound

The yield component of **seeds/pod** is also established during the **R3-R4** stage, but tends not to be much impacted by water stress. In fact, a 2.5 value is used as general rule-of-thumb value for pods/plant (if it is not directly measured) – though it can range from about 2.4 to 2.6.

R5 – BEGINNING SEED:

At least **one seed 3 mm (1/8 inch) in diameter** is present at any of the top four nodes with "fully expanded" leaves.

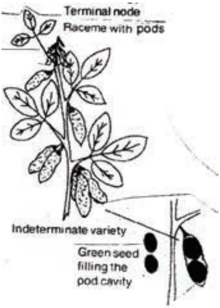


For staging purposes, split a suspected **R5** pod open to see the size of the seeds (red arrow). Or just pick off a pod and hold it up against the bright sky (but NOT the sun) to view seed size. **A pocket-sized flashlight can also be used to back-light a pod in the dark canopy – you can then readily see the seed size in a non-detached pod.**

Flowering essentially ceases at R5, but you may find a few plants with one or a few flowers at stem tip (as seen the above right photo). **N-fixation peaks at R5, but thereafter declines.** This occurs because of the redistribution of carbon and nitrogen from other plant parts to the developing seeds, leading to nodules gradually receiving less photosynthetic carbon and energy from the plant.

R6 – FULL SEED:

At least **one pod in which green enlarged seeds span the complete <u>width</u> of the cavities (<u>suture-to-suture</u>)** is found at any of the top four nodes with "fully expanded" leaves.



Unlike the advance from **R5** to **R6**, during which the seeds in the pod cavities increase in size (see guide page 61), the advance from **R6** to **R7** (next page) is difficult to track. Pod color will gradually change from a dark green to lighter green and then to a yellowish green on the approach to **R7**. Canopy leaf color will also undergo this color change. The developing seeds in a given pod do not fully close the intervening gap between them. **During the R6 seed-filling stage, nitrogen present in other plant parts is mobilized and redistributed to the developing seeds** *[Reference: Salvagiotti et al (2008)]*. Because the leaf chloroplast carboxylation enzyme **(i.e., Rubisco) accounts for about 1/4 of all leaf protein**, its nitrogen is eventually also used for redistribution during the final stages of seed development. Still, **R7** abscised soybean leaves typically have a high amount of leftover nitrogen (more than corn leaves).

R7 – BEGINNING MATURITY AND R8 – FULL MATURITY:

At R7, one "normal" seed-filled pod on a plant will have matured to a brown (in some varieties, a tan) pod color. Leaf drop typically commences just before, at, or just after stage R7 depending on the coincident weather conditions.

At R8, 95% of the plant's pods will have matured to a final brown (or tan) color. Weather permitting, combine harvest can commence when seed moisture falls to <16%.

Stage R7 is also known as physiological maturity. If you open a pod on a near-R7 plant, and find the pod membrane no longer clings to the seed coat (next page), but instead remains attached to the pod wall, <u>this signifies the end of seed-filling in that pod.</u>
This is the soybean equivalent of black layer formation in corn.

REPRODUCTIVE DEVELOPMENT (R3 TO R8 POD STAGES):

Below are photos of pods progressing from R3 > R4, from R5 > R6, from late R6 to R7, and then to R8.

↓ **R3.0 1/8"**

↓ **R3.5 1/2"**

↓ **R4.0 3/4"**

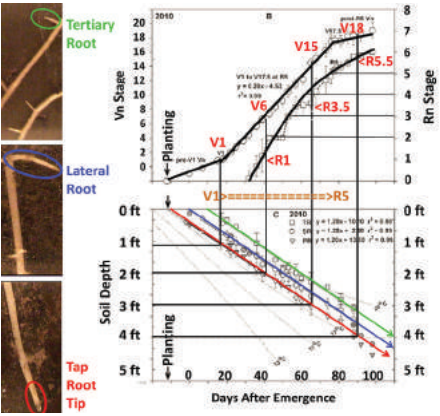
→ **R5.0** → **R5.5** → **R6.0**

→ **R6.9** →**R7.0** → **R7.1**→ **R7.5** → **R8.0**

As the plant approaches stage **R7** (prior page), individual pods will also pass through the **R6.9** to **R7.1** and then to the **R7.5** and **R8** stages (photo). During the **R6.9** to **R7.1 phase, the pod-wall membrane will cease clinging to the seed coat, thus signifying seed physiological maturity.**

SOYBEAN ROOT DEVELOPMENT DURING STAGES VN AND RN:

Recent UNL research has shown that the **soybean tap root tip extends downward (if not obstructed) at a linear rate of 1.2 cm (0.47 in.) per day**, beginning with the eruption of the radicle root from the germinating seedling (see guide page 42), and continuing on to **R5.5** (see guide pages 58-59), when the experiment ended (tap root tip was about 4.5 feet deep – red line in the chart). Lateral roots emerged from the tap root about 10 cm (4 in) behind its tip (blue line); thus at a given soil depth, lateral roots appeared around 10 days after the tap root tip had extended beyond that depth. The temporal correspondence of the tap root tip depth (red line) with Vn and Rn stage appearance is shown in the chart. Tap root tip is **12 inches deep at V1, 24 inches at R1, 36 inches at R3.5, and 48 inches at R5.5.** Because new main stem nodes appear at a linear rate of 3.7 days per node between **V1** and **R5**, the Vn and Rn stages are better predictors of the depth of root zone than is plant height. **Note: Vn and Rn stages in a soybean field can be forecast using UNL SoyWater** (see guide page 90).



Reference: Torrion et al. (2012) (Note: Fig. 3 in that paper was printed here but was colorized for use as a graphic on this guide page.)

SOYBEAN NODULATION AND N_2 FIXATION:

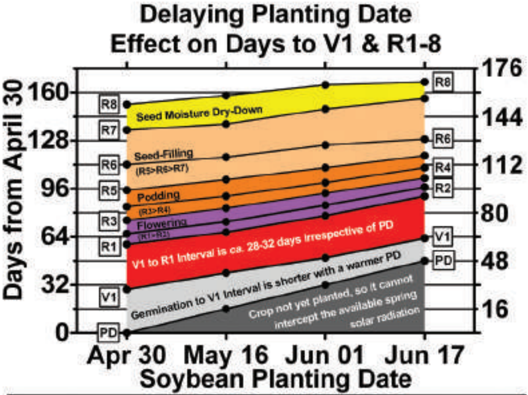
In most fields where soybeans have been rotated with corn for many years, natural inoculation by rhizobia is normally sufficient for the establishment of a suitable number of N-fixing nodules (photo: **V6** plant roots).

Active nodules, when split open, will have a pink interior, as shown in the left photo for a lateral root from a V6 plant.

Root nodules on a stage **R6** plant taken from a high-yield irrigated site are shown in the right photo. Though several of the cut-open nodules (8" to 9" zone) are green (no N-fixation activity), many others are still pink (i.e., signifying potential N-fixation activity).

DAYS TO V1 AND R1 TO R8 – EFFECT OF PLANTING DATE:

When soybean planting is delayed beyond April 30, the crop is precluded from harvesting much of the spring-available solar radiation (below chart – also see guide page 30). The germination to V1 phase is shorter with a later (warmer) planting date, *but V1 is still delayed, thus delaying the V1 start of the phyllochron (period of sequential leaf emergence* - see guide page 51). Note that a **<u>48</u>-day planting delay** from April 30 to June 17 led to respective R7 dates of 135 to 156 days after April 30. **This 21-day difference resulted in <u>48</u> – 21 = 27 fewer days for Vn/Rn development in the late planting.** Because main stem node accrual ceases at R5 irrespective of the planting date (see guide page 51), so plants in later plantings will have fewer nodes, and more importantly, fewer nodal leaves available for photosynthetic-driven seed-filling. The 28-32 day interval from **V1 to R1** for MG 3.0-3.9 varieties was not impacted by planting date, nor would there be much impact on MG 2.0-2.9 varieties (though the interval would be shorter). The R7 to R8 dry-down period is about 12 days or so.



Charted Data for MG 3.0 - 3.9 Varieties at Lincoln, NE - Reference: Bastidas et al. (2008)

For information about the R7 to R8 dry-down phase length, see: https://www.iasoybeans.com/news/articles/how-fast-do-soybeans-dry-down-during-the-preharvest-time/.

CONVERTING MATURE PLANTS/FOOT INTO PLANTS/ACRE:

Count the number of plants in a 10-foot section of row and then divide by 10. Use the below table to convert the averaged plant count per foot of row into plants/acre.

Plant Count/Foot of Row In these Row Widths			Plants/ square foot	1000 Plants/ Acre
7.5-in	15-in	30-in		
0.7	1.4	2.9	1.15	50
0.9	1.7	3.4	1.38	60
1.0	2.0	4.0	1.61	70
1.1	2.3	4.6	1.84	80
1.3	2.6	5.2	2.07	90
1.4	2.9	5.7	2.30	100
1.6	3.2	6.3	2.53	110
1.7	3.4	6.9	2.75	120
1.9	3.7	7.5	2.98	130
2.0	4.0	8.0	3.21	140
2.2	4.3	8.6	3.44	150
2.3	4.6	9.2	3.67	160
2.4	4.9	9.8	3.90	170
2.6	5.2	10.3	4.13	180
2.7	5.5	10.9	4.36	190
2.9	5.7	11.5	4.59	200
3.0	6.0	12.1	4.82	210
3.2	6.3	12.6	5.05	220
3.3	6.6	13.2	5.28	230
3.4	6.9	13.8	5.51	240
3.6	7.2	14.3	5.74	250

Formula to use for any row width not listed above:

Plants/Acre = **[43,560 / (Row Width/12)] x Plants/Foot of Row**

Example: You counted 3 plants/foot in 10-inch wide rows:
[43,560 ÷ (10 ÷ 12)] x 3 = **156,186 Plants/Acre**

HOW NASS ESTIMATES SOYBEAN YIELD PRIOR TO HARVEST:

The National Agriculture Statistics Service (NASS) forecasts national, state, and county soybean yields using 18-square-foot field samples. The NASS basal formula is shown below. Pod number is counted in a field sample, those pods are weighed (grams) and the average gram weight of a pod is estimated.

Gross Pod Weight / Acre =

$$\frac{(\textbf{pod number per 18 sq.ft.}) \times (\textbf{gram wt. per pod}) \times (43{,}560)}{(18) \times (453.6) \times (60)}$$

where 43,560 sq. ft. = 1 acre, 453.6 grams/pound, and 60 = pounds/bushels of soybeans.

NASS uses some complicated methods to convert the gross pod weight/acre into a net seed yield (bushels/acre). Essentially, the **average gram weight per pod** term in the above formula is replaced with an **average seed weight per pod** term. NASS uses historical data to estimate the latter term, but after plant maturity, the actual seed weight per pod is directly determined by threshing of pods collected in the 18-square-foot sample. Any pre-harvest loss is also estimated when converting from gross to net.

The above (simplified) text is from a more detailed comprehensive description that can be found at this NASS website – see soybean chapter 6, pp 41-56 in this PDF: https://www.nass.usda.gov/Education_and_Outreach/Understanding_Statistics/Yield_Forecasting_Program.pdf.

DO-IT-YOURSELF PRE-HARVEST YIELD ESTIMATION:

Soybean producers interested in estimating the yield of a soybean crop in a given field can do that on their own. *See:* http://croptechcafe.org/soybeanyieldestimator/.

Yield estimation can be attempted after the crop attains soybean stage R5 (beginning seed-fill). However, pre-harvest yield estimation will be more reliable the closer the crop is to stage R7 (physiological maturity).

The yield estimation method described in this guide is based on collecting pods from plants present in a sample length of a row that equals to 1/10,000th of an acre. NOTE: The size of this sample is purposely kept small to lessen the burden of counting the number of pods therein. Keep in mind that the reliability of a pre-harvest yield estimate will be critically dependent on a non-biased selection of a small sample that should truly be field *representative*.

Use the below table to determine the single row length (in feet or in inches) needed for a 4.356-square-foot sample of 1/10,000th acre relative to some common row widths.

Row Width (inches)	Single row length that corresponds to 4.356 sq. ft. = 1/10,000th of an acre	
	Measured in Feet	Measured in Inches
7.5	6.97	83.6
15	3.48	41.8
20	2.61	31.3
30	1.74	20.9
36	1.45	17.4
40	1.31	15.7

Formula to use for a row width not listed above:

Row Length (Feet) = (43,560 ÷ 10,000) ÷ (Row Width ÷ 12)

Example: If you have a 30-inch row width:

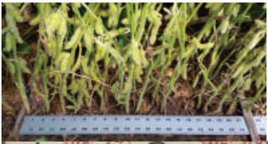
(43,560 ÷ 10,000) ÷ (30 ÷ 12) = 1.74 feet of row length

To convert the 1.74 feet into total inches of row length:

(1.74 x 12) = 20.9 inches (about 21 in.)

STEP 1 – COUNT PODS IN A 4.356 SQ. FT. SAMPLE AREA:

Wait until crop stage R5 or later before collecting plants in a length of row equal to 1/10,000th of acre (see previous page). Counting pods can be quite tedious, so first estimate the field's



plant population (see guide page 65) to get a sense of the plant numbers likely to be present in a *representative* 1/10,000th acre sample.

Example: A field of soybeans of MG 3.1 planted on May 8 in 30-inch rows was estimated at R6.5 to have 140,000 plants/acre (eight plants per foot). The 20.9-inch row length sample had 14 normal plants and two very small plants (likely due to a late emergence). Pods excised from stems and branches of all 16 plants were sorted into piles of 1-, 2-, 3-, and 4-seed pods, which totaled to (38+319+400+4=) 761 pods.

Step 1 – Formula for estimating number of seeds/acre:

Seeds/acre = [(1-seed pods x 1) + (2-seed pods x 2) + (3-seed pods x 3) + (4-seed pods x 4)] x 10,000

Example: Using this field's pile pod counts (above photo):

Seeds/acre = [(38 x 1) + (319 x 2) + (400 x 3) + (4 x 4)] x 10,000 = (38 + 638 + 1200 + 16) x 10,000 = 1892 x 10,000 = 18,920,000 seeds/acre

*Note that one also could simply multiply the pod count total of 761 by 2.5 (a general rule-of-thumb seeds/pod value): **761** x 2.5 = 1903 seeds. The small difference in the two numbers (i.e., 1892 – 1903) suggests that pod-sorting may not necessarily be worth the time it takes.*

STEP 1 – COUNT PODS (CONT.):

NOTE: Many of the pods in the photo on the previous page had a cavity in which a seed had aborted at some point after its seed-filling began (bottom two pod sets in below photo). Also, in many late-formed pods, seeds were small due to their late seed-filling start (top two pods in below photo). Given that **R7** (end of seed-filling) was projected to occur about seven days after the **R6.5** sampling date, these small seeds will not be able to attain a normal seed size. Using a flashlight to backlight the 761 pods to see seeds therein, we estimated that about 20% of the 1892 pod cavities had **(1) aborted light-weight seeds too small to be retained by a combine** properly set to separate chaff from normal-sized seeds, or **(2) incompletely filled seeds** that when combined with the completed filled seeds, would result in a less than expected seeds/pound value.Both will be discussed later.

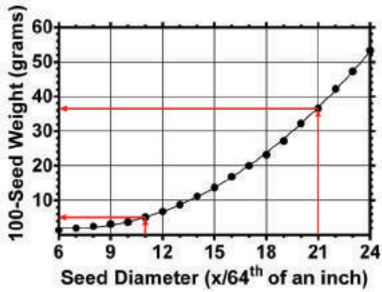
STEP 2 – PREDICT A FINAL SEED SIZE:

You will next need to *estimate* a final average seed size. This yield component is ordinarily not firmly established until the crop actually attains stage R7 (physiological maturity). See pages 43-44 and 47 for more details on seed maturation and R5 > R6 > R7 time intervals.

STEP 2 – PREDICT A FINAL SEED SIZE (CONT.):

In rainfed fields, late-season soil water deficits can make a forecast of a post-R7 final seed size very "dicey." This is less of a problem in irrigated fields, where late-season water stress can be mitigated. Soybean varieties do vary in seed size (a heritable trait), ranging from around 3600 to 2400 seeds/pound. This number may be listed on the seed bag tag (if not, contact your seed dealer), and is a useful starting point when trying to predict final seed size. Keep in mind that the seeds produced by a given plant (or by sample of plants) are never all the same size; in fact, a batch of harvested seed can be sorted into x/64th diameter fractions using a set of 20 x/64-size sieve screens. See the photo below for individual seeds with 11/64 to 21/64 inch diameters. The below chart shows the 6 to 36 gram span in 100-seed weight (red arrows) *versus* photo seed diameters.

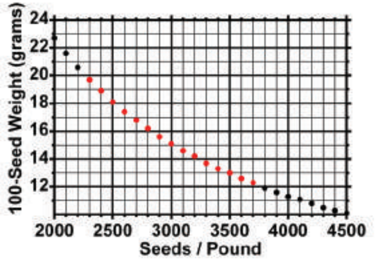
Seed Mass (g/100-seed) *vs.* Seed Diameter:



STEP 2 – PREDICT A FINAL SEED SIZE (CONT.):

The below chart shows the relationship between 100-seed weight and seeds/pound. **Modern soybean varieties have a 100-seed weight range of approximately 12 to 20 grams (red dots) that corresponds to a range of around 2300 to 3700 seeds/pound.**

Translation: Grams/100 Seed *vs.* Seeds/Pound:



Unlike the Step 1 formula (see guide page 68), there is no particular Step 2 formula for easy estimation (at R stages prior to R8) of the actual R8 stage final number of seeds/pound. Normally, all other yield components (see guide page 57) will have been firmly established by R5 or soon thereafter, which makes seed-filling (R5 to R7) and its seed size yield component bear the brunt of abnormally low rainfall during August. For **Step 2 estimation of seeds/pound**, we suggest you start with your variety's known seeds/pound value, and then adjust that value as needed based on your judgment of impact of unfavorable August weather. For this R6.5 stage sample (described on guide page 68 & 71), we estimated a 2750 seeds/pound value.

STEP 3 – ESTIMATE PRE-HARVEST YIELD:

Soybean yield (bushels/acre) is essentially a simple function of two basal yield components:

(1) number of seeds produced per acre
(2) number of seeds per pound

The **1st component** was estimated in **Step 1** and the **2nd** component was estimated in **Step 2** (see guide pages 68-71), using the early planted irrigated Nebraska soybean field described on guide page 68 to demonstrate pre-R7 yield estimation conducted at soybean stage **R6.5**.

The **761 total pods** collected in the 4.356 sq. ft. field sample translated into 761/4.356 = **174.7 pods per sq. ft.** When multiplied by 2.5 seeds/pod, the result is **437 seeds per sq. ft. However**, as noted on guide page 69, this 437 seed number included aborted seed "flakes" and very small (incompletely filled) seeds, necessitating a 20% downward adjustment from 437 to 350 seeds per sq. ft.

To estimate yield, use this two-component yield equation: Yield (bu./acre) = (**Seeds/Acre** ÷ **Seeds/Pound**) ÷ **60 lb./bu.**

Relative to components (1) and (2) above (see guide pages 68 and 71), the 1st component was **350** seeds/sq. ft. x 43,560 sq. ft. = 15,246,000 seeds/acre. The 2nd component of 2750 seeds/pound was a judgment "call" that considered the varietal seed size and favorable August 2016 weather. SO: Yield (bu./acre) = (**15,246,000** ÷ **2750**) ÷ **60** = **92.4** bu./acre. Note: A 1/10,000th of an acre sample of post-R8 plants collected from this same field generated a **87.9** bu./acre estimate. A plot combine harvest of four nearby standard research plot replicates revealed a mean field yield of **79.0** bu./acre.

The next table shows yield values associated with each combination of harvested seeds/sq. ft. and seeds/pound. **This table can be used by yield-contest-witnessing judges to independently verify the veracity of any record soybean yield entry.** Contact Jim Specht (jspecht1@unl.edu) for details.

YIELD COMPONENTS OF SEEDS/SQ. FT. *VERSUS* SEEDS/POUND

Sq ft per foot of row:			Seeds**	Note: Below numbers apply when the soybean seed moisture content is 13%									
0.625	1.25	2.5	present	seeds/oz >	250	234	219	203	188	172	156	141	125
Seeds produced per			in a one	oz/seed >	0.0040	0.0043	0.0046	0.0049	0.0053	0.0058	0.0064	0.0071	0.0080
foot in this row width:			square	seeds/lb >	4000	3750	3500	3250	3000	2750	2500	2250	2000
7.5-in	15-in	30-in	foot area	g/100seed >	11.3	12.1	13.0	14.0	15.1	16.5	18.1	20.2	22.7
					Yield (bu/ac)								
62.5	125	250	100		18.2	19.4	20.7	22.3	24.2	26.4	29.0	32.3	36.3
78.1	156	313	125		22.7	24.2	25.9	27.9	30.3	33.0	36.3	40.3	45.4
93.8	188	375	150		27.2	29.0	31.1	33.5	36.3	39.6	43.6	48.4	54.5
109.4	219	438	175		31.8	33.9	36.3	39.1	42.4	46.2	50.8	56.5	63.5
125.0	250	500	200		36.3	38.7	41.5	44.7	48.4	52.8	58.1	64.5	72.6
140.6	281	563	225		40.8	43.6	46.7	50.3	54.5	59.4	65.3	72.6	81.7
156.3	313	625	250		45.4	48.4	51.9	55.8	60.5	66.0	72.6	80.7	90.8
171.9	344	688	275		49.9	53.2	57.0	61.4	66.6	72.6	79.9	88.7	99.8
187.5	375	750	300		54.5	58.1	62.2	67.0	72.6	79.2	87.1	96.8	108.9
203.1	406	813	325		59.0	62.9	67.4	72.6	78.7	85.8	94.4	104.9	118.0
218.8	438	875	350		63.5	67.8	72.6	78.2	84.7	92.4	101.6	112.9	127.1
234.4	469	938	375		68.1	72.6	77.8	83.8	90.8	99.0	108.9	121.0	136.1
250.0	500	1000	400		72.6	77.4	83.0	89.4	96.8	105.6	116.2	129.1	145.2
265.6	531	1063	425		77.1	82.3	88.2	94.9	102.9	112.2	123.4	137.1	154.3
281.3	563	1125	450		81.7	87.1	93.3	100.5	108.9	118.8	130.7	145.2	163.4
296.9	594	1188	475		86.2	92.0	98.5	106.1	115.0	125.4	137.9	153.3	172.4
312.5	625	1250	500		90.8	96.8	103.7	111.7	121.0	132.0	145.2	161.3	181.5

** Note: Seeds per sq ft divided by plants per sq ft = seeds/plant; seeds/plant divided by 2.5 = pods/plant.

NOTES:

Here is the complete soybean yield component equation:

________**Yield (bu./acre)** (use your yield goal)

=_______**average plants/acre**

x_______**average final nodes/plant**

x_______**average number of pods/node**

x_______**average number of seeds/pod (typically 2.5)**

÷_______**average number of seeds/pound**

÷__60___**pounds per bushel**

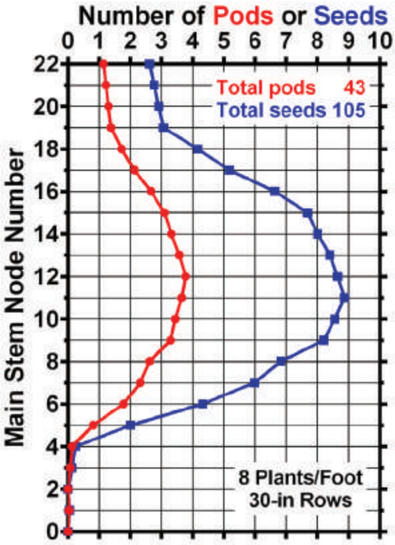
=_______**Yield (bu./acre) (calculated value)**

On a rainy fall harvest day, you may begin musing about some lofty soybean yield you would like to harvest some year in your best managed, most fertile farm field. If so, go to the top of this page and enter (in pencil) that **yield goal**. Then, pencil in a number for each of the **listed five yield components**. Enter numbers that you think would be needed to achieve your yield goal. Then use a calculator to **mathematically compute a yield based on your five yield component choices**. If your choices are reasonable, the calculated yield value will be close to your penciled-in yield goal value. If not, revise one or more of your chosen yield component numbers. It may take some time to get a match between your calculated yield and your yield goal, but consider this to be a rainy day "brain-teasing learning activity!" If you need a starting hint, go to guide page 73 and on the right side of the table, find a same-color set of yield values that brackets your above-chosen yield goal. Pick just one of those bracketed table cells and go to the top of the table to find a seeds/pound value to pencil in above.

If you have questions and/or comments, please feel free to email these to Jim Specht (jspecht1@unl.edu).

POD AND SEED DISTRIBUTION ALONG THE MAIN STEM NODE:

The below chart shows how pods and seeds are typically distributed over the main stem nodes based on data collected from 275 replicate R8 plants growing in an early May planted field (30-inch row spacing) that had approximately 140,000 plants/acre (i.e., approximately 8 plants/foot of row). Note that 105 seeds/plant x 8 plants/foot ÷ 2.5 sq. ft. per ft. of row = 336 seeds/sq. ft. The 100-seed weight average was 16.5 grams (i.e., 2750 seeds/pound). The actual yield was 83.7 bu./acre, which is less than the 88.9 bu./acre predicted for 325 seeds/sq. ft. and 2750 seeds/pound (see table on guide page 73).



Reference: Ruff et al. (2016)

UNDERSTANDING SOYBEAN FLOWERING AND BRANCHING:

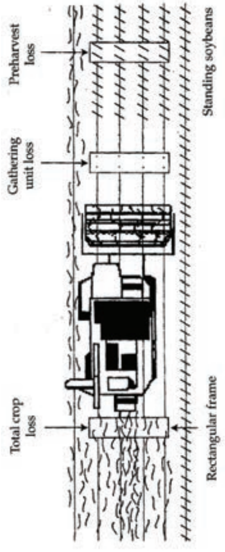
Higher plant populations suppress the number of branches that emerge from the main stem, particularly at the lowest stem nodes, but peer-reviewed scientific data quantifying this relationship is not readily available. Still, you can expect to see more branches per main stem (and more at lower stem nodes) when plant density is low. The **V11-R2** soybean plant shown in the left photo was pulled from a May 8 planted field (30-in. row spacing) that had **140,000 plants/acre** (i.e., **8 plants/foot of row**). The intersection of any trifoliolate-bearing petiole (**P**) with the stem is defined as an **axil** (see photo). Two **axils** are present at stem nodes 0 (cotyledon pair) and 1 (unifoliolate leaflet pair). The **primordial meristems** formed in the **axils** before stage V0-V1 are vegetative, and will produce a branch (**B**), but only if branching is not suppressed by within-row shading that can occur at high plant densities. This **V11-R2** plant (photo) did not have a **B** at the cotyledonary node (0) axils, but a long and short **B** had emerged from each unifoliolate node (1) axil. A **B** was present in the node 2 axil; the 1st trifoliolate there had abscised (and its petiole was about to do so as well). **B** was present in each axil of the main stem nodes 3, 4, 5, and 6.

A 92-hr germinated seed already has stem node axils 0-3; axils at nodes 4-8 successively form at approximately two day intervals at the stem apex by stage V0 (guide pages 51-52, *phyllochron vs. plastochron* chart). **Floral induction begins at stage V0** *[Reference: Wilkerson et al. (1989)]*, (see guide pages 45-47), at which time any new axillary **vegetative meristem** (in any existing stem axil) that has not yet committed to become a branch (like those in stem node axils 1-6) will be converted to an **inflorescence meristem** (IM) that will subsequently produce flowers. Up to three IMs can emerge from an axil to produce flowers and then pods (left photo). The stalk of the IM (known as a **peduncle**) can be thick and short or long and slender. The central IM in a given axil can exhibit an elongated peduncle (i.e., a **raceme**). In the prior page photo, a long raceme is present at stem node axils 7, 8, and 9, and at the first node axil of a branch (B) at stem node 6. These indeterminate racemes produce flowers on short lateral stalks (**pedicles**) that arise from a raceme peduncle in a successive **acropetal** fashion (new flowers form at the extending peduncle tip) until flowering ends at R5 (see guide page 58). Late-forming flowers at the raceme tip typically abort, and the portion of the slender raceme tip without pods is usually lost (top photo). The IM peduncles that flank the central raceme IM in an axil typically generate lead to just one pod (above photo), but can generate two or even three flowers (pods) at their peduncle tips (see left photo of a mature plant axil). Note that the left peduncle tip has three pods, the right peduncle tip has two pods, but the central peduncle has just one pod — other flowers on this raceme had aborted.

ESTIMATING SOYBEAN PRE- AND POST-HARVEST LOSSES:

Back up combine 20 feet. Count seeds on the ground (also in non-threshed pods) in three 20 sq. ft. rectangular areas located in a **(1) pre-cut soybean zone, (2) post-cutter bar zone** (count seeds in pods left with the stubble), and **(3) post-combine zone**. See diagram. The rectangles should have a length equal to the header and a width that creates a 20 sq. ft. area. Use colored twine to outline rectangular areas in the field. For a header length not listed in the table, divide header length by 20 to obtain the rectangle width.

Area seed count ÷ 20 is the **seed number loss per sq. ft.**



Combine Header Length	Rectangle Width for 20 sq. ft.
In feet:	**In inches:**
30	8
24	10
20	12
15	16
10	24

Four seeds/sq. ft. = 1 bu./acre. Mitigate pre-harvest (pod-shatter) seed loss by timely harvest. Reduce header loss by using sharp knives and a properly set reel speed and height. In low plant density fields, set cutter bar as low as possible to gather pods located at low stem nodes. Diminish any seed/straw separation loss by properly adjusting combine blower and sieve settings. More detailed information is available at: https://coolbean.info/pdf/soybean_research/library/grain.production/Measuring%20and%20Reducing%20Harvesting%20Losses.pdf.

SOYBEAN SEED MOISTURE SHRINK CONSIDERATIONS:

The marketable gross weight of soybean seed delivered to an elevator will be subjected to “shrink” (1) if the initial seed moisture content is greater than 13%, and/or if (2) the foreign material (FM) is greater than the 1% allowed in U.S. No. 1 grade soybean.

Starting Seed Moisture (%)	Ending Seed Moisture (%)				
	11	12	13	14	15
	Shrink Percentage*				
20	10.1	9.1	8.0	7.0	5.9
19	9.0	8.0	6.9	5.8	4.7
18	7.9	6.8	5.7	4.7	3.5
17	6.8	5.7	4.6	3.5	2.4
16	5.7	4.6	3.5	2.4	1.2
15	4.5	3.4	2.3	1.2	0.0
14	3.4	2.3	1.2	0.0	----
13	2.2	1.2	0.0	----	----

For more details, go to: https://msue.anr.msu.edu/news/understanding_soybean_discount_schedules.

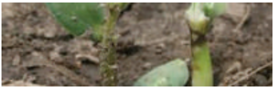
Seed Moisture (%)	Change in Weight of Bushel	Seed Moisture (%)	Change in Weight of Bushel
21	66.1	13	60.0
20	65.3	12	59.3
19	64.4	11	58.7
18	63.7	10	58.0
17	62.9	9	57.4
16	62.1	8	56.7
15	61.4	7	56.1
14	60.7	6	55.5

A 60-lb soybean bushel at 13% seed moisture consists of 52.2 pounds of dry matter and 7.8 pounds of water. The water part of bushel weight *increases* or *decreases* when 13% moisture seeds are *moist-air hydrated* or *dry-air dehydrated*.

SOYBEAN MATURE STEM SYNDROME:

Green stem syndrome (GSS) is a descriptive term used whenever soybean stems remain green after R7 (physiological maturity) and then stay green after R8 (95% of the pods are mature). The green stems make combine harvest difficult, and the sap forced out of mashed green stems can significantly reduce the seed quality. The term GSS is applied when many green-stem plants are present, either in distinct field "patches" or evenly distributed over a field. It is not applied when just a few field-scattered mutant male-sterile plants stay green (these have no pods to fill). In fields with GSS, the green-stem plants nearly always exhibit a reduced pod load, which could be due to being infected with the yield-reducing bean pod mottle virus (vectored by the bean leaf beetle), or to environmental stress (i.e., July drought) that reduced pods/plant. Both carbon and nitrogen are mobilized from non-seed plant parts to be redistributed to developing seeds, and this normally causes non-seed parts to naturally senesce at R7. BUT, in green-stem plants, a low pod load allows those other plant parts to retain sufficient carbon and nitrogen to survive (thus staying green). Green stems can plug-up at the cutter bar. The combine ground speed may have to be slowed. Make sure the knives are kept sharp. Some producers have found that cutting green-stem plants is sometimes easier when the combine direction is offset 20-25° from the plant row direction, because the green stems in the rows are then not cut by just a specific cutter bar knife; instead, the row-planted green-stem plants "meet" the cutter bar on a "rolling" basis that spreads the green stem cutting across the entire cutter bar.

SOYBEAN HAIL DAMAGE – GENERAL CONSIDERATIONS:



Yield loss arising from hail damage during the pre-R7 Vn stages will typically be low to moderate based on the defoliation percentage, BUT yield loss arising from hail during late season Rn stages (R1 to R6.5) will usually be much higher if leaf defoliation is accompanied by: (1) Lost or damaged main stem and branch tip meristems (at which future leaf primordia are produced). Note that leaf primordia production ceases after stage R3. (2) Lost or damaged pods on main stem and branch nodes. Note: No new pods will form after R5 (i.e., flowering ends at R5). (3) Too few days left in the season to allow recovery from the hail damage. Note that hail can wound pods to the extent that fungal pathogens can enter the pod and damage the quality of the seeds therein. In wounded pods, the normal hormonal prevention of seed germination may be lost, leading to seeds germinating ("sprouting") in the pods. For UNL information on soybean crop hail damage, see: https://cropwatch.unl.edu/hailknow. In particular, see: https://cropwatch.unl.edu/hail-know/video-hail-damage-evaluation-and-management-soybean. See also: http://extensionpublications.unl.edu/assets/pdf/ec128.pdf.

The National Crop Insurance Services Agency provides information for insurance adjusters about estimating yield loss arising from hail damage. Soybean producers interested in crop hail insurance information can go to:

https://www.rma.usda.gov/Fact-Sheets/Topeka-KS-Region-Fact-Sheets/Soybeans-2018-NE.

SOYBEAN LATE SPRING FROST/FREEZE DAMAGE:

Unlike corn, soybean seedling growing points are located at the cotyledon node which, at emergence, will be located above the soil surface. However, the air temperature near the ground is closer to the soil

temperature in an unstirred air zone called the "boundary layer," within which the generally warmer soil and typically colder air modulate each other. The temperature of wet soil changes much more slowly than the temperature of dry, cold soil. Thus, the air temp surrounding the cotyledons just above the ground may not be as cold as the reported air temp measured higher up by news media. Seedlings in which the epicotyl is still enclosed by the cotyledons can temporarily tolerate temperatures down to 28° F, due to solutes in the cotyledon cytoplasm serving as a modest antifreeze that can depress the cotyledon tissue freezing point by 1-2° F.

If soybean seedlings are damaged by a late spring freeze, inspect the hypocotyl (see guide pages 44-46). A water-soaked or discolored hypocotyl is indicative of a dead seedling. But, if the hypocotyl and cotyledons are still green, the seedling will likely survive, even if its main stem tip froze. The axillary meristems in cotyledon axils will generate branches that become replacement stems (see guide page 46). For a post-frost/freeze replant decision (see guide pages 38-39), wait a few days before counting the seedlings/foot to ensure your count only includes seedlings likely to recover and survive (as is evident in the above photos).

Reference:

https://cropwatch.unl.edu/2016/three-key-considerations-early-planting-corn-and-soybean.

SOYBEAN EARLY FALL FROST/FREEZE DAMAGE:

An early fall frost/freeze after R7 (physiological maturity) will not damage soybean pods, though it may kill leaves and plants and speed up pod and seed dry-down to R8.

The impact of an early fall freeze will depend on the temp (how much lower than 32° F), duration, and pre-R7 stage of its occurrence. A 28° F or colder freezing temperature for a few hours will likely kill all plants, or at least completely defoliate them, effectively stopping all further seed-filling in pods that had not individually reached R7. These are likely located at the upper stem nodes.

Soybean plants about 7-10 days before R7 will not have completed much of the seed-filling period that had started at R5 (begin seed). If the plants are frozen at R6-7, expect a 10% yield loss. If plants are frozen well before that, expect a proportionately greater yield loss, which can be 50% or more if the freeze were to occur at stage R5.

With fall freezes much before R7, the seeds in the pods will remain green and the moisture dry-down will be slow. It is best to let the crop remain standing in the field for as long as possible to allow natural sunlight to bleach out some of the greenness, given the significant elevator price discount that may be applied for excessive numbers of green seeds.

References:

http://cropwatch.unl.edu/frostfreeze-effects-corn-and-soybean.

http://crops.extension.iastate.edu/cropnews/2009/10/soybean-quality-issues-2009.

SOYBEANS – RESPONSE TO FLOODED/SATURATED SOILS:

Heavy rainfall events can result in flooded soybean fields or field sections. The extent of plant flooding damage will vary. The worst case scenario is flooding that completely submerges the plants – the duration of that submergence is critical. Even if submergence quickly subsides, a long-term water-saturated soil condition will also result in yield loss; the degree of damage will depend on the Vn stage attained just before submergence or soil water saturation.

If the plants survive a short period of submergence, but are then subjected to a (post-flood) protracted saturated soil condition (see above photo), they will grow, but only slowly. Eventually a white spongy tissue filled with gas spaces forms in the (1) stem below the cotyledonary node (i.e., the hypocotyl region in a young seedling), (2) upper part of the tap root, (3) lateral roots near the soil surface, and (4) even in parts of nodules *[Reference: Yamauchi et al. (2013)]*. Plant recovery is invariably slow and typically incomplete after flooding – expect a significant yield loss.

References:

http://www.plantstress.com/articles/up_waterlogging_files/Aerenchyma%20formation%202014.pdf.

http://cropwatch.unl.edu/corn-and-soybean-survival-saturated-and-flooded-soils.

SOYBEANS – LIGHTNING STRIKE DAMAGE:

The below-shown photo may cause some head-scratching by an observer trying to diagnose the cause of this circular zone of dead plants – don't worry, it was a lightning strike.

Photo Credit: Donald Groth, Louisiana State University AgCenter, Bugwood.org.

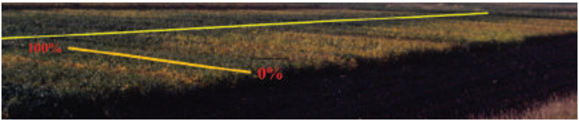
SOYBEANS – IMPACT OF DROUGHT:

The below photo shows a MG 3.0 variety in a droughted (non-irrigated) central strip, in an irrigated section strip on the right, and in a later-planted strip on the left.

Soybeans are generally tolerant of droughts prior to the R3-R6 stages, though pre-R3 droughts typically decrease seed number per plant. If a rainfall event at the R3 (or pre-R4) stage terminates a July drought, and normal rainfall resumes for the rest of the season, soybean yields will be near-normal. However, soybeans are highly yield-sensitive to droughts (1) during the pod-forming R3-R4 stages, and (2) during the seed-filling R5 to R6 stages. Water stress during seed-filling results in smaller seeds, so more seeds will be needed per pound (see guide pages 70-72) and in turn, more seeds per 60 lb. bushel and thus less yield! If an August drought is terminated by rainfall prior to R7 (physiological maturity), partial recovery is possible, but the degree of recovery will depend on the pre-R7 rainfall event timing and amount. Planting late (left side of above photo) is a costly means of drought avoidance (see guide page 29). Instead, plant early, but use a later MG variety that will have more time to "catch" a drought-terminating rainfall event. Many Nebraska rainfed producers do exactly that (see guide page 26).

SOYBEANS – IMPACT OF DROUGHT (CONT.):

The primary impact of an August drought is a hastening of maturity (see guide page 26). In the below soybean field photo, the yellow line depicts the location of a sprinkler line that delivered water in a 100% to 0% gradient perpendicular to the sprinkler (orange line), which resulted in the variety strips at the 0% watered plot ends being subjected to drought stress. The hastening of maturity is clearly evident in going from the 100% well-watered end to the 0% end in each variety strip.



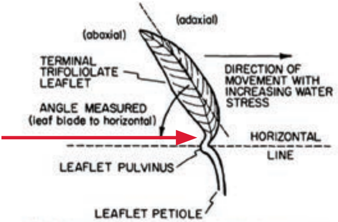


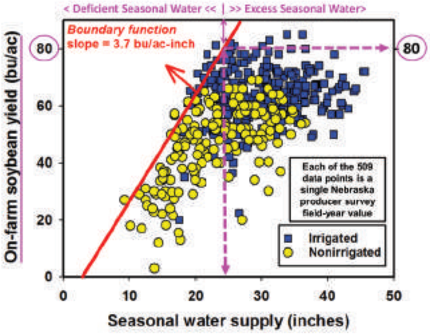
Fig. 1. Representation of a terminal soybean leaflet showing the leaflet, pulvinus, angle measured, and direction of leaflet movement with increasing water stress.

Reference: Oosterhuis et al. (1985)

Producers are familiar with the leaf-rolling that occurs when corn plants are water-stressed. When soybeans are water-stressed, the trifoliolate terminal leaflet flips over (red arrows), displaying a greyish leaf underside that is reflective to incoming solar, thereby lessening radiative absorption to reduce the heat load. This flip-over occurs when soybean leaves transpire water faster than the rate of soil water absorption by root hairs in droughted plants, but it can also occur naturally at midday in irrigated fields if the evaporative demand is high.

SOYBEAN IRRIGATION MANAGEMENT:

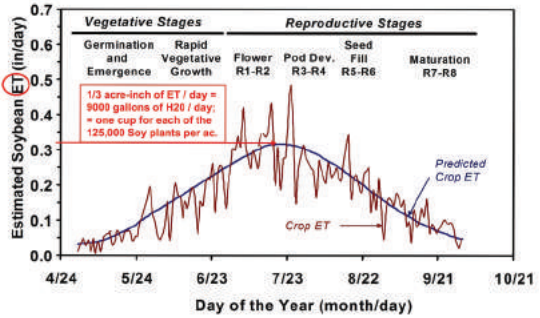
The **"water productivity"** of a soybean field was shown, in recent UNL research, to have a **maximum value**, in which **yield rises or falls by 3.7 bu./acre per acre-inch of up or down change of seasonal water supply** (chart red line). In both irrigated and rainfed fields, the vertically arrayed field yield charted values are indicative of field yield potential, which rises in accordance with the producer's skill in using "best management practices" (e.g., early planting, better soil storage of pre- and in-season rainfall, etc.), despite the limits imposed on yield potential by weather and soil factors. Irrigation mitigates a seasonal rainfall deficit (the main yield potential limiting factor), but as seen in the chart, **high yields in many irrigated fields could be attained with an optimally distributed seasonal supply of rain + irrigation amount of just 25 acre-inches!**



Source: Grassini et al. (2015) EC 3000

To maximally capture the yield potential available in an irrigated field, water should be applied in a "just-in-time-and-in-just-the-correct-amount" fashion that will mitigate over-usage of ground and surface water resources. Doing so will optimize **irrigation water use efficiency (IWUE).**

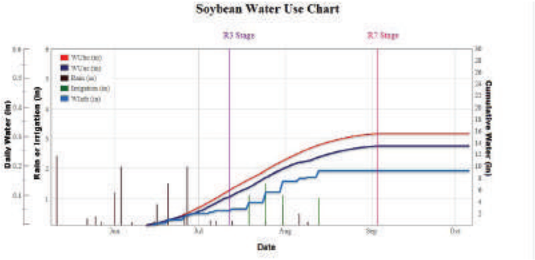
Crop water use consists of: (1) water vapor escaping from open leaf stomatal pores via transpiration (T) and (2) evaporation (E) of water from soil surfaces and (post-rain) wet leaf surfaces. When combined, these amounts are called crop "ET." As shown in the chart, daily soybean crop ET values for a MG 3.0 variety planted in late April have a seasonal pattern that is low at emergence, then increases before it peaks at about 0.3 inches per day just prior to R3-R4 (pod elongation stage), before gradually declining to zero at R7 (physiological maturity stage). The smooth (normal) 30-year historical average daily crop ET is predictive, but in any given year, daily crop ET values typically deviate from the expected normal, spiking upward on a hot, sunny, windy, low humidity day, or inversely spiking downward on a cool, cloudy, calm, high humidity day. Daily soybean ET values, when summed over the entire growing season, translate into about 20 acre-inches of water (one acre-inch = 27,154 gallons, and this x 20 = 543,080 gallons) that must be absorbed from the soil by the plant's root hairs.



(Graph courtesy of Bill Krantz, Nebr NE R&E Ctr)

SOYBEAN IRRIGATION MANAGEMENT (CONT.):

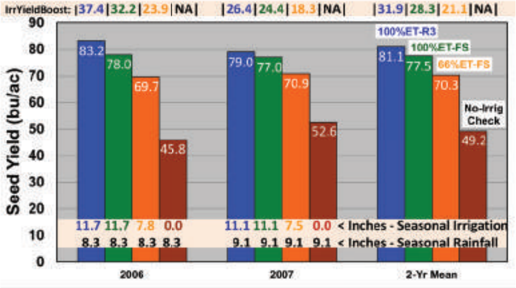
Soybean irrigation scheduling is now quite convenient if you use the Nebraska Soybean Board-funded **SoyWater website:**



http://hprcc-agron0.unl.edu/soywater/. Just click on the 23-minute video there that shows how **SoyWater** works. The **SoyWater** water use chart shows the historic and actual field-specific seasonal crop water use lines, and also shows the dates and amounts of the four irrigation events that this (real) producer had to apply to this field due to very low July and August rainfall. By using **SoyWater**, the producer ensured that the amount of irrigation (plus rain) received by the crop in this field (light blue line) would track the seasonal crop water use (dark blue line), but just below it, to allow unexpected rainfall water to be stored in the soil rather than running off. Irrigation was “triggered” when the crop had withdrawn the (root zone) soil water to 50% of field capacity (for more details about soybean rooting, see guide page 62). **SoyWater** showed the producer that irrigation in this field was not needed prior to R1-R2 – many producers still apply an often unneeded 1-2 inches prior to R2 (see guide page 55). And, by using **SoyWater**, the producer was able to schedule the date and amount of the last irrigation to save about one more inch.

A dual corn and soybean irrigation scheduling website was also recently developed and made available at: http://hprcc-agron0.unl.edu/cornsoywater/public_html/Home.php.

The impact of **delaying the first scheduled irrigation until R3** in a field with a silty-clay-loam soil at a field capacity water content at planting (early May) was examined in recent UNL research *[Reference: Torrion et al. (2014)]*. When irrigation was commenced at stage **R3** (begin pod), to avoid applying it during **R1-R2** (flowering), yields were higher (**blue** *vs.* **green** bars). Full-season **deficit** irrigation (i.e., 1/3 of seasonal crop water use NOT replenished), did "save" about 3 inches of irrigation (11.7-7.8 and 11.1-7.5), but also resulted in significantly lower yields (**orange** bars). The July-August rainfall in each year was low; thus, non-deficit irrigation yields were about 46 to 82 percent higher than **rainfed-only** check yields (**brown** bars). Dividing the **2006** irrigation-induced **yield boosts** of **37.2**, **33.2** and **23.9** bu./acre by the **11.7**, **11.7** and **7.8** acre-inch amounts of applied water resulted in **IWUE values** of **3.2**, **2.8** and **3.1** **bu./acre per acre-inch**. Dividing the **83.2**, **78.0**, **69.7** and **45.8** bu./acre yields by the sum of the rain (8.3) + irrigation amounts of **22.0**, **22.0**, **16.5** (+2*) and 0 (+4**) inches resulted in **Water Productivity (WP) values** of **3.78**, **3.54**, **4.22** (3.77*) and **5.51** (3.72**) versus the **3.7** bu./acre-inch value in the guide page 88 chart. The computed (WP**) values account for the extra 2 and 5 inches of soil water depleted by the deficit and check treatments **between** planting (100% field capacity) **and** stage R7 end of soybean root water extraction.



SOYBEAN SCOUTING CALENDAR:

PLANT PATHOLOGY
Institute of Agriculture and Natural Resources

A UNL soybean scouting calendar in an electronic format was recently released for soybean producers: https://cropwatch.unl.edu/2016/new-soybean-web-tool-focuses-current-pest-management-tasks. This new scouting calendar, known as **SoyCal**, can be accessed at: http://cropwatch.unl.edu/soycal/.

SoyCal provides the user with seasonal calendar date timelines (and soybean Vn and Rn dates) that represent the best times to scout fields for (1) known soybean diseases, (2) insects known to feed on soybeans, and (3) weeds that may emerge in soybean fields. The output includes photos and videos that will help the SoyCal user make an initial diagnosis or identification, and provides recommendations and research results to aid in management decisions. A quite unique feature is an option that allows a producer to customize SoyCal to display scouting timelines specific for each soybean field on a farm. The user needs only to input into SoyCal the field location and date of planting, and the MG of the planted variety. You will find this SoyCal field-specific option quite handy!

NEBRASKA SOYBEAN INSECT PESTS:

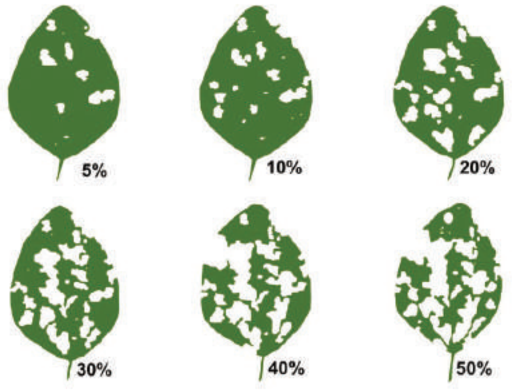
The soybean insect photos in this section will help you make an **initial identification** when you scout a field and discover what appears to be insect-feeding injury on multiple plants in the field. **To confirm your initial identification**, collect the insect, and collect leaf, stem, and/or root tissue that the insects damaged, and bring these to any county extension office (see guide page 374). For an expert diagnosis, submit the insect specimens and tissue samples to the Nebraska Plant and Pest Diagnostic Clinic (see page 7 for how-to-submit details). The clinic will identify the insect and provide written UNL recommendations relative to the control of that insect.

For more detailed coverage of soybean insects, go to:
http://cropwatch.unl.edu/insect/soybeanpestmgt.
For two publications that have insect photos, go to:
http://extensionpublications.unl.edu/assets/pdf/ec1574.pdf.
http://extensionpublications.unl.edu/assets/pdf/ec1575.pdf.
http://soybeanresearchinfo.com/soybeanpests.html.

Insecticides Available for Soybean Insect Control:
This pocket guide is too small to include comprehensive information about currently available seed treatment or foliar spray insecticides. We recommend the purchase of the ***Guide for Weed, Disease and Insect Management – UNL Extension Circular EGC130***. This publication is available for $15 in a printed form or as a PDF at:
https://marketplace.unl.edu/extension/ec130.html.
See pages 300-306, and 310-314 in the 2018 **EC130** for soybean insecticide information.

HOW TO ASSESS INSECT-MEDIATED LEAF DEFOLIATION:

The degree of insect-mediated leaf defoliation can vary from 0 to 100 percent. Use the below photos of six leaves that exhibit a 5 to 50 percent gradient in leaf defoliation as a guide for assessing insect feeding in a scouted soybean field.

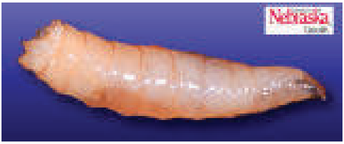


Reference: W.J. Ohnesorg & T.E. Hunt, Managing soybean defoliators
http://extensionpublications.unl.edu/assets/pdf/g2259.pdf.
https://cropwatch.unl.edu/2016/decision-making-soybean-defoliating-insects.

You should scout soybean fields once or twice a week to ensure that increased insect feeding is detected early enough to schedule any needed corrective action – use the new Nebraska-specific scouting calendar app (see guide page 92). For a detailed insect-only specific scouting calendar, *see:* https://extension.entm.purdue.edu/fieldcropsipm/soybean.php.

In the vegetative stages (i.e., pre-R1 flowering), consider treatment if the particular insect is present, and if it is feeding to the extent that defoliation is likely to soon exceed 30% leaf area loss.
In the reproductive stages (i.e., R3-R4 pod-forming and R5-R6 seed-filling), the equivalent criterion for considering treatment is >20% leaf area loss.

SEEDCORN MAGGOT *(Delia platura)*:



Description: Pale, yellowish white maggot. Unlike grubs and caterpillars, **maggots lack defined heads and legs**.

Seasonal Peak: Planting to mid-June (**stages VE-V2**).

Tissue Injured: Reduce stands by burrowing into seeds and destroying the germ, especially in heavily manured/high-residue fields. Usually cause damage when germination and growth are slowed due to cold and wet conditions.

Sampling: Scouting is usually initiated only after damage or poor emergence has been noted. Dig up non-germinated seeds to determine the presence or absence of maggots or puparia. Seed remnants often rot due to secondary fungal infections.

Economic Threshold: No rescue treatments are available. Use of an appropriate rate of seed-applied insecticide is advised if planting or replanting into heavily manured or residue-covered fields. Control with **seed-applied insecticides is generally satisfactory**.

References or Informative Websites:
http://www.ent.iastate.edu/soybeaninsects/seedcorn_maggot.
http://www.soybeanresearchinfo.com/pests/insectpests.html.

WHITE GRUBS *(Cyclocephala, Phyllophaga, Popillia,* spp.*)*:

Description: White, C-shaped larvae with large brown heads. The true white grub (*Phyllophaga*) is the most troublesome, especially following sod or forages.

Seasonal Peak: April to late June (**stages VE-V8**). See also **SoyCal**: http://cropwatch.unl.edu/soycal/app/index.html.

Tissue Injured: Root pruning, wilting, and possible plant death; may result in gaps along row.

Sampling: It is very difficult to sample the white grub population in a field because they are patchy in distribution and often burrowed deep into the soil before planting. One method is to dig up a soil sample before planting 2 feet long x 1 foot wide x 6 inches deep (1 cubic foot) in 5 areas of a field and sort for grubs. Also look for grubs during spring tillage.

Economic Threshold: Do not plant soybeans if two or more true white grubs per cubic foot of soil are found. Japanese beetle or Cyclocephala grubs are not known to cause economic root damage in soybeans. **No rescue treatments are available.**

References or Informative Websites:
http://www.ent.iastate.edu/soybeaninsects/grubs.
http://www.soybeanresearchinfo.com/pests/insectpests.html.

WIREWORMS: *(Agriotes, Limonius,* spp.*)*:

Description: Slender, hard-bodied, brownish larvae.

Seasonal Peak: April to late June (**stages VE-V8**). See also **SoyCal**: http://cropwatch.unl.edu/soycal/app/index.html.

Tissue Injured: Feed on the seed or seedling below ground causing wilting and sometimes plant death, resulting in gaps along row.

Sampling: Two to three weeks before planting, set up five bait stations in different areas of a field with a suspected infestation. The bait station protocol is described at: https://extension.entm.purdue.edu/fieldcropsipm/insects/soybeanwireworms.php.

Economic Threshold: No rescue treatments are available. Seed-applied insecticides generally protect stands with low to moderate wireworm infestations. Among early-season root-feeding pests, high wireworm populations are difficult to manage with seed-applied insecticides.

References or Informative Websites:
http://www.soybeanresearchinfo.com/pests/insectpests.html.

BEAN LEAF BEETLE *(Cerotoma trifurcata)*:

Description: Yellow, tan, or red beetles with a distinct black triangular mark between the wing covers, behind the head (black spots sometimes present on wing covers).

Seasonal Peak: Two generations per year after over-wintering beetles feed on young stage V0-V2 seedlings (notably the earliest planted fields), before laying eggs in the soil below seedlings. The larva feed on root nodules.

Tissue Injured: Leaf defoliation and pod feeding (scarring).

Sampling: Inspect five plants in five field areas and estimate percent defoliation, or inspect all pods in two linear feet of row in those five areas to estimate percent pod damage.

Economic Threshold: During the vegetative stages, consider treatment if leaf-feeding beetles are present and defoliation is expected to exceed 30 percent. During the reproductive stages, consider treatment if the beetles are feeding on leaves and defoliation is expected to exceed 20 percent. Also consider treating if there are 10 or more beetles per foot of row feeding on pods, and 5 percent pod damage is expected.

BEAN LEAF BEETLE (*Cerotoma trifurcata*) (CONT.):

Pods damaged by beetles can lead to fungal pathogen entry that damages developing seeds, which leads to a seed quality price discount. In the below table, the damaged seed numbers per foot in 30-inch rows are **threshold break-even values** for the per-acre cost of a beetle-controlling treatment versus soybean price. For 15- or 7.5-inch rows, divide the tabulated seed numbers for 30-inch rows by 2 or 4, respectively. To convert damaged seed numbers to damaged pod numbers, divide by 2.5 (a typical seed/pod value).

	Acre Cost of a Beetle-Controlling Treatment					
Soybean	$10	$12	$14	$16	$18	$20
Bu. Price	Number of damaged seeds/foot (30"rows)					
$8	12	14	17	19	22	24
$9	11	13	15	17	19	21
$10	10	12	13	15	17	19
$11	9	11	12	14	16	18
$12	8	9.6	11	13	14	16

Assumptions: 168,000 seeds per harvested bushel (2800 seeds/pound). Compare damaged seed number loss on a price/acre yield loss to the current price/acre treatment cost.

NOTE: Bean leaf beetles (BLB) can transmit the bean pod mottle virus (BPMV) (see guide page 132). BPMV infection reduces yields, notably so when over-wintering beetles transmit BPMV to seedlings, which later serve as plant-infected BPMV reservoirs that 1st and 2nd generation BLBs feed on and then vector BPMV to other plants. BLB feeding seedling injury is NOT as critical as BLB-vectored BPMV. Consider using an insecticide seed treatment in early planted fields.

References or Informative Websites:

https://entomology.unl.edu/insecticide-treatment-options-bean-leaf-beetle-soybean.
https://cropwatch.unl.edu/insect/beanleafbeetleid.
https://academic.oup.com/jipm/article/3/1/B1/807688.
https://www.ent.iastate.edu/soybeaninsects/bean_leaf_beetle.

To estimate defoliation for this insect, see:
http://extensionpublications.unl.edu/assets/pdf/g2259.pdf.

JAPANESE BEETLE (*Popillia japonica*):


Description: Adults are metallic green with bronze-colored wing covers and white tufts of hair around the abdomen.

Seasonal Peak: July to September (stages R1–R6). See also **SoyCal:** http://cropwatch.unl.edu/soycal/app/index.html.

Tissue Injured: Adults skeletonize leaves leaving some veins intact. The larvae feed on soybean roots (also see guide page 95 that has text on white grubs).

Sampling: Examine five plants in each of five areas of a field to estimate percent of defoliation.

Economic Threshold: In vegetative (pre-flowering) stages, consider treatment if the insects are present and feeding, and if defoliation is expected to exceed 30 percent. In pod-forming or pod-filling stages, consider treatment if the insects are present and if the defoliation is expected to exceed 20 percent. Spot treatments may be adequate.

References or Informative Websites:
https://cropwatch.unl.edu/2018/scout-corn-and-soybean-japanese-beetles.
http://www.soybeanresearchinfo.com/pests/insectpests.html.
http://www.ent.iastate.edu/soybeaninsects/japanese_beetle.
http://www.ent.iastate.edu/soybeaninsects/grubs.

To estimate defoliation for this insect, see:
http://extensionpublications.unl.edu/assets/pdf/g2259.pdf.
http://cropwatch.unl.edu/2016/decision-making-soybean-defoliating-insects.

SOYBEAN APHID (*Aphis gylcines*):

Description: Small, barely visible; usually yellow to green, sometimes white; globular shaped; not very mobile.

Seasonal Peak: June through August (**stages R1-R6**). See also **SoyCal**: http://cropwatch.unl.edu/soycal/app/index.html.

Tissue Injured: Aphid removes sap from plant phloem tissue using its needle-like sucking mouth parts. Most are found on lower side of leaves.

Sampling: If aphids are present, inspect 20 plants in various areas of a field and calculate average number of aphids per plant. Also take note of any plant stress (drought), and the presence or absence of aphid predators (e.g., lady beetles), or any observed diseased aphids (discolored and fuzzy).

Economic Threshold: Consider treatment in the late vegetative through R5 stage soybeans if there are 250 aphids per plant, 80 percent of the plants are infested, and the aphid populations increasing. Aphids transmit SMV - see guide page 133.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/html/g2063/build/g2063.htm.
http://extensionpubs.unl.edu/publication/9000016368033/soybean-aphid-speed-scouting-spreadsheet/.
https://cropwatch.unl.edu/insect/soybeanaphid.
http://cropwatch.unl.edu/2016/soybean-aphid-management.
http://www.soybeanresearchinfo.com/pests/aphid.html.
http://www.ent.iastate.edu/soybeaninsects/aphids.

SOYBEAN THRIPS (*Neohydatothrips variabilis*):

Description: Immature thrips are elongated, white to orange-yellow, and wingless. Brownish-black adults have yellow stripes and two pairs of fringed wings that lay flat on the back.

Seasonal Peak: May through August (**stages V1-R7**). See also **SoyCal:** http://cropwatch.unl.edu/soycal/app/index.html.

Tissue Injured: Rarely a pest, but many tiny, longitudinal scars on leaves can lead to leaf discoloration (mottling). Thrips can vector the soybean vein necrosis virus (SVNV), a new viral disease, but there is not much information yet available to assess its yield impact (see guide page 134).

Sampling: Look for mottling along the leaf's veins. Use a hand magnifying lens to look for thrips on leaf undersides.

Economic Threshold: Dry weather with more than 75 percent of the trifoliolates mottled by 8 or more thrips per leaf.

References or Informative Websites:

https://extension.entm.purdue.edu/fieldcropsipm/insects/soybean-thrips.php.

http://graincrops.blogspot.com/2016/07/how-to-monitor-and-when-to-control.html.

GREEN CLOVERWORM (*Hypena scabra*):

Description: Larvae are pale yellow to green. They have two narrow white body stripes, and have three pairs of prolegs near its body center and one pair near its tail end. A similar greenish caterpillar is the soybean looper (*Pseudoplusia includens*), but it has only two proleg pairs at its center.

Seasonal Peak: July to leaf abscission (**stages V6-R7**). See also **SoyCal:** http://cropwatch.unl.edu/soycal/app/index.html.

Tissue Injured: Leaf defoliation, ragged holes in the leaves.

Sampling: Inspect five plants in five areas of a field and estimate percent defoliation.

Economic Threshold: In vegetative (pre-flowering) stages, consider treatment if the insects are present and feeding, and defoliation will be greater than 30 percent. In pod-forming or pod-filling stages, consider treatment if the insects are present and defoliation will be greater than 20 percent. Before considering chemical control, determine percentage of larvae diseased (discolored) and/or parasitized (white eggs on larvae).

References or Informative Websites:
http://cropwatch.unl.edu/insect/geencloverwormid.
http://www.ent.iastate.edu/soybeaninsects/green_cloverworm.
http://www.ent.iastate.edu/soybeaninsects/soybean_looper.
http://soybeanresearchinfo.com/pests/greencloverworm.html.
To estimate defoliation for this insect, see:
http://extensionpublications.unl.edu/assets/pdf/g2259.pdf.
http://cropwatch.unl.edu/2016/decision-making-soybean-defoliating-insects.

GRASSHOPPERS (*Melanoplus* spp.):

Description: Adults are gray to brown. Nymphs resemble adults but are smaller and lack developed wings.

Seasonal Peak: June to pod maturity (**stages V1-R8**). See also **SoyCal:** http://cropwatch.unl.edu/soycal/app/index.html.

Tissue Injured: Irregular holes chewed in leaves (usually extending from leaf margin inward) to 100 percent defoliation.

Sampling: Damage is typically greatest on field edges, which should alert you to the need for more detailed field evaluation. Estimate damage and grasshoppers per square yard in five different locations throughout the field.

Economic Threshold: Eight or more adults or 15 or more nymphs per square yard in the field borders. In vegetative (pre-flowering) stages, consider treatment if the insects are present and feeding, and defoliation will exceed 30 percent. In pod-forming or pod-filling stages, consider treatment if the insects are present and defoliation will exceed 20 percent. Spot treatments may be adequate.

References or Informative Websites:

http://cropwatch.unl.edu/insect/grasshoppers.
http://extensionpublications.unl.edu/assets/pdf/ec1569.pdf.
http://cropwatch.unl.edu/2016/watch-grasshoppers-crops.
http://soybeanresearchinfo.com/pests/grasshoppers.html.
http://www.ent.iastate.edu/soybeaninsects/grasshoppers.

To estimate defoliation for this insect, see:

http://extensionpublications.unl.edu/assets/pdf/g2259.pdf.
http://cropwatch.unl.edu/2016/decision-making-soybean-defoliating-insects.

TWO-SPOTTED SPIDER MITE (*Tetranychus urticae*):

Description: These tiny eight legged spider-like arachnids (visible only with a magnifying lens) are white, green, or reddish with two distinct dark spots on each body side.

Seasonal Peak: Mid-May to September (**stages V2-R7**). See also **SoyCal:** http://cropwatch.unl.edu/soycal/app/index.html.

Tissue Injured: At first, leaves appear stippled, but later seem sand-blasted or bronzed; heavily infested leaves turn red-brown and die. Damaged areas will not recover.

Sampling: Inspect five field areas for mites and discoloration. Shake suspect leaves over white paper; look for "moving specks." Inspect leaf undersides for mites and/or eggs. Mites are more prevalent during hot, dry weather.

Economic Threshold: If leaf discoloration and mite presence are apparent, and hot, dry conditions are expected to persist, consider treatment. Just border treatment may be needed (infestations often begin at field margins) with early detection of a mite problem.

References or Informative Websites:

http://cropwatch.unl.edu/2016/identifying-spider-mite-damage-species-responsible.
http://www.soybeanresearchinfo.com/pests/mites.html.
http://www.ent.iastate.edu/soybeaninsects/two-spotted_spider_mite.

GREEN STINK BUGS (*Acrosternum hilare*) AND BROWN STINK BUGS (*Euschistus servus*):

Description: Green stink bug adults have black banded antennae. Brown stink bug adults are solid mottled brown and have rounded shoulders. Nymphs have a variety of dark and light colors and are wingless.

Seasonal Peak: Mid-July to harvest (**stages R3-R7**). See also **SoyCal:** http://cropwatch.unl.edu/soycal/app/index.html.

Tissue Injured: A straw-like mouthpart penetrates pods and removes seed fluids causing discolored, deformed, and/or small beans.

Sampling: Take 20 sweeps (using a sweep net) in five different locations in a field. Use average number of bugs per sweep.

Economic Threshold: Commercial: 40 stink bugs per 100 sweeps (0.4 bugs per sweep) and pods are still green. Seed: 20 stink bugs per 100 sweeps (0.2 bugs per sweep) and pods are still green.

References or Informative Websites:
http://cropwatch.unl.edu/stink-bugs-reported-nebraska-corn-and-soybeans.
http://soybeanresearchinfo.com/pests/stinkbug.html.
http://www.ent.iastate.edu/soybeaninsects/stink_bugs.

STEM BORER (*Dectes texanus*):


Description: Adult is a gray elongated beetle about ½-inch long, with black/gray banded antennae longer than the body. Larvae are cream-colored, legless, and widest at the head with the body gradually narrowing to the tail end and are ½- to ⅝-inch long at maturity.

Seasonal Peak: Adults are active from late June through August, with one generation/year. Females lay eggs singly on the leaf petioles. See also **SoyCal:** http://cropwatch.unl.edu/soycal/app/index.html.

Tissue Injured: Initial injury occurs when the hatched larvae tunnel down the leaf petiole to enter the stem, causing the leaf to wilt/die in an otherwise healthy canopy. Larvae then tunnel up and down the stem, ending up at the base of the plant at plant maturity where the girdling of the plant stem there weakens stem sturdiness.

Sampling: Split open stems to look for tunneling larvae at plant maturity. Estimate number of tunneled plants/foot.

Economic Threshold: Economic loss arises from girdled plants falling to the ground before harvest. Lodging may be greater in early planted fields and in early MG varieties. Harvest the heaviest infected fields first.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/g2082.pdf.
http://cropwatch.unl.edu/2016/soybean-stem-borer-feeding-south-central-nebraska.
http://www.soybeanresearchinfo.com/pests/borer.html.
http://www.ent.iastate.edu/soybeaninsects/dectes_stem_borer.

SOYBEAN GALL MIDGE (RESSELIELLA SPP.):

Description: Adults are about ¼-inch long with black and white banded legs and an orange abdomen (not visible, under wings). Larvae are legless, change from white to orange and are about $^{1}/_{10}$-inch long at maturity.

Seasonal Peak: Little is known about soybean gall midge field movement. Adults present in early- to mid-August.

Tissue Injured: Injury typically occurs below the unifoliate node appearing as a darkened area on the stem. Removal of the outer tissue reveals larvae feeding within or at the leading edge of these darkened areas. Heavily infested plants may wilt during the day under high temperatures.

Sampling: Damage is usually greatest at the field edge. Plants with darkened stems should be split or peeled to determine if larvae are present prior to R8.

Economic Threshold: Economic losses caused by plant death, but stem-damaged surviving plants also yield less. Weakened stems increase lodging risk, so fields with heavy infestations should be harvested first.

References or Informative Websites:
https://cropwatch.unl.edu/2018/survey-orange-gall-midge.
https://cropwatch.unl.edu/2018/soybean-gall-midge-adult-stage-identified.
https://crops.extension.iastate.edu/cropnews/2018/07/new-soybean-pest-iowa-soybean-gall-midge.

NEBRASKA SOYBEAN DISEASES (PLUS THE PARASITE SCN):

PLANT PATHOLOGY
Institute of Agriculture and Natural Resources

For a customized farm-field-specific soybean disease scouting calendar, go to the **SoyCal** website (guide page 92). The disease symptom photos herein will help you make an **initial diagnosis** when you discover what looks to be a diseased plant. **To confirm your initial diagnosis,** collect the symptomatic leaf, stem and/or root tissue, and bring it to a Nebraska Extension office (see guide page 374). **Diagnostic services are also provided by the University of Nebraska Plant and Pest Diagnostic Clinic** (see guide page 7 for details on how to submit). The clinic will provide an official diagnosis and provide written recommendations.

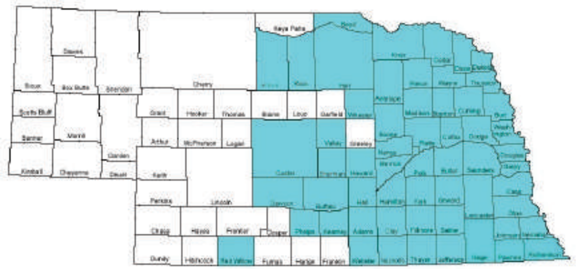
For much more detail on any soybean disease, click on any disease listed on the right side of the 1st webpage listed below. For more photos see websites in the list below:
http://cropwatch.unl.edu/plantdisease/soybean.
http://extensionpublications.unl.edu/assets/pdf/ec1903.pdf.
http://extensionpublications.unl.edu/assets/pdf/ec1904.pdf.
http://cropprotectionnetwork.org/encyclopedia/.
https://cropprotectionnetwork.org/resources/articles/diseases.

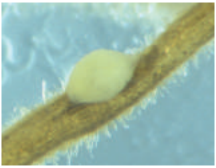
To view videos of UNL Plant Pathologist Dr. Loren Giesler discussing various soybean diseases and recommendations:
https://www.youtube.com/playlist?list=PLdssrgg38jJ3YVfPKvQ_KT2f_zOMlvaoP.

For comprehensive coverage of NE-specific soybean diseases:
https://cropwatch.unl.edu/2018/2018-weed-disease-and-insect-management-guide.
See pages 241, & 249-255 in 2018 NE EC130 for soybean fungicides and cost per acre information. Purchase it at:
https://marketplace.unl.edu/extension/ec130.html.

SOYBEAN CYST NEMATODE (*Heterodera glycines*):

SCN is a major Nebraska yield-reducing pest detected in 58 (94%) of the Nebraska counties where soybeans are grown.

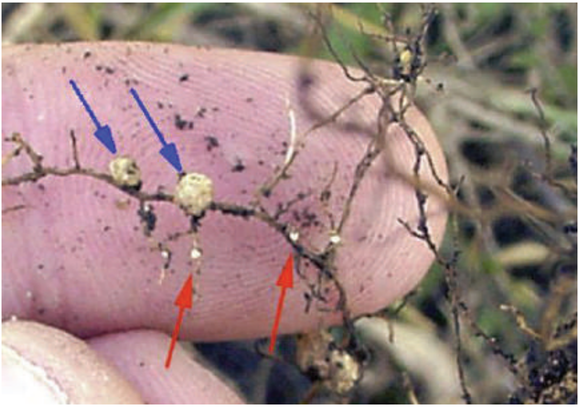




The most obvious SCN indicator is a "cyst" present on a root. Soybean fields with a severe SCN infestation (see below photo) will suffer a substantial yield loss. However, expect at least a 5-10 bu./acre (or more) yield loss even in fields that have a moderate SCN infestation, despite the lack of any visible above-ground symptoms of stunting, leaf yellowing, or plant death, exclusive of similar symptoms caused by diseases or by soil factors (e.g., nutrient deficiency).

SOYBEAN CYST NEMATODE (CONT.):

Inexperienced observers may not recognize the difference between cysts and N-fixing nodules. However, the below photo shows that cysts (red arrows) are much smaller than fully developed N-fixing nodules (blue arrows).



Description: SCN is a plant-parasitic roundworm that survives in a persistent stage referred to as a cyst. When soybean or other hosts are present, the eggs hatch to release juvenile nematodes that are attracted to the roots where they move to the vascular tissue (i.e., phloem) for feeding. Eventually the female enlarges and ruptures through the root. The amber colored egg-filled lemon-shaped body of the dead female is what is referred to as the cyst. Each cyst can contain up to 400 eggs.

Damage: Infestations can occur at any time, though symptoms, if any, could appear during any stage of development depending on population density of SCN. Yellowing and stunting of plants, typically in circular or oval patches that run elongated in the direction of any equipment movement. Symptoms can be more severe if drought, nutrient deficiency, or disease is also stressing the crop.

Sampling: In most SCN-infested fields in Nebraska, females are usually evident on soybean roots by July 4; however, the absence of visible cysts on the roots at any seasonal time is not a guarantee the field is free of SCN. In fact, in fields with a low SCN population, a few cysts on roots will be missed if the scouting for SCN is insufficient. The only sure way to confirm the presence of SCN in a field is a soil test. The UNL Plant and Pest Diagnostic Clinic (guide page 7) offers soybean cyst nematode sample analysis. Collect a composite sample of 20-25 six-inch deep soil samples (taken with a soil coring tool) from random locations in a given field. Of course, if you strongly suspect that an SCN patch might be present in your field, be sure to include a soil sample from that patch. Detailed SCN sampling instructions are provided in the "Sampling Procedure" section of the first website reference listed below.

Economic Threshold: Once a field is infested with SCN, the parasite cannot be eradicated. The main management tool is the use of an SCN-resistant variety. Such varieties have differing sources of their SCN resistance genes, so it is recommended to rotate resistant varieties, given the adaptability of SCN to eventually overcome host plant resistance. Nematicides and biological seed treatment are not consistently yield-improving, but can be integrated into an overall management plan. Finally, thoroughly clean (to the extent possible) equipment used in an SCN-infested field (i.e., planters, cultivators, combines, etc.) to avoid the transfer of SCN to fields not yet SCN-infested.

References and Informative Websites:

http://cropwatch.unl.edu/plantdisease/soybean/soybean-cyst-nematode.
http://cropwatch.unl.edu/2016/scn-scouting-recommendation-changed-scn-resistance-possible.
http://extensionpublications.unl.edu/assets/pdf/g1383.pdf.
http://www.soybeanresearchinfo.com/diseases/scn.html.

BACTERIAL LEAF BLIGHT (*Pseudomonas savastanoi* pv. glycinea):

Description: Angular, dark spots on leaves with water-soaking visible on leaf underside. Centers of older lesions will darken and can fall out leaving a tattered appearance.

Epidemiology: Pathogen survives in residue and on seed. Plants from infected seed can have lesions on cotyledons. Cool, wet weather favors bacterial blight (70-80° F). Symptoms will typically be confined to tissue zones on the plant that were injured by hail and/or by wind-driven raindrops in thunderstorms. Hot weather slows development.

Management: Select varieties that are less susceptible to the disease. Crop rotation can help reduce overwintering inoculum. Tillage will aid in residue breakdown to further minimize disease overwintering. Avoid traffic in fields when canopies are wet as this can spread the disease.

References or Informative Websites:
http://cropwatch.unl.edu/bacterial-blight-soybeans.
http://extensionpublications.unl.edu/assets/pdf/g2058.pdf.
http://www.soybeanresearchinfo.com/diseases/bacterialblight.html.

BACTERIAL PUSTULE (*Xanthomonas axonopodis* pv. glycines):

Description: Small spots with raised centers (pustules) on bottom leaf sides (photos). Individual spots can coalesce, developing into larger, irregular-shaped brown areas. Centers of older lesions are dark and typically do not fall away as with bacterial blight, and water soaking is not observed.

Epidemiology: Pathogen survives primarily in soybean residue and on seeds. Splashing rain or equipment moving through fields when leaves are wet can spread the disease. Disease development is favored by hot, wet weather (86-92° F).

Management: Select varieties that are less susceptible to the disease. Rotation away from soybean can help avoid overwintering inoculum. Tillage will help destroy infected residue and minimize disease impact. Avoid cultivation when foliage is wet to reduce injury and disease spread.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/soybean/bacterial-pustule.
http://extensionpublications.unl.edu/assets/pdf/g2058.pdf.
http://www.soybeanresearchinfo.com/diseases/bacterialpustule.html.

ANTHRACNOSE (*Colletotrichum truncatum*):

Description: Typically a late-season disease observed on mature soybeans. Early infection results in reddish veins, leaf rolling and premature defoliation. Stems and petioles typically have red to dark brown blotches. Early pod infection can result in seedless pods. Black fruiting structures (acervuli) are produced on infected plant parts.

Epidemiology: The fungus survives on infested crop residue and infected seed. Most infections occur during the late reproductive stages. Long periods of free moisture (≥12 hours) and warm weather are required for infection.

Management: No resistance is available for this disease but varieties can vary in susceptibility. Crop rotation and tillage can reduce overwintering. Fungicide applications, if needed, should be made during early reproductive stages, but may be warranted only in limited situations.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/soybean/anthracnose.
http://www.soybeanresearchinfo.com/diseases/anthracnose.html.
http://www.soybeanresearchinfo.com/pdf_docs/CPN1002_ScoutingSoybeanStemDiseases051515.pdf

BROWN SPOT (*Septoria glycines*):

Description: Small, angular, light brown lesions form on leaves (photo), typically starting in the lower canopy. Lesions can grow together to form large irregular-shaped lesions. Infected leaves eventually turn yellow and drop prematurely. Lesions are not commonly observed on stems, petioles and pods.

Epidemiology: Fungus survives on crop residue and will be more severe in fields where soybean is continuously grown. Prolonged periods of warm and wet weather with moderate temperatures (60-85° F) favor this disease.

Management: Varieties vary in susceptibility but are not typically rated. Crop rotation and tillage will help reduce overwintering inoculum. Fungicides applied at R3 to early R4 will slow disease development and may be needed on fields prone to problems with brown spot.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/soybean/brown-spot.
http://extensionpublications.unl.edu/assets/pdf/g2059.pdf.
http://www.soybeanresearchinfo.com/diseases/septoria.html.

BROWN STEM ROT (*Phialophora gregata*):

Description: Foliar symptoms of BSR will vary depending on the soybean variety and fungal type in the field. In some cases, no foliar symptoms will be present, but in most cases, interveinal chlorosis and necrosis occur on leaves. Foliar symptoms are similar to sudden death syndrome (see guide page 131), but dead leaflets in BSR remain attached. Onset of foliar symptoms is typically at stage R4-R5. Left photo: stem pith (center) is brown, but the cortex is normal (this will not be the case with SDS).

Epidemiology: Fungus survives in soybean residue, especially when left on soil surface. Cool, wet weather during flowering favors disease development. Higher temperatures and dry conditions suppress foliar symptoms.

Management: Select varieties that are resistant and include SCN resistance in SCN infested fields. Crop rotation for two or more years will significantly reduce disease potential. Tillage will aid in breaking down infected residue.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/soybean/brown-stem-rot.
http://www.soybeanresearchinfo.com/diseases/brownstemrot.html.
http://www.soybeanresearchinfo.com/pdf_docs/CPN1002_ScoutingSoybeanStemDiseases051515.pdf

CERCOSPORA LEAF BLIGHT & PURPLE SEED STAIN (*Cercospora kikuchii*):

Description: Symptoms occur from the time of seed set onward and start in the upper canopy. Leaves become dark red and leathery. Irregular purple lesions develop on the leaves (photo) and veins on leaf underside will often have dark purple lesions. Infected leaves will prematurely drop, but their petioles remain attached to stem. Lower leaves will remain green. Purple seed blotching occurs and can range from just specks to coloration of the entire seed coat that spreads outward from the hilum (photo).

Epidemiology: The fungus survives in crop residue and infected seed. Warm conditions with high humidity favor the disease. Leaf blight and purple seed stain may not always be observed to occur together, even though both are caused by the same fungus.

Management: Select varieties resistant to Cercospora leaf blight. Resistance to purple seed stain is known, but has not yet been introduced into high-yield varieties. Rotation away from soybean can help reduce overwintering inoculum and tillage will help break down infected residue and minimize disease potential. Seedlots with a high percentage of purple seed stain should be treated with a seed treatment fungicide before planting.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/soybean/purple-seed-stain.
http://www.soybeanresearchinfo.com/diseases/cercosporaleafblight.html.

CHARCOAL ROT (*Macrophomina phaseolina*):



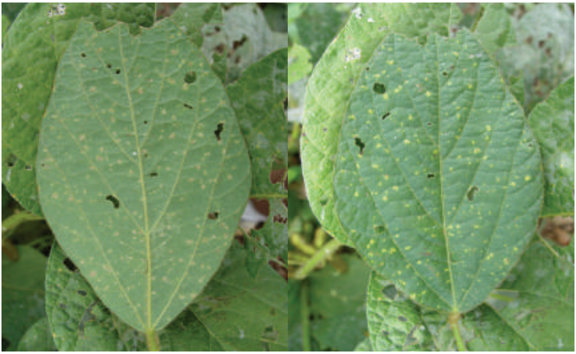
Description: Early-season infection appears as red-brown lesions similar to those caused by Rhizoctonia. Initial symptoms later in the season are patches of wilted plants. Yellowing of top leaves and early senescence are associated with the disease. Root system will typically be rotted and black streaks will be evident in the lower woody stem and crown. Small black specks (microsclerotia) can be seen just beneath the epidermis of the roots and lower stems.

Epidemiology: Microsclerotia survive in soil and on soybean residue. The fungus has a very broad host range and infects corn and sorghum as well as soybean. Root infection can occur very early in the season; hot, dry weather favors symptom expression during reproductive stages.

Management: Select varieties that are less susceptible to the disease. A two-year rotation away from soybean can help reduce overwintering; however, it should include a small grain. Avoid high seeding rates to reduce plant completion for water and nutrients during dry seasons.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/soybean/charcoal-rot.
http://www.soybeanresearchinfo.com/diseases/charcoalrot.html.
http://www.soybeanresearchinfo.com/pdf_docs/CPN1002_ScoutingSoybeanStemDiseases051515.pdf

DOWNY MILDEW (*Peronospora manshurica*):



Description: Small light-yellow spots occur on the upper leaf surface. These will be more common on younger leaves which are more susceptible. Underside of the leaf will have fuzzy, gray tufts beneath chlorotic spots of upper leaf surfaces. Lesions will vary in size. Infected pods will not exhibit external symptoms, but a seed may have a white, crusty, fungal growth on it. Seed coats may be cracked and seed will be smaller.

Epidemiology: The fungus survives on residue and seed. Long periods of leaf wetness with high humidity and moderate temperature are favorable for infection. This disease does not typically develop to significant levels due to older leaves being more resistant and warmer temperatures not being favorable for development.

Management: The disease rarely causes economic yield loss. Varieties vary in resistance and many biotypes of the pathogen exist. Crop rotation and tillage will reduce overwintering inoculum.

References or Informative Websites:
http://www.soybeanresearchinfo.com/diseases/downymildew.html.

FROGEYE LEAF SPOT (*Cercospora sojina*):

Description: The leaf exhibits small circular specks that are dark reddish-brown to purple. These small spots eventually enlarge to ¼-inch in diameter, and have a tan center with a reddish brown or purple outer ring. Infected leaves may prematurely drop. Lesions on stems and pods are not as common, but appear as red-brown lesions that also develop light colored centers with dark margins as they mature. Infected seed can have light to dark gray blotches with cracked seed coats.

Epidemiology: Fungus survives in soybean residue and on infected seed. Early season infection develops inoculum for later season infection that is favored by warm, humid weather. Young leaves are more susceptible to infection than older leaves. It is very common for this disease to be layered in the canopy during specific growth stages that had favorable weather for disease development. It is most commonly observed in the upper canopy.

Management: Plant resistant varieties in fields with a history of the disease. Rotation and tillage can help reduce overwintering inoculum. Resistance to strobilurin fungicides has been documented in the U.S. for this pathogen; fungicides with multiple (two or more) modes of action are recommended at the R3 to early R4 stages.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/soybean/frogeye-leaf-spot.
http://extensionpublications.unl.edu/assets/pdf/g2213.pdf.
http://www.soybeanresearchinfo.com/diseases/frogeyeleafspot.html.

POWDERY MILDEW (*Microsphaera diffusa*):

Description: Dusty-like appearance of the white, fungal growth on leaves. Primarily the upper leaf surface will be affected. Typically occurs in the mid to late reproductive stages. Leaves can become chlorotic and premature defoliation can occur.

Epidemiology: The fungus survives on crop residue and is more prevalent during cool and cloudy conditions. Disease can be more severe in later planted soybeans

Management: Most varieties have some resistance to this disease. Fungicides can be used, but in only a few cases will a fungicide actually be needed.

References or Informative Websites:
http://soybeanresearchinfo.com/diseases/powderymildew.html.

PHYTOPHTHORA ROOT & STEM ROT (*Phytophthora sojae*):

Description: This fungus can affect plants at any growth stage. Seedling symptoms can include seed decay and damping. On older plants, wilting and premature plant death occurs. Dark brown to black stem discoloration will extend from the soil line upward on the plant and be visible on the outside.

Epidemiology: The fungus survives as resistant spores (oospores) in soil and crop residue. Fine textured soil and wet conditions favor disease development.

Management: Use of disease-resistant varieties is the best management practice. Varieties with genes for race-specific Phytophthora-resistances – combined with a good score for partial resistance – are recommended. Avoid planting into wet, compacted soils, and improve soil drainage if possible. Fungicide seed treatments containing metalaxyl or mefenoxam can be useful in fields that have surface depressions where water collects and results in wetter soil than elsewhere in the field.

References or Informative Websites:

https://cropwatch.unl.edu/plantdisease/soybean/phytophthora-root-and-stem-rot.

http://extensionpublications.unl.edu/assets/pdf/g1785.pdf.

http://www.soybeanresearchinfo.com/diseases/phytophthorarootstemrot.html.

http://www.soybeanresearchinfo.com/pdf_docs/CPN1002_ScoutingSoybeanStemDiseases051515.pdf

POD AND STEM BLIGHT AND PHOMOPSIS SEED DECAY (*Diaporthe* spp.):

Description: Small, black fruiting bodies (pycnidia) appear in linear lines on the stem and are scattered over pods. Poor seed quality can result from infected plants. Phomopsis-infected seed will be cracked and seed coats will be chalky and wrinkled. Insect damage and virus infection favors seed infection. Seeds emerging from infected seed will have small reddish-brown lesions on the cotyledons. Streaks may appear on stem base.

Epidemiology: Fungus survives in seed and crop residue. Warm, wet weather during seed maturity favors disease development. Disease is more severe with harvest delay.

Management: This disease rarely causes economic yield loss but can reduce seed quality. Varieties vary in response and resistance has been identified. Early maturing varieties are at higher risk. Crop rotation and tillage will reduce disease potential. Timely harvest can reduce mature seed infection.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/soybean/pod-and-stem-blight.
http://cropprotectionnetwork.org/soybean-diseases/pod-and-stem-blight-phomopsis-seed-decay/.
http://www.soybeanresearchinfo.com/pdf_docs/CPN1002_ScoutingSoybeanStemDiseases051515.pdf

FUSARIUM WILT AND ROOT ROT (*Fusarium* spp.):

Description: Seedling plants may have poor vigor and roots will have reddish-brown to dark brown discoloration that is often more severe in the lower root system. Symptoms in more mature plants occur under dryer conditions with high temperatures. Plants will have brown discoloration of vascular tissues in the roots, but this discoloration does not extend into the lower stem. Overall, plants will typically wilt and leaves may appear scorched on the upper canopy. Extensive leaf drop may occur. Tap root will be rotted.

Epidemiology: Fungus survives in soil and crop residue. Infection can occur at any stage of plant development, but it is more severe when plants are weakened by stress. High soil pH, iron chlorosis, nematode feeding and herbicides are some of the stressors that have been associated with higher disease severity.

Management: Varieties vary in susceptibility, but complete resistance has not been identified. Selecting varieties with resistance to other stress factors can reduce root rot problems. Planting in warmer soils will reduce disease potential. Seed treatment fungicides should be used in fields with a history of this disease.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/g2181.pdf.
https://crops.extension.iastate.edu/cropnews/2009/05/scouting-soybean-seedling-diseases.
http://www.soybeanresearchinfo.com/pdf_docs/CPN1002_ScoutingSoybeanStemDiseases051515.pdf

RHIZOCTONIA ROOT ROT (*Rhizoctonia solani*):

Description: One of the most common seedling diseases of soybean. Pre- and post-emergence damping-off can occur. Seedlings will have reddish-brown lesions on hypocotyls at or near the soil line. Root rot may occur and continue through late vegetative stage. Cortical rot may occur and result in plants breaking at the soil line later in the season.

Epidemiology: Fungus survives in soil and crop residue as resistant sclerotia. Coarse-textured soils are more conducive for disease development, and the disease occurs more commonly in sandy fields. Disease can be more severe with added stress of hail or other injury.

Management: Use of seed treatments is the primary tool for management. Treatment products vary in activity and need to be carefully selected for this disease. Reducing stress factors, such as herbicides that injure soybean plants, can reduce the potential for this disease.

References or Informative Websites:
http://cropwatch.unl.edu/rhizoctonia-root-rot.
http://www.soybeanresearchinfo.com/diseases/rhizoctonia.html.
https://crops.extension.iastate.edu/cropnews/2009/05/scouting-soybean-seedling-diseases.

SEED ROTS AND SEEDLING BLIGHTS (*Pythium, Phytophthora, Rhizoctonia, Diaporthe/Phomopsis, Fusarium,* and other spp.):

Disease	Fungus	Vn	Symptoms	Control
Seed rot	Pythium; Phytophthora; Phomopsis	V0-VE	Soft decay of seed; missing seedlings in a planted row.	Fungicide treated seed. Phytophthora-resistant varieties.
Seedling Mortality	Phytophthora; Rhizoctonia	VE-V4	Yellow, wilting leaves that later exhibit necrosis; diseased leaves do not abscise.	Fungicide treated seed. Phytophthora-resistant varieties.
Root and lower stem decay	Rhizoctonia; Fusarium; Phytophthora	VE-V6	Red-brown lesions on taproot and hypocotyl are mostly superficial; Phytophthora causes brown lesions on stem above soil line.	Fungicide treated seed. Phytophthora-resistant varieties.

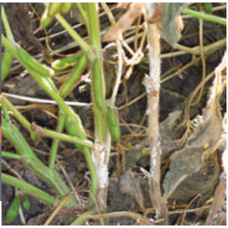
Source: http://fyi.uwex.edu/fieldcroppathology/files/2010/11/Common-Soybean-Seedling-Diseases.pdf. Note: Above table was modified from original.

Epidemiology: These fungi are common in nearly all soils with the exception of Phytophthora. Cool, wet, compacted soils and a slow seedling emergence are conducive to seedling diseases.

Management: Plant high-quality seed into warm, dry soils. In problem fields, use of seed treatment fungicides is recommended.

References or Informative Websites:
See photo gallery of above seedling diseases at below websites:
http://www.soybeanresearchinfo.com/diseases/soybeanseedlingdiseases.html.
http://www.soybeanresearchinfo.com/pdf_docs/Soybean_Seedling_Diseases_CPN1008.pdf.
http://www.soybeanresearchinfo.com/pdf.docs/BP136W.2017.pdf.
http://www.soybeanresearchinfo.com/resourcelibrary.html#seedlingdisorders.

SCLEROTINIA STEM ROT (*Sclerotinia sclerotiorum*):



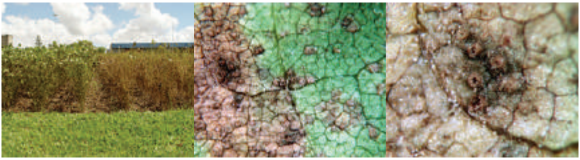
Description: Lesions consist of bleached plant tissue originating at a main stem node. White, cottony fungal growth will be associated with lesions (white mold photo). Black sclerotia develop on surface of infected tissue and inside stems and pods (photo). Lesions expand and cause premature plant death several weeks after flowering. Seed infection may occur.

Epidemiology: Fungus survives as sclerotia. During cool, humid, wet weather (70-85° F), spores are produced in fruiting bodies that emerge from sclerotia. Spores infect senescing flowers. Dense canopies favor disease development (notably narrow rows), as does irrigation applied during flowering. Temperatures >85° F will slow disease development.

Management: Varieties less susceptible or moderately resistant to the disease are available. A rotation of two to three years away from soybean to corn, small grains, or forages will help reduce the amount of sclerotia present in the soil. Decrease plant populations and increase row width to help thin canopy density. Fungicide applications during the flowering period are recommended.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/soybean/sclerotinia-stem-rot.
https://cropwatch.unl.edu/2016/sclerotinia-stem-rot-white-mold-soybean-what-look.
http://www.soybeanresearchinfo.com/diseases/whitemold.html.
http://www.soybeanresearchinfo.com/pdf_docs/CPN1002_ScoutingSoybeanStemDiseases051515.pdf

SOYBEAN RUST (*Phakopsora pachyrhizi*):



Description: Soybean rust has not developed into a significant issue for Midwestern U.S. production areas. Symptoms will be similar to other foliar diseases and can be confused with bacterial pustule and brown spot. Small spots initially appear on the lower leaf surface, changing from tan to reddish-brown. As the lesion matures, it will have small pustules that occur on the lower leaf surface. Pustules produce spores that can be evident upon microscopic observation. Premature defoliation and a hastening of maturity can occur.

Epidemiology: Soybean rust overwinters in the southern U.S. and needs to geographically move northward on winds generated by storms each year. We have not observed any significant movement of this disease into the Midwest since it originally was found in the U.S.

Management: The primary management action for this disease is fungicide applications made when the disease is first detected or even slightly before if it is forecasted to be an issue or found in the local area.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/soybean/soybean-rust.
http://www.soybeanresearchinfo.com/resourcelibrary.html.
http://www.soybeanresearchinfo.com/pdf_docs/soyrustIDcard.pdf.

STEM CANKER (*Diaporthe phaseolorum* var. Caulivora):

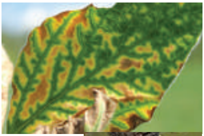

Description: Small, reddish brown lesions form in the lower canopy after pod set. Lesions expand to form sunken cankers running along the stem. Lesions are typically not surrounding the stem the entire length of the lesion. Interveinal chlorosis and necrosis may occur in foliage. Leaves remain attached. Early-season infections have higher impact on yield.

Epidemiology: Fungus survives in soil and in crop residue. The disease will be more severe when the crop suffers hail injury. There are two types (Northern and Southern stem canker) and both are favored by cooler or warmer than normal temperatures and by wet weather.

Management: Resistant varieties are available. Crop rotation and tillage can reduce disease potential. Seed treatment use may reduce early season infection. If a soybean crop is near the pod set stage when hail occurs in a field with a history of stem canker, a fungicide application may be needed.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/soybean/stem-canker.
http://www.soybeanresearchinfo.com/diseases/stemcanker.html.
http://cropprotectionnetwork.org/resources/articles/diseases/stem-canker-of-soybean.

SUDDEN DEATH SYNDROME (*Fusarium virguliforme*):



Description: Foliar symptoms (photo) typically appear after flowering. A yellow, interveinal leaf chlorosis develops into necrotic regions between leaf veins. The veins remain green until a leaflet becomes fully brown and drops from its petiole (which remains attached to the stem). The outer layer of the internal stem will have brown-gray streaks, but the pith color is normal. Infection occurs during the early vegetative stages, but leaf symptoms typically occur at pod-filling. The tap root will be rotted, but not upper (later developed) roots. Cobalt blue fungal growth (photo) may be visible on the outer root surface.

Epidemiology: Fungus survives in soil and crop residue. Cool, wet weather in early vegetative stages and wet conditions during flowering, followed by warm dry weather, favor foliar symptom development. SCN enhances SDS severity.

Management: Less SDS-susceptible varieties are available. Select those that also have SCN resistance. Early planting can favor infection. Alleviate soil compaction where possible. Some specific seed treatments have shown promise relative to lessening the severity of SDS.

References or Informative Websites:
http://cropwatch.unl.edu/2016/sds-showing-several-areas.
http://extensionpublications.unl.edu/assets/pdf/g2243.pdf.
http://www.soybeanresearchinfo.com/diseases/suddendeathsyndrome.html.
http://cropprotectionnetwork.org/resources/articles/diseases/sudden-death-syndrome-of-soybean.
https://cropwatch.unl.edu/2016/ilevo%C2%AE-seed-treatment-shows-promise-sudden-death-syndrome.

SOYBEAN BEAN POD MOTTLE VIRUS (BPMV):

Description: Bean Leaf Beetles (BLB) vector BPMV (see guide pages 98-99). Infection results in mottled leaves that exhibit a rugose “blistered” appearance (i.e., a puffy leaf surface that resembles a quilt in which leaf veins look like the stitches in a quilt). Newer growth will be most symptomatic and symptoms can disappear during very hot weather. Seed from infected plants may be mottled with banding originating at the hilum.

Epidemiology: Virus overwinters in perennial legumes and in the gut of the BLB. Disease occurrence is directly related to population density of BLB. Early season infection will result in the greatest potential yield loss.

Management: Varieties vary in response but are not typically rated. BLB management with the use of seed treatment insecticides and foliar application can reduce incidence of BPMV. Yield loss will be very low with later season infection and therefore management is typically not needed after pod set. Early season management is the most important time for reducing subsequent yield loss.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/soybean/bean-pod-mottle.html. https://www.ent.iastate.edu/soybeaninsects/node/141.

To control the bean leaf beetles that vector BPMV:
See guide pages 98-99, and also see:
https://www.ent.iastate.edu/soybeaninsects/node/137.

SOYBEAN MOSAIC VIRUS (SMV):



Description: SMV was more common when harvested seed was reused (prior to the development of herbicide-tolerant soybean varieties). Initial symptoms include mosaic or mottled green areas, chlorosis and rugose or puckered leaves. Leaves may be curled downward, with the youngest leaves most severely affected. Seed may appear mottled and seed germination may be lower. SMV leaf symptoms look similar to dicamba or 2,4-D herbicide drift leaf symptoms, but the two are distinguishable. Nearly every plant in a herbicide drift zone will display upwardly cupped leaf symptoms; however, SMV-affected plants will be scattered across the field zone and will typically display downwardly curled leaf margins.

Epidemiology: Seed transmission is the primary source of infection. The virus is spread by aphids (see guide page 101), with many aphid species being able to transmit it.

Management: Clean seed sources (free of SMV infection) are the primary control. Planting later can result in higher risk of SMV due to aphid populations being more prevalent. In fields with the virus present and notable aphid populations, insecticides can be used to reduce vector populations.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/soybean/mosaic-virus.
http://www.soybeanresearchinfo.com/diseases/soybeanmosaicvirus.html.

To control the aphids that vector SMV:
See guide page 101, and also see:
http://extensionpublications.unl.edu/assets/pdf/g2063.pdf.

SOYBEAN VEIN NECROSIS VIRUS (SVNV):

Description: SVNV symptoms include yellowing that occurs in or near veins. Yellowing will progress into orange and brown lesions extending over the leaf veins and expanding to make the leaf appear scorched. The primary vector of SVNV are thrips (see guide page 101), but the virus does not result in a systemic infection and produces only localized lesions. Lesion discoloration can be similar to ACCase herbicide injury (see guide page 349).

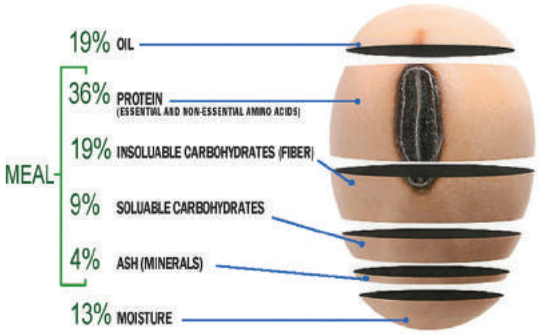
Epidemiology: Warm and dry weather favors increases in thrip populations. The distribution and appearance of SVNV lesions are similar to those of brown spot, except SVNV is an atypical virus (on-systemic activity). Still, thrips can reproduce rapidly, so the disease can spread quickly.

Management: As of October 2016, this disease has not been confirmed to be present in Nebraska. SVNV is a new disease in the U.S. Insufficient data precludes providing management recommendations at this time.

References or Informative Websites:
http://www.soybeanresearchinfo.com/diseases/SVNV.html.
http://cropprotectionnetwork.org/resources/articles/diseases.

To control the thrips that vector SVNV:
https://graincrops.blogspot.com/2016/07/how-to-monitor-and-when-to-control.html.

NOTES:


19% OIL
36% PROTEIN
(ESSENTIAL AND NON-ESSENTIAL AMINO ACIDS)
MEAL
19% INSOLUABLE CARBOHYDRATES (FIBER)
9% SOLUABLE CARBOHYDRATES
4% ASH (MINERALS)
13% MOISTURE

CORN MANAGEMENT

In this section, photos, charts, tables, worksheets and brief commentary are provided for a variety of corn management issues. Due to space considerations, comprehensive coverage of each and every corn management topic is not possible. Additional web references have been included at the end of each topic for those who might be interested in obtaining more detailed information. For up-to-date information during the growing season, please visit the websites listed on the next page.

IN-SEASON CORN MANAGEMENT INFORMATION:

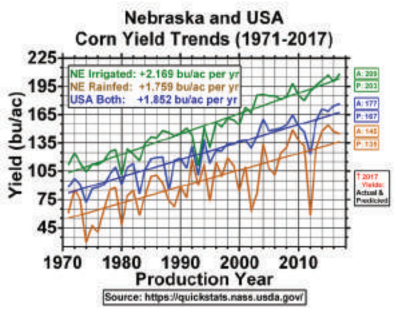
At http://cropwatch.unl.edu/corn, you can find a wealth of corn-specific management information and links to other useful websites. By subscribing (free) to **CropWatch**, you will be emailed reports that are issued weekly during the growing season. These reports contain articles written by University of Nebraska-Lincoln (UNL) and other experts about current issues of producer concern. You can also search the CropWatch archive for past season articles that may be of interest to you. (Remember, problems often reoccur!)

If you are interested in corn research trials that were conducted on producer farms and targeted at specific crop management questions, you can view results and conclusions at: http://cropwatch.unl.edu/farmresearch.

Several UNL Institute of Agricultural and Natural Resources (IANR) experts have blogs or websites for reporting issues of local interest. A listing of Nebraska Extension blogs and websites can be found at: http://extension.unl.edu/extension-blogs/.

CORN IRRIGATED AND RAINFED ON-FARM YIELD TRENDS:

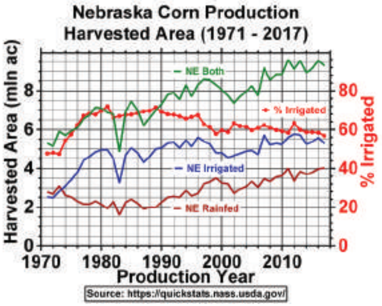
Since 1971, Nebraska's **irrigated yields** have improved by about **2.17 bu./acre per year, with rainfed yields** increasing by about **1.76 bu./acre per year.** Note actual & predicted 2017 yields (boxes).



The rate of rainfed yield increase during the past 15 years would have been higher were it not for the drought years of 2002 & 2012. Rainfed yield gains may be due to producers using less tillage and more stress-tolerant hybrids.

IRRIGATED AND RAINFED CORN ACREAGE TRENDS:

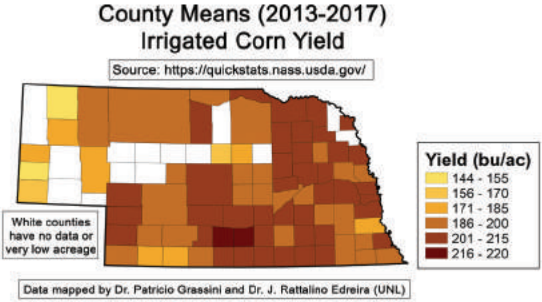
The fraction of irrigated acres of the 9.5 million total Nebraska corn acres has stabilized at approximately 60% of that total corn acreage (see red line in the chart), but those irrigated acres account for nearly 75% of all NE corn produced.



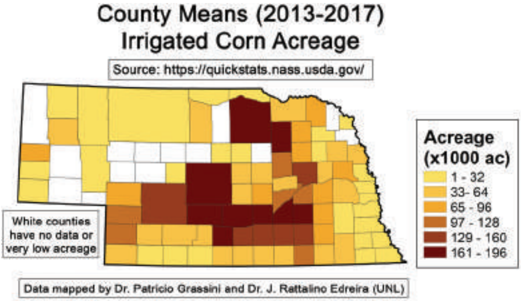
For a NE map of 2017 corn production density, see guide page 17.

IRRIGATED CORN YIELDS AND ACREAGES BY COUNTY:

Nebraska irrigated yields have increased more rapidly than rainfed yields. The east-to-west, high-to-low yield gradient in the map below reflects a growing season that shortens with the east-to-west increase in elevation. The highest irrigated corn yields are found in those counties that have naturally fertile soils with good water infiltration rates.

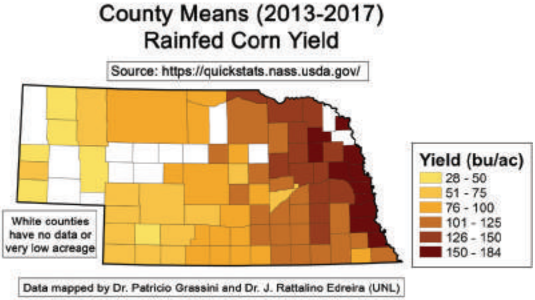


County **irrigation acreage statistics** in the below map are biased toward larger counties and, of course, reflect counties that possess surface or ground water irrigation resources and also soils suitable for growing corn. That said, the most intensive irrigated corn production areas are located in South Central Nebraska.

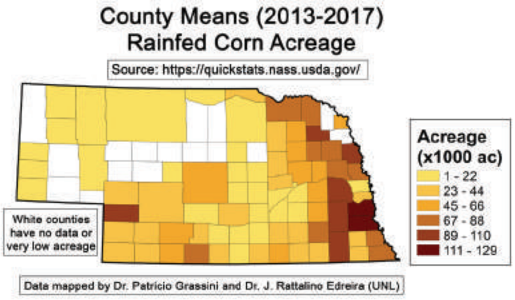


RAINFED CORN YIELDS AND ACREAGES BY COUNTY:

Rainfed yields and acreages show a similar pattern. The east-to-west, high-to-low rainfed corn yield gradient arises from the east-to-west gradient in high-to-low seasonal rainfall, as well as reflecting soil series types differing in water retention across the state. Rainfed corn yields are possible in eastern counties where rainfall is adequate in most years to support corn production.



County water resource availability (for conversion from rainfed to irrigated production) also impacts the proportion of rainfed to irrigated acres throughout the state. Adoption of **no-till**, as well as eco-fallow management systems, coupled with the availability of new drought-tolerant hybrids, have led to higher yields in lower to moderate rainfall NE counties that, in lower rainfall years, has resulted in increases in rainfed acreage committed to corn.



CORN PLANT DEVELOPMENT:

Vegetative Corn Leaf Stages:

Corn leaf stages are generally used to classify the growth of the crop during the vegetative stages of growth. The term **VE** is used to describe the stage at which the **coleoptile (first leaf with a round tip) emerges** from the soil (Figure 1). This round-tipped leaf (coleoptile) is counted in staging. Successive stages describe how many leaves or leaf collars are visible.

Figure 1

Figure 2

Leaf Collar Method:

Most producers and crop consultants use this method to determine growth stage. The **"leaf collar" is a band of tissue, generally lighter in color than the leaf,** which wraps around the stalk where the leaf blade and leaf sheath intersect (see Figure 2). Plants are examined, and the visible leaf collars are counted. For example, if just six leaf collars are visible, the plant is said to be in the V6 stage, even if parts of seven or more leaves can be seen.

A plant in the **V6 stage** is shown in Figure 3 (next page). The plant's first leaf is round-tipped (you can't see that in the figure), and the sixth leaf collar is the last visibly observable – about halfway up the plant.

Iowa State University researchers first described this method in a booklet which can be found at:
http://store.extension.iastate.edu/Product/Corn-Growth-and-Development.

Figure 3

"Droopy Leaf" Method:

Crop insurance and hail adjusters often use the droopy leaf system to determine defoliation and leaf damage. It is similar to the leaf collar method, in that **leaves just starting to emerge from the whorl generally stand straight up**, while leaves which have developed external collars tend to droop (see Figure 3). Leaves are counted, including the last one, at 40-50% emerged from the whorl. For **corn up to stage V5 (leaf collar method)**, the droopy leaf method will generally result in a **plus one higher leaf count** than the leaf collar method (e.g., a V3 corn plant according to the leaf-collar method will generally be called a four-leaf plant in the droopy leaf method). In addition, **after V5**, the droopy leaf method generally results in a leaf number call that is **plus two** greater than the leaf collar system.

Whole Field Staging:

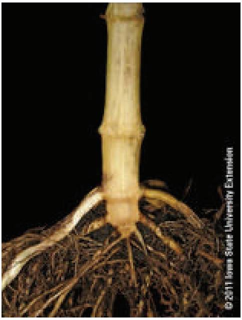
For some crop management decisions (e.g., timing of herbicide applications), a whole field staging may be critical if some plants are likely to be somewhat more advanced than the average. For example, if 70% of the plants are at V5, **and 30% are at V6**, do **NOT** apply a herbicide recommended for V5 or earlier, because the more advanced plants may be damaged!

The accuracy of staging a whole field will depend upon the uniformity of soil, emergence, terrain (north *vs.* south slopes, low areas *vs.* hills, etc.) as well as the location and size of the sample of plants you use for staging. Remember, corn can grow rapidly, and a field staged just after dawn can advance a leaf stage by dusk, so conduct your staging in a **conservative fashion relative to herbicide applications** and other management decisions.

Staging Larger Corn Plants:

After plants get about two to three feet tall (or if one has serious weather events), the first several leaves and collars become harder to find, because the **first few leaves tend to be torn off** by emerging roots. In these instances it is usually necessary to dig or pull the corn plant, and split it with a sharp knife. Examining the inside of the stalk, the **conical-shaped base will usually hide the first four nodes** (darker color). The first visible internode (white, pithy stem region) is generally about a half-inch long or less. The node above this first internode is usually the fifth node in most hybrid corn adapted to Nebraska's latitude.

CORN PLANT DEVELOPMENT (CONT.):



Gently, find the leaf collar attached to this node, and it will be the fifth leaf collar. Continue to count upward to find the last leaf collar visible to determine the stage. In the left photo, the first four nodes are in the darker cone-shaped region. **The upper "brace roots" are growing out of the fifth node**.

In this next photo, the fifth leaf (the bottom leaf on the lower right side of the photo) is attached at, or below, the soil surface on this V12 plant.

Some modern hybrids, especially the drought-tolerant hybrids, silk very early and strongly compared to the hybrids we used just a few years ago. **Under ideal conditions, some of these hybrids silk BEFORE pollen is shed**, thus confusing our usual stage classification, as silking (R1 stage) CAN come before tassels are fully emerged and shedding pollen.

Reproductive Corn Stages:

When the first silks emerge, we shift to an **"R" notation**, which indicates reproductive stages.

Typical R1 Plant

The **R1** stage indicates that **silk has emerged** from the ear shoot, and is visible outside of the husk leaves. After silks emerge, they "capture" pollen grains, which germinate and send a pollen tube down the length of the silk. The nucleus in the tube divides, then divides again to form **two nuclei, one of which fertilizes the ovule** (which forms the '2N germ'), **the other of which fertilizes the polar nuclei to form the '3N endosperm**' of the kernel. R1 generally lasts approximately 300 Growing Degree Days (GDD) which is when fluid begins to form in the developing kernels.

Silks emerge from the **base** of the ear shoot first, and then continue to develop upward toward the tip of the cob. Individual silks remain **receptive to pollen three or four days** if they don't desiccate due to heat and dry air. If good amounts of water and light are available, the silk emergence times closely with pollen shed. Drought (and excessive density) can significantly slow silk emergence from the ear shoot in some hybrids and, **if delayed for more than three or four days, can drastically reduce kernel set and yield.**

Ears that set seed **only at the base reflect a scenario in which pollen was nearly gone** when those ears silked. Seed set only at the tip indicates that silking was too early relative to pollen availability. During R1, pollination and fertilization occurs.

“Silk balling” can slow or prevent silk emergence in some genetic backgrounds (with tight husk tips) and environmental conditions, typically with very cool weather.

Some modern drought-tolerant hybrids are purposely bred to silk aggressively. Under cool, wet conditions, they may silk four or more days before pollen is shed, which **occasionally** results in ears with reduced kernel sets at the base of the ear (i.e., the silk aged and desiccated before pollination). **Insects (notably corn rootworm beetles) can feed aggressively on the silk at R1** and reduce kernel set.

R2 Stage Ear in Cross Section

R2 is generally considered to start at the **blister stage** of the kernels, as they continue to grow and develop. At this stage, the developing kernels are white and filled with clear, sugary liquid, reflecting the rapid accumulation of sugars from the plant. **R2 usually begins about 10 days to two weeks after silk emergence**, by which time the silks have mostly turned brown.

Inside the developing kernels on the ear, the radicle, coleoptile and first embryonic leaf are already being formed by R2. **In late R2, the fluid turns milky** (due to increasing starch and sugar content), and the kernels begin to turn yellow. R2 typically lasts about 200 GDDs.

The developing kernels then expand beyond the glumes, becoming more rounded. **The plants reach maximum size at R2, and ears will have reached their maximum length**. Dry matter increase of the grain is still minimal at R2.

Drought stress, or photosynthetic stress (hail, cloudy weather, etc.) at R1 or R2, can lead to **kernel abortion**, due to insufficient sugars being available to the developing embryos.

R3 Milk Stage Ear

R3 is considered to be the **milk stage**, where kernels are fully yellow, but the kernel contents are still fluid. Attainment of R3 requires about approximately 300 GDDs, which spans a timeframe of about 18 to 22 days past silking. **R3 is often called the roasting ear stage**, because kernels are rapidly accumulating sugar and turning it into starch. By this time, **most of the cell division in the endosperm** (where starch accumulates) portion of the kernel **has concluded**. Continued kernel growth is largely caused by filling with starch and expansion of existing cells. Stress at this stage can still cause kernel abortion, but not as severely as stress at R1 and R2. **Severe stress at the R3 stage will cause preferential filling of the kernels toward the base of the ear,** while kernels toward the tip can become shriveled "corn flakes."

R4 Dough Stage Ear

R4 is the dough stage, when the kernel contents solidify and kernels begin to dent, a phase that spans approximately 200 GDDs.

This "doughy" consistency becomes increasingly more solid as starch continues to be stored in the endosperm. The "germ" or embryo is fully developed, and several leaves of the next generation plant can be seen in the kernel examined with a microscope. **By R4, kernels have accumulated 50-60% of the final kernel dry weight**. If the plant has the genes for cob color, the **cobs will begin to become pink or light red**. Stress usually does not cause kernel abortion at R4, but if stress does occur, lighter, less dense kernels will form, particularly toward the tip of the ear, which will result in **low test weight grain** at harvest.

R5 Dent Stage Ear

R5 is considered to be the **full dent stage**, and starch is being laid down rapidly as kernels fill. Kernels tend to be soft, and can be cut with your fingernail. R5 tends to last from 300 to 400 GDDs, depending on hybrid maturity and whether adequate weather, nutrients, and moisture are available. **All the remaining kernel weight is added in this stage**. During this stage, the "milk line" is visibly halfway down the kernel, about 90% of final kernel weight has been accumulated and the germ core of the kernel is fully functional. At the R5 stage, **severe stress results in lower grain test weight** (just like stress at R4), and ears can show **"die back,"** with kernels toward the base of the ear being full and normal, but with lighter kernels in the middle and "corn flakes" present toward the tip.

R6 Black Layer Ear

R6 is defined as when a **"black layer"** develops at the base of a kernel where it attaches to the cob. The **black layer is largely an artifact** of the cessation of sugar supply to the developing kernels, at which time the milk line quickly disappears, and several layers of cells connecting kernels die and turn black. The black layer forms because sugar is no longer moving through these cells. This usually occurs about 55 days after silking, after which corn is safe from yield loss even if a killing frost occurs.

From this point on, corn maturity is essentially a drying issue. While the plant is still green, drying can occur and is usually indicated by tan husks. The **bulk of the drying is a matter of evaporation**, so temperature, humidity, wind and "husk looseness" are the biggest factors in drying rate. Also, softer starch tends to dry more quickly than hard, vitreous starch.

Black Layer Stage Kernels

HEAT UNITS, MATURITY FOR CORN:

The GDD Concept and Its Calculation:

Day length affects corn maturity much less than soybeans and many other crops. **Corn tends to mature based on the amount of "heat units"** encountered during development. Corn matures faster with warmer, rather than cooler, day and night temperatures (as long as they are not too hot so as to cause stress, see guide page 184).The most common system used for heat unit calculation for corn development was developed by the National Oceanic and Atmospheric Administration. It has been designated as the Modified **Growing Degree Day** formula. Because corn plants tend not to grow faster when the temperature exceeds **86° F**, and because growth effectively stops when temperature falls below **50° F** (i.e., a limit applicable to most corn hybrids), these limits are used in heat unit calculation (i.e., any temperature hotter than 86° F is simply reset to 86, and any temperatures cooler than 50° F is reset to 50 before the average growing degree (GDD) value is calculated for the given day).

For example, for a spring day with a high of 75° F and a low of 55° F, we would calculate:

$$((75 + 55) \div 2) - 50 = 15 \text{ GDD}$$

For a hot summer day, say a high of 98° F and a low of 72° F, the 98° F value would be replaced with 86 to calculate:

$$((86 + 72) \div 2) - 50) = 29 \text{ GDD}$$

For a cold late September day, say a high of 54° F and a low of 37° F, the 37° F value would be replaced with 50:

$$((54 + 50) \div 2) - 50) = 2 \text{ GDD}$$

Of course, development can vary depending on how long during the day the temperature is warm or cool. Nebraska often has widely fluctuating temperatures, and if the day warms rapidly, low night temperatures have somewhat less effect than in areas with more stable temperatures.

HEAT UNITS, MATURITY FOR CORN (CONT.):

Two useful websites to compare current, historical and projected GDD accumulations given different Nebraska locations and planting dates are at http://cropwatch.unl.edu/gdd-etdata and at https://mygeohub.org/groups/u2u/gdd, which give historical GDD data by zip code. You can also get weather data from the UNL High Plains Climate Center at:
http://mrcc.illinois.edu/U2U/gdd/.

The following illustration shows the approximate GDD (heat unit) accumulations available across Nebraska under a moderate risk of a killing freeze, averaged across 30 years.

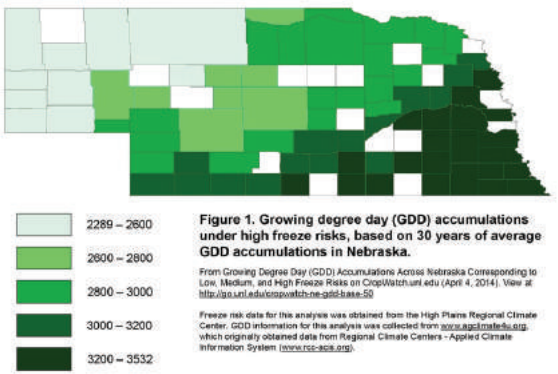


Figure 1. Growing degree day (GDD) accumulations under high freeze risks, based on 30 years of average GDD accumulations in Nebraska.

From Growing Degree Day (GDD) Accumulations Across Nebraska Corresponding to Low, Medium, and High Freeze Risks on CropWatch.unl.edu (April 4, 2014). View at http://go.unl.edu/cropwatch-ne-gdd-base-50

Freeze risk data for this analysis was obtained from the High Plains Regional Climate Center. GDD information for this analysis was collected from www.agclimate4u.org, which originally obtained data from Regional Climate Centers - Applied Climate Information System (www.rcc-acis.org).

Source: http://cropwatch.unl.edu/growing-degree-day-gdd-accumulations-across-nebraska-corresponding-low-medium-and-high-freeze-risk.

This cited CropWatch site gives excellent information on the number of **GDD available for various regions of the state**, given risk tolerance for late spring and early fall freezes.

PREDICTING LEAF STAGES AND MATURITY:

It is possible to predict leaf stages if you know the **planting date** and the **GDD accumulation since planting**. Research at Purdue has shown that it takes 90 to 120 GDDs from **planting to emergence**. Then, from emergence to V10, it takes about **82 GDDs per leaf**. After V10 until tasseling, it takes about 50 GDDs per leaf. So by knowing the planting dates and the accumulated heat units (either real or historical) by date, it is possible to predict the growth stages with reasonable accuracy. The largest **errors in predictions are caused by stress**. Drought, cold, heat, etc., can also impact your predictions.

A VERY useful tool for corn growers is the **UNL Hybrid Maize Model**. It is a software tool that allows you to enter rainfed or irrigated field-specific data, such as the hybrid, planting date and weather/climate data for your location **to predict development and even final yield** with significant accuracy. The software can be purchased for a nominal fee, and help and training in its use is available from your local extension personnel. Find it at: http://hybridmaize.unl.edu/.

Also, see guide page 169 for more on “in the field” yield estimation based on plants, ears and kernels. The HybridMaize Model can also be used to provide a pre-harvest forecast of corn yield in a given field – see guide page171.

SEEDING RATES:

A recent UNL publication provides useful information on planting rates and row spacing in Nebraska. *See Neb Guide G2216*, available at http://extensionpublications.unl.edu/assets/pdf/g2216.pdf. This research-based publication indicates that the optimum planting rate depends on both the price of seed corn and the price of corn grain.

Table: Percentage of Maximum Yield Expected in Irrigated or Rainfed Fields for Various Planted Corn Densities

Corn Seeding Rate	Irrigated Fields	Rainfed Fields	
		>115 bu./ acre	<115 bu./ acre
Kernels/Acre	%	%	%
42,000	100	---	---
40,000	100	100	---
38,000	99	98	---
36,000	98	97	84
34,000	97	95	87
32,000	---	93	89
30,000	---	92	92
28,000	---	90	95
26,000	---	88	97
24,000	---	87	100
22,000	---	85	---
20,000	---	84	---
18,000	---	82	---

Source: http://extensionpublications.unl.edu/assets/pdf/g2216.pdf.

Research in both the public and private sector shows that **modern corn hybrids are remarkably capable of tolerating crowding stress** and that yield actually tends to be optimized at relatively high plant densities in both rainfed and irrigated fields. For irrigated sites or for high-yield potential rainfed sites **(assuming good subsoil moisture and normal planting dates),** a seeding rate of 32,000 to 40,000 seeds per acre seems appropriate. For **rainfed environments with drier subsoil** and a lower than average expectation of rainfall, a lower plant density is indicated. Guide page 154 shows a chart of attained yields (percent of maximum). This data is from the Nebraska On-Farm Research Network 2014 report, which was mostly compiled from farms located in Eastern and Central Nebraska.

For drier areas and soils with less water-holding capacity, see: http://extensionpublications.unl.edu/assets/pdf/g2068.pdf. This *NebGuide G2068* shows the impact of row spacing and pattern, soil moisture at planting and yield goals relative to suggested plant densities.

Note that for rainfed conditions in dry years and locations, one might make an *a priori* decision to increase plant density to take advantage of an expected good year, but **a yield penalty will occur if the reality is a bad year**.

Not all hybrids respond uniformly to increasing density. Depending upon plant size, leaf angle, rooting pattern, ear size, plus a host of other physiological factors, different hybrids can maximize their yields at populations ranging from **24,000 to 50,000+**. Consult your seed supplier concerning their recommendations for the hybrids you might choose to plant in different fields on your farm.

WITHIN-ROW SPACING:

It is often useful to know how far apart to place kernels in a row when considering various densities and various row widths. See the table below for within-row kernel spacing that corresponds to various plant densities and various row widths.

Kernels per Acre Planted	Row Width (inches)					
	15	20	30	36	38	40
	Within-Row Kernel Spacing (inches)					
12,000	34.8	26.1	17.4	14.5	13.8	13.1
14,000	29.9	22.4	14.9	12.4	11.8	11.2
16,000	26.1	19.6	13.1	10.9	10.3	9.8
18,000	23.2	17.4	11.6	9.7	9.2	8.7
20,000	20.9	15.7	10.5	8.7	8.3	7.8
22,000	19.0	14.3	9.5	7.9	7.5	7.1
24,000	17.4	13.1	8.7	7.3	6.9	6.5
26,000	16.1	12.1	8.0	6.7	6.3	6.0
28,000	14.9	11.2	7.5	6.2	5.9	5.6
30,000	13.9	10.5	6.7	5.8	5.5	5.2
32,000	13.1	9.8	6.5	5.4	5.2	4.9
34,000	12.3	9.2	6.1	5.1	4.9	4.6
36,000	11.6	8.7	5.8	4.8	4.6	4.4
38,000	11.0	8.3	5.5	4.6	4.3	4.1
40,000	10.5	7.8	5.2	4.4	4.1	3.9
42,000	10.0	7.5	5.0	4.1	3.9	3.7

For seeding rates not listed in the table, use this formula:

Within-row spacing (inches) =

12 ÷ [(kernels/acre ÷ 43,560) x (row width ÷ 12")]

Example:

12 ÷ [(30,000 ÷ 43,560) x (30 ÷ 12)]

12 ÷ [0.68871 x 2.5)

12 ÷ 1.72176 = 6.6996 inches – round to 6.7 inches

PLANTING DATES:

Optimum planting dates vary by location and situation. Intrinsically, the word **"optimum" implies that there are planting dates too early, as well as too late**, for the best range of yield performance. Corn generally will not grow at soil temperatures below 50° F, but **several soil pathogens** will grow just fine. While modern seed treatments are of tremendous value, planting earlier than April 15 in most years and situations **shifts the balance in favor of soil pathogens**. These organisms can cause significant stand losses. Moreover, <50° F during the first 48 hours of kernel germination (when imbibitional water uptake is very rapid) can lead to chilling injury that can damage or kill seedlings.

Because little growth occurs when environmental temperatures average less than 50º F, in most years there is little growth difference or yield potential difference between corn planted between **April 15 and May 1**. The table in the **Replant Decisions** section (guide page 165) illustrates the tradeoffs between planting date and effective stands. **Clearly, after May 10 we begin to lose yield potential for every day that planting and emergence is delayed.**

Also, see the table on guide page 167, which illustrates the relationship between planting date, plant density and yield. It is clear that moderate stands established "on time" have more yield potential than full stands planted later, especially after mid-May.

DELAYED PLANTING, HYBRID MATURITY AND GDD:

Corn hybrid maturity is often described as “days to maturity,” which generally classifies hybrids taking into account days to flowering, grain filling period, and drying rate. This is often referred to as **comparative relative maturity**. However, this system does NOT directly relate to calendar days. It traditionally has been used to compare hybrids by their RELATIVE climatic and GDD needs to produce mature grain.

The GDD system (see guide page 151) more accurately describes the developmental phenology (stages) of corn hybrids from planting or emergence date to the dates of silking and/or physiological maturity (black layer). Optimum planting dates have been estimated for several Nebraska corn-growing areas, and typically, highest yields are obtained by planting before May 1, when soil moisture and temperature conditions allow this. However, in some years and locations, weather-related delays in planting do occur, sometimes into late May and early June. Research in Indiana *(Nielsen, et al., 2015)*, as well as grower experience, has shown that when planted later than usual, adapted corn hybrids require **FEWER** GDDs compared to normal planting dates, which has been estimated to be about **6.8 GDD per day of planting delay**. This translates into about a quarter of a day of typical GDD accumulations during May.

DELAYED PLANTING, HYBRID MATURITY AND GDD (CONT.):

EXAMPLE: With a planting delay from April 20 to May 20, a 114-day hybrid ordinarily requiring 2700 GDD might need only 304 (6.8/day x 30) fewer GDD to maturity, or about 2500 GDD. Stated in "days to relative maturity" the **114-day** hybrid would act as if it were 7.5 (0.25 x 30) days earlier – i.e., a **106-day** hybrid. One can compare this value with records of mean GDD accumulated at a location by zip code and planting dates, along with the probability of freezing temperatures, at:
https://hprcc.unl.edu/gdd.php
See also guide pages 151 through 153.

Typically, **changing from normal, adapted maturity hybrids to earlier hybrids is not advisable unless planting is much delayed** – at least to May 25 to May 31. Of course, the yield penalty from later planting still applies (reduced grain-fill period), and it is also likely that the grain will be wetter at harvest. The number of GDDs available in the growing season drops rapidly after June 10 or 15, and if planting is delayed until then, switching to a crop other than corn is likely the best option.

Reference: Nielsen, R.L. (Bob). 2015. The Planting Date Conundrum for Corn. Corny News Network, Purdue Univ. [online] http://www.kingcorn.org/news/timeless/PltDateCornYld.html*.*

ROW SPACING:

Recommended plant populations continue to increase, leading corn producers to wonder if corn might actually yield better in narrower

rows. Most corn in Nebraska is grown in 30-inch rows. An interesting older study compared 15-30 and 38-inch rows, and found that the yield responses to narrowing the row width were small.

	Relative bu./acre yield difference between a 30-inch row width and narrower or wider rows:	
Year	**15-inch**	**38-inch**
1995	**+2.2**	**-----**
1996	**0.0**	**-----**
1997	**-1.9**	**-----**
1998	**+1.2**	**-7.5**
1999	**-1.2**	**-0.5**
2000	**+1.8**	**-2.7**
Average	**+0.3**	**-2.9**

Source: ISU Corn Planting Guide. Go to:
https://store.extension.iastate.edu/Product/pm1885-pdf.

ROW SPACING (CONT.):

The key issue is that **by the time the crop gets to about V8 (when ear differentiation is occurring), it is already intercepting most of the light,** regardless of row width.

Some studies have found a significant hybrid to row width interaction (meaning some hybrids perform better in narrower rows), but **most hybrids** respond in a comparatively parallel fashion. And, the alleged **advantages of so-called "narrow row hybrids" when planted in row widths less than 30 inches were still small.**

Recent research at UNL, as well as in Alabama, Indiana, Iowa, Missouri and Ohio, indicates that there is little or no apparent advantage to narrowing the rows to 15 or 20 inches, nor is there an advantage to twin rows on 30-inch centers. Go to: http://extensionpublications.unl.edu/assets/pdf/g2216.pdf.

Again, these results seem logical, given that **almost all of the solar irradiation is being intercepted by V8** (when we get ear differentiation) in 30-inch rows, and **corn roots (when planted at normal density) almost completely colonize the soil zones** between the rows to take advantage of available nutrients and moisture. There is probably little agronomic advantage to be gained from rows narrower than 30 inches or from twin rows.

The best row width (from an economic standpoint) is likely the one that utilizes the same equipment for both corn and other crops. Experience has shown that **concentrating on planting dates and securing uniform stands** at adequate plant populations are far more important than row width.

ROOT ESTABLISHMENT IN CORN:

Successful initial establishment of the corn plant root system helps ensure successful crop establishment. If you are attempting to diagnose the cause of stunted (or otherwise poor-looking) corn early in the season, you will definitely want to **begin the search below ground**.

One of the more critical periods for successful root establishment is the period from emergence to about the V6 stage of development. **Stresses that stunt or restrict the root system during this period (including dry soil, wet soil, cold soil, insect damage, herbicide damage, sidewall compaction, tillage compaction) can stunt the entire plant's development** throughout the growing season.

To better understand root development and root restriction problems, it is important to understand that corn root development is dependent upon where the roots originate relative to the seed and its depth in the soil. **Seminal roots** originate at the seed from embryonic nodes and are comprised of the radicle and lateral seminal roots.

RADICAL (THICKEST ROOT) AND LATERAL SEMINAL ROOTS:

The seminal root system anchors the young plant and absorbs small amounts of water and nutrients for the first two to three weeks. Seminal roots **cease new growth** shortly after the seedling coleoptile emerges from the soil.

Subsequent root development **occurs from individual nodes** of the stalk. The triangular pithy area near the plant's crown is typically comprised of four stalk nodes. The stalk internodes begin to elongate about growth stage V4, and shortly thereafter, one can distinguish additional nodes and internodes.

<Nodal Roots from Nodes 1 through 5

A few days after the coleoptile and first true leaf emerge, roots begin to elongate from the first and lowermost node and are **clearly visible by growth stage V2.** Roots elongate sequentially over time, from nodes 2 through nodes 6 or 7. The latter two nodes are typically above ground, and roots that originate from those nodes are called **brace roots**. Brace roots are functionally similar to roots that originate from below ground stalk nodes. Initially, the number of visible nodal root sets is typically one fewer than the leaf stage number. For example, at leaf stage **V5, you can typically identify four sets** of nodal roots.

RADICAL AND LATERAL SEMINAL ROOTS (CONT.):

At about **V3, plants transition from a reliance on kernel carbohydrate reserves for sustenance to using mineral nutrients extracted from the soil by developing nodal root systems and carbohydrate provided from the leaves**. With favorable growing conditions, corn plants normally complete this transition by about V6. The success or failure of the transition period is critical in terms of health and uniformity of the crop by the time it reaches V6.

<V6 plant with 5 Nodes of Roots Developed

Because a young corn seedling depends primarily on the kernel's carbohydrate reserves until the nodal roots are well established, **damage to the seminal roots, kernel or the mesocotyl prior to successful root formation will stunt or kill the plant**. Examples of such damage include salt injury from excessive starter fertilizer rates, seedling blight, herbicide injury and insect feeding or cultivator damage.

Cool soils slow nodal root development, interfere with the transition period and prolong the seedling's dependence on dwindling kernel reserves. These cold soil and stress conditions make the plant more vulnerable to damaging soil-borne pathogens, insects or pesticides prior to successful nodal root establishment.

REPLANT DECISIONS:

Photo: http://cropwatch.unl.edu/time-dig-and-assess-need-replanting-corn.

Deciding whether or not to replant is always difficult. Often we are forced into these decisions by weather – cold, rain/flooding, hail or other catastrophes and emotions are often intermingled with rational factors in the decision-making process. Some of the key factors to consider are: remaining plant population, health/vigor of remaining plants, expected yields and date of potential replanting. In the case of flooding or continued wet weather, there is an uncertain date of replanting.

The crux of a replant decision is essentially:
Remaining Potential Yield Value *vs.*
Replanted Potential Yield Value (minus the replant cost).

REPLANT DECISIONS (CONT.):

To gather the information you need, follow these steps:

- **Determine the remaining plant density** by counting plants in a 1/1000th acre sample. Use the following table to find the suitable row length that equals 1/1000th of an acre for any listed row width.

Row Width (inches)	Row Length to Measure for 1/1000th Acre
15	34 feet, 10 inches
20	26 feet, 2 inches
30	17 feet, 5 inches
36	14 feet, 6 inches
38	13 feet, 9 inches
40	13 feet, 1 inch

If your corn row width is not listed above, use this formula:
(sq. ft. in 1/1000 acre ÷ row width (in feet))
Example: 43.560 sq. ft. ÷ 2.5 ft. (30 inches = 2.5 feet)
= 43.56 ÷ 2.5 = 17.424 = 17 feet 5 in.

- **Determine probable yield potential** for the remaining stand. This includes assessing the health and vigor of the remaining plants, and the relative uniformity of remaining plants. In some situations, like hail and/or diseases, the surviving plants may be damaged and thus may take more time to fully recover. It is often best to wait a few days after the damaging event to better assess the vigor and health of the surviving plants. Use the table below as a guide.

Table: Percentage of Yield Potential for Various Seeding Relative to Planting Date Windows

	Planting Date Windows (from > to):				
Kernels Per Acre	4/20-5/05	5/06-5/15	5/16-5/25	5/26-6/05	6/06-6/15
45,000	97	93	85	68	52
40,000	99	95	86	69	53
35,000	100	96	87	70	54
30,000	99	95	86	69	53
25,000	95	91	83	67	51
20,000	89	85	77	63	48
15,000	81	78	71	57	44
10,000	71	68	62	50	38

Source: https://crops.extension.iastate.edu/node/1871.

REPLANT DECISIONS (CONT.):

- The foregoing table makes clear that **planting date is a huge factor** – planting delays affect yield more substantially than decreases in plant density. In any event, replant decisions require consideration of all of the data in this table. Significant stand losses can be tolerated in a corn field (relative to yield loss); however, some environmental issues (like heavy rains that come with a hailstorm) preclude some choices for optimally recovering from a plant stand damaging event.

Replant Decision Steps:

1) **Determine probable yield potential** from replanting (at a date later than the original planting date) at full stand. The above tables are useful for determining potential yield from replanting at the later date. Even a full stand planted two weeks later will scarcely have more yield than a significantly reduced stand planted near the optimum dates.

2) **Calculate the costs of replanting**. Consider your time, tillage, fuel, equipment wear and, of course, seed costs. Subtract the costs/acre from your replanted crop bu./acre value. If the year turns out to be cool and damp, late planting can lead to higher harvest and drying costs.

3) **Consider herbicides and weed management**. If replanting requires tillage, residual herbicide barriers will be interrupted. Be especially cautious if you consider switching crop species, given that the applied corn herbicide may be incompatible with other crop choices.

For an excellent discussion of replant decision-making go to: http://cropwatch.unl.edu/assessing-corn-replant-options.

ESTIMATING CORN YIELDS BEFORE HARVEST:

Photo: John Hay. See: http://cropwatch.unl.edu/bioenergy/corn.

In many instances, it may be helpful to have a reasonable estimate of yield from a field (or a whole farm). There are two methods that have been used to good effect.

Yield Component Method

The **Yield Component Method** can be used as early as the **milk stage**, assuming "normal" development during the rest of the season. It essentially estimates the number of kernels that will be harvested in an acre and uses an estimated number of kernels per bushel to estimate yield per acre.

1. Determine the row length in 1/1,000th of an acre (see guide page 166).
2. Count the number of harvestable ears (ignore nubbins, dropped ears and badly lodged plants) in the 1/1000th of an acre sample. It is a good idea to use more than just one sample; choose five or 10 (more is better) spots in the field to repeat this process. Average the results from these sampled spots.

3. For every fifth ear in the 1/1,000th of an acre, count the number of kernel rows on each and count the average number of kernels per row. Multiply row number of that given ear by its kernels per row to calculate the total number of kernels for each ear.

4. Calculate the average number of kernels per ear. One bushel of corn (assuming 56 lb. test weight, 15.5% moisture) will usually have about 85,000 kernels per bushel. However, depending on seed set (rounds are large and heavy), the environment and the hybrid, this number can range between 65,000 and 100,000.

5. Multiply the number of harvestable ears by the average number of kernels per ear, then divide by 85 (or whatever number thousand kernels per bushel you chose in Step 4), keeping in mind that this sample is from 1/1000th acre.

<u>Example:</u> There are 30 harvestable ears in 17 feet, 4 inches of 30-inch row corn. You counted 6 ears, averaging 14 kernel rows and 42 kernels per row. Multiply 14 by 42 = 588 kernels per ear. Multiply 588 by 30 ears per 1/1000th acre = 17,640 kernels per 1/1000th acre. Finally, divide 17,640 by 85 = 207.5 bushels/acre.

<u>Ear Weight Method</u>

The **Ear Weight Method** cannot be used until after the date of **black layer**, when the grain is about 30-32% moisture. The method requires a shelled sample, corrects for moisture, estimates shelling percentage, and changes pounds per 1/1000th acre into bushels per acre.

ESTIMATING CORN YIELDS BEFORE HARVEST (CONT.):

1. Determine the row length in 1/1000th of an acre.
2. At several sites in the field, count the number of harvestable ears in 1/1000th acre.
3. Harvest and weigh every fifth ear, then shell for a grain moisture sample.
4. Determine percent grain moisture of sample.
5. Multiply ear number by average ear weight.
6. Multiply grain moisture by 1.411, add 46.2 to the result (adjusts for shelling percentage and 15.5% moisture).
7. Divide the item 5 result by the item 6 result, then multiply by 1000 to estimate yield in bushels per acre.

Example: For 30-inch rows, say we counted 24 ears in 17.5 feet. The ear weights averaged 0.5 pounds, and the grain tested 30% moisture. Our yield estimate calculation is:
[(24 x 0.5) ÷ ((30 x 1.411) + 46.2)] x 1000 = 135 bu./acre.

For more information on pre-harvest yield estimation, see: http://extension.unl.edu/statewide/burt/estimating-corn-soybean-yields/. Keep in mind that these are quick and dirty estimates. Both methods tend **to overestimate yields** in excellent environments, as well as in poor ones. For that reason, you should NOT use these values to estimate net profits or to market (buy or sell) your grain!

You can also use the HybridMaize Model to estimate the corn yield in your field pre-harvest. See: https://hybridmaize.unl.edu/. Each year, this model is used to forecast rainfed and irrigated corn yield at various locations in NE and other NC States. See this URL for CropWatch articles on this subject published in 2018: https://cropwatch.unl.edu/tags/corn-yield-forecasts.

CORN GRAIN SHRINKAGE FROM MECHANICAL DRYING:

Photo: http://cropwatch.unl.edu/grainstorage2.

Corn grain drying always involves the loss of weight, almost all of which is water, during the drying process. Grain buyers determine how much dry grain they will pay for when actually buying wet grain. The number of "dry" bushels at the desired moisture obtained after drying a given number of "wet" bushels at delivery moisture can be calculated from the following equation:

"Dry" bushel = "Wet" bushel - ("wet" bushel x SF x PR)

Where:

"Wet" corn bushels = wet corn weight ÷ 56 lbs. per bushel

SF = Shrinkage Factor – the SF value to use depends on your choice of a final dry moisture – see page 171.

PR = Points (of moisture) to be removed from "wet" bushels.

Example: If 56,000 pounds of corn (1000 "wet" bushels) was delivered at 25%, you would be paid for the number of bushels that, after drying, would be at 15% moisture:

(1000 "wet" bushels @ 25%) – (1000 x 0.01176 X 10)

= 1000 – (117.6) = **882.4 "dry" bushels @ 15%**

CORN GRAIN SHRINKAGE (CONT.):

In this case, the corn delivered equals 882.4 bushels when adjusted to 15% seed moisture. Note: Some buyers may subtract a so-called specific "standard" shrink that may be somewhat larger than what was demonstrated in the above calculation. This may be done to provide compensation to the buyer for handling losses incurred in the drying process after purchase of the wet grain.

Shrinkage Factors for Various Final Moistures:

Final Kernel Moisture (%)	Shrinkage (per percentage point of water removed)
15.5	0.01183
15.0	0.01176
14.0	0.01163
13.0	0.01149
12.0	0.01136

An excellent shrinkage worksheet is available online at: www.extension.iastate.edu/agdm/crops/html/a2-32.html.

ABIOTIC STRESS FACTORS IN CORN:

Modern hybrid corn is remarkably resilient, but several environmental factors can result in yield limiting growth and development, which are discussed in this section.

Cold Soils:

Cold soils can cause injury in at least two ways. **First**, cold temperatures of ≤ 50° F can bring germination and seedling development nearly to a stop. Delays in emergence will lengthen the period during which seed/seedlings **are exposed to soil pathogens** that result in seed decay and damping-off and **to belowground insects** (i.e., wireworms, cutworms, etc.) that can inflict damage. Both can significantly reduce stands – even with the excellent seed insecticide and fungicide treatments used today.

Second, the cold soil and soil water can have a direct impact on the seed/seedlings. **Imbibitional chilling injury** happens when the water imbibed into the seed causes damage to the mitochondria of the cells, resulting in the seedling being less able to generate energy for growth. Its symptoms include coleoptiles (shoots) that fail to emerge from the germinating seed, slow emergence from the soil, mesocotyls and coleoptiles that "corkscrew," split coleoptiles and true leaves emerging below ground from the coleoptiles. Slight differences in chilling injury tolerance exists among hybrids, but soils, slope direction, morning *vs.* afternoon planting (when temps are near critical levels) all have additional significant effects.

PURPLING OF SEEDLINGS (AND MATURE PLANTS):

Corn with a "correct" combination of anthocyanin genes can exhibit purple discoloration (top photo) at the seedling stage, exacerbated by cold weather, and also at later reproductive stages (right photo). **This purpling is caused by an accumulation of sugars in the leaf and stalk tissue.** Factors that retard seedling growth, such as cold, soil compaction, etc., can also cause this effect. If you see young purplish plants when the **temperature is cold, examine the roots of V4 or smaller plants to determine if there is soil compaction or other soil-related stress**. Those plants often grow out of the condition when the stress factor is alleviated. During the reproductive (R) stages, purpling indicates an **accumulation of sugars** in the stalk of **barren plants** or those with poor seed set. Check for barrenness and/or reasons for reduced seed set or ear size in the reproductive stages.

SPRING FROST CONSIDERATIONS:

If temperatures stay above about 28° F, frost or freeze damage on small seedlings **usually** doesn't cause long-term damage. Leaves of emerged plants may turn white, then brown and black, but **the growing point is generally below ground level** until the V4 or V5. Plants will usually produce new green leaves in a couple of days. If it is wet, cloudy and cold, however, bacterial rot infection can occur, resulting in significant stand loss.

Very cold temps, below 25° F, can **freeze the growing point** just under the soil surface. While this is rare, it is useful to locate the most frost damaged plants, dig them up, and split them with a knife. The **growing point is a white V-shaped structure above the kernel**. If it is still greenish white, it is alive and will grow. If it is starting to brown, however, you will need to sample the field to see what portion of the plants may be dead. Within three days (with sun and warmer weather) it is usually obvious which plants are green and growing and which are dying or dead.

SATURATED SOILS AND FLOODING:

Growth stage makes a huge difference in length of survival during flooding and soil saturation following heavy rains. **Seeds, seedlings, and young plants need oxygen in the soil** to survive and grow, and just 24 to 48 hours of flooding will kill them, especially if it is warm. **When temperatures are about 75° F or higher, V6 and younger plants may die in less than 24 hours of flooding.** There is some amount of hybrid difference in ability to have seeds/seedlings survive flooded or saturated conditions.

Larger plants (V6 and later stage corn) may have their growing point above the water level which greatly increases their chance of survival. However, **larger plants that survive flooding may still exhibit increased damage and death to their roots.** Damaged roots and lower stalks will become brown and discolored within a day or two. If the growing point is still creamy white, it is alive and will continue to extend leaves. Corn that gets water in its whorls will often show **"crazy top" downy mildew**, and all plants in the flooded areas will be more subject to stalk and root rots.

See: http://cropwatch.unl.edu/flooding-and-corn-survival.

HAIL DAMAGE:


Hail affects corn yields three ways: stand reduction, direct damage and defoliation. Before the V4 stage, corn is affected much less, even by extreme hail events, due to the growing point being underground. After the growing point (the source of all successive leaves, ears and tassel) gets near or above the soil surface (V5 or V6), it becomes vulnerable to damage by hail. **From V6 through VT, the plant becomes ever-more vulnerable** due to the development of more of the final leaf area. Hail causes the **most damage at silking and tasseling,** as losing all of the tassels in a field can result in 100% yield loss. After pollination, as grain-filling proceeds, hail loss risk due to defoliation decreases. However, hail at later growth stages may result in **stalk damage**, which can lead to stalk rot and lodging, and ears that may have regions of hail-impacted rotten kernels. Hail damage also leads to **more common smut** infection, and reduced leaf area results in weed problems.

For additional details on estimating corn crop hail damage, see: http://extensionpublications.unl.edu/assets/pdf/ec126.pdf. https://cropwatch.unl.edu/hailknow. https://cropwatch.unl.edu/hail-know/video-hail-damage-evaluation-and-management-soybean.

The National Crop Insurance Services Agency provides information for insurance adjusters about estimating yield loss arising from hail damage. For corn crop hail insurance information, go to: https://www.rma.usda.gov/Fact-Sheets/Topeka-KS-Region-Fact-Sheets/Corn-2018-NE.

DROUGHT STRESS:

Corn is sensitive to lack of moisture in all its growth stages. Water availability is critically tied to nutrient status, particularly nitrogen. Whenever upper corn leaves roll or wilt, the stress is significant and will result in yield loss. Four consecutive days of leaf-rolling during vegetative growth can cause 5-10% yield loss, and up to 50% yield loss at silking and pollinating. With severe drought stress, plant tissue can desiccate and die, and whole plants will die if drought is not quickly alleviated. **Heat (above 95° F) compounds the drought-induced damage**.

Maximum number of kernel rows is determined at **V6 to V8.** At this stage stressed plants (showing rolled leaves and or graying/wilting) or stressed areas of fields will likely **reduce row numbers**. From **V6 to V16** growth is very rapid if moisture and nutrients are available. Stress at this stage **shortens internodes** and **reduces the size of leaves**. The more stress the plants feel, the fewer florets (potential kernels) per row will develop. **The most critical stage for drought stress is the period from 10 days before to 10 days after pollination.** Photosynthesis (sugar production) and making that sugar available to the florets of ears at this stage keeps florets from aborting. If you see severe leaf rolling, stomates have closed, plants are not taking in CO_2 and photosynthesis virtually stops.

DROUGHT STRESS (CONT.):

Silks are 95% water by weight. If water is short, silk emergence is delayed, and silks from the tips of the ears may never emerge. The timing of silk emergence with pollen shed is absolutely critical, and the largest drought losses generally result from silk emergence delays or pollination failure. *See:*

http://cropwatch.unl.edu/how-does-hot-dry-windy-weather-affect-corn-plants-now.

KERNEL ABORTION OR POLLINATION FAILURE?:

These two symptoms of stress are easily distinguishable.

Pollination failure (due to stress) is often seen at the tip of the ear. Often silks don't emerge from the florets near ear tips in synchrony with pollen flow, or it may result from insects (rootworm adults or Japanese beetle) feeding on silks, and kernels are never formed. The cob will be small in diameter, soft and smooth near the tip, with little indication that kernels were ever present.

The potential primary causes of pollination failure are:

1. Drought or evapotranspiration demand stress that leads to pollen and silk timing issues. Drought affects tassels and pollen shed much less than it impacts silking.

2. Extreme heat stress ($>100°$ F) that leads to insufficient and/or non-viable pollen. Heat can also lead to silk delay.

3. Insect feeding on tassels that lessens the amounts of available pollen.

4. Silk "balling," which occurs in cool conditions in some hybrids (derived from some genetic families).

KERNEL ABORTION OR POLLINATION FAILURE? (CONT.):

5. Long-eared hybrids planted at below optimum density are often unable to express silks from the tips of those ears in time to be pollinated.
6. Excessive rain over several days, right at silking and pollinating time. (Not caused by pivot irrigation since pivots won't be in the same place over successive days).
7. "Drought" hybrids (selected for early silking) grown under ideal conditions can show pollination failure near base of the ear, when silks can emerge several days before pollen shed, which may indicate low population density.

Kernel abortion is typically observed in the **upper half** of the ear (see above photo) and is **usually associated with severe stress** (heat, drought, nitrogen, etc.). However, any abiotic or biotic factor that restricts photosynthesis – examples include a week of dank, cloudy weather; hail-mediated leaf area reduction; leaf diseases that reduce effective leaf area; insect-feeding on leaves or ear shanks; successive 24-hour cycles of **high temperatures during the day and (especially) during the night** – can be causal contributors to kernel abortion.

KERNEL ABORTION OR POLLINATION FAILURE? (CONT.):

Kernel abortion can occur at any time from late R1 through R3. When kernels abort, they shrivel from the size they were at the stage the stress occurred. **Abortion at late R1 and R2 results in nearly clear, tiny aborted florets at the top of the ear, but at R2 to early R3, leads to "corn flakes" and flattened yellow florets – again at the top of the ear**. When sugars are in low supply (stress limiting the photosynthesis), the plant will fill kernels from the base end of the ear, working up toward the ear tips. At the point where there aren't sufficient sugars to keep the florets alive, kernels will begin to abort, particularly in the first 10 days after pollination.

HEAT STRESS:

Even when soil water is plentiful, **heat alone can cause significant damage to corn**. Corn originally developed in the

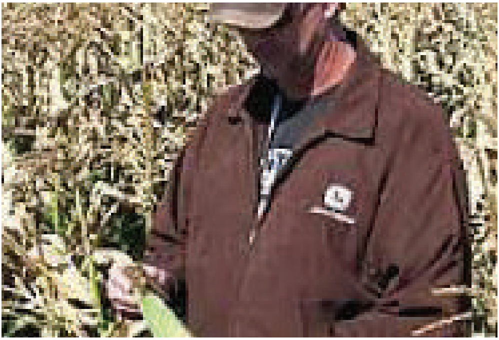
mountain valleys of Mexico, and thus prefers warm (85-88° F) days and cool (50-60° F) nights. The highest yields in the U.S. and the world invariably occur in high areas with very few daytime clouds, (80-90° F) days, and cool (45-55° F) nights (common at high elevations). A hot day or two (above 95° F) generally does not cause severe damage if adequate moisture is available. **Heat (above 95° F) and low humidity can lead to high evapotranspiration that will cause leaf rolling, even in well-watered conditions, due to stomatal closure, which in turn reduces CO_2 uptake and lessens photosynthesis.** Extreme heat can cause "blasting" of top leaves even on well-watered plants in a single day. Moreover, when corn experiences four or five sequential days of heat (generally 100-110° F), photosynthesis is greatly reduced and can cause significant damage to the photosynthetic apparatus. It takes several days of cooler weather to recover. **High night temperatures** (over 80° F), often experienced in July and August during grain fill, causes respiration to proceed at rapid rates at night, consuming a larger part of the sugars produced that day by photosynthesis. Extreme heat at or near pollination can desiccate silks, making them unreceptive to pollen, kill the tassel with the top leaves, and/or desiccate pollen. This can result in a scattered seed set on ears. *See:*

http://cropwatch.unl.edu/how-does-hot-dry-windy-weather-affect-corn-plants-now.

“ZIPPER” EARS

A peculiar seed-set pattern is sometimes called “zipper” ear. Typically such ears will be smaller and missing two to four rows of kernels from one side of the ear due to kernel abortion or pollination failure. This results in a (usually smaller) **“banana-curved” ear with kernels on about 3/4 of the diameter** (as the kernels expand, they force the barren side to curve). Photosynthetic stress usually causes this ear shape, and can be due to drought, or chemical/herbicide damage when ears are being formed, excess population density, nutrient (especially nitrogen) deficiency, and hail defoliation. It is commonly seen on second ears of plants growing in excellent conditions, and where the primary ear is also malformed due to stress.

EARLY FALL FROST/FREEZE CONSIDERATIONS:



Nebraska, particularly in more northern and/or higher elevation areas, occasionally experiences a frost or freeze before corn is mature. Later maturity hybrids or later planted corn is obviously more vulnerable. **Damage is greater on corn that is still in the grain filling process** (before black layer), and results in corn grain being softer (kernels not completely filled) and wetter, since all water loss will be due to evaporation rather than both evaporation and transpiration. This grain will be lower in test weight, subject to more damage at harvest and may be harder to dry for storage. A frost or light freeze (30° F or above) will likely kill leaves from the top down, but generally won't freeze the stalks – the sugar in the stalks can still be stored in the ears and keeps cells in the stalk alive and healthy. **If stalks freeze, expect an increase in stalk rots, along with other issues**. Yield loss estimates and more information can be found at: http://cropwatch.unl.edu/frostfreeze-effects-corn-and-soybean.

YIELD LOSS FROM PREMATURE PLANT DEATH AT GRAIN FILL:

Premature plant death, leaf death or defoliation due to frost/freeze or disease during grain fill will result in significant yield loss. Relative yield loss **depends upon the growth stage** when damage occurs, as well as the extent of damage. The table below provides estimates of grain yield and moisture when frost/freeze-induced premature plant death occurs and may also be useful relative to early plant death from insects, disease or hail.

Crop Stage At Which Damage Occurred	Yield Loss (%) At Death Of:	
	Leaves Only	Entire Plant
Soft Dough	35	55
Full Dent	27	41
Milk Line ½ down kernel	6	12

The following table estimates percent yield reduction due to defoliation, when the crop is harvested immediately *vs.* left to maturity (allowing stalk to translocate solids).

Stages of Kernel Development	% Yield Reduction When Harvested At	
	Defoliation	Maturity
Soft Dough	51-58	34-36
Fully Dented	39-42	22-31
Late Dent	11-12	4-8

Source: Above tables are modified versions of tables in the Purdue Extension publication NCH-57.

Also see the UNL Extension Publication by Robert Klein that contains extensive tables for estimating yield loss from defoliation and plant death at different stages from hail, but which are useful for other damage at:
http://extensionpublications.unl.edu/assets/pdf/ec126.pdf.

CORN IRRIGATION MANAGEMENT:

Over 8 million acres of Nebraska cropland is irrigated each year; corn is produced on about 70% (about 5.6 million) of those Nebraska irrigated acres. However, surface and groundwater resources are limited in many areas, so irrigation-efficient water use is critical. An excellent discussion of corn irrigation needs and management is available in Nebraska Extension *NebGuide G1850*, which has extremely useful information for corn producers. Find it online at: http://extensionpublications.unl.edu/assets/pdf/g1850.pdf.

In some areas, ground and surface water availability is so limited that irrigation can only be used to supplement water supply, notably when rainfall is deficient during **the most water-sensitive critical development phase timeframe, from about a week prior to silking/tasseling to the R2 stage**. Irrigation applied (only as needed) during this timeframe, but not prior to or just after (less water-sensitive stages), can maximize the bu./acre yield response per unit of applied water. For details, go to: http://extensionpublications.unl.edu/assets/pdf/ec2007.pdf.

Videos that describe the use of deficit irrigation strategies are available from Nebraska Extension at: http://cropwatch.unl.edu/presentations-extension-deficit-irrigation-workshop-now-online.

SOIL-PLANT-WATER RELATIONSHIPS:

Effective irrigation management requires a knowledge-based understanding of plants, soils and water in each environment. Critical soil properties include water holding capacity, water intake rate, and whether soil restrictive layers (hard pans) exist. Crop seasonal water use, daily water use at each growth stage and rooting depth are important to irrigation planning. Nebraska is also fortunate to have (predominantly) high quality water for irrigation.

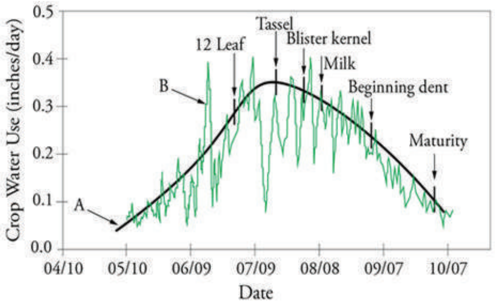
WATER USE IN CORN:

The term crop "evapotranspiration" (ET) refers to **(1)** water lost from the soil by evaporation, plus **(2)** water used by plants, when leaf stomates are opened to allow the entry of CO_2 into the leaf for photosynthesis, but simultaneously allow H_2O to escape from the humid leaf interior – this plant water loss is known as transpiration. In Nebraska, evaporation accounts for about 20-30% (depending upon temperature, wind, humidity and sunshine), while transpiration accounts for about 70-80%. Higher temps, wind, clear sky and low humidity obviously increase crop ET. When plants are small, they don't have the leaf area to transpire much water compared to the much greater leaf area in larger plants.

Water use for a full corn crop varies from 28 inches in Southwest Nebraska to less than 24 inches in Northeast Nebraska. **Hybrid maturity** plays an important role in total water use as well. A 114-day relative maturity hybrid will require considerably more water than a 100-day hybrid, though the longer-season hybrid also has the potential to produce more grain, due to longer filling period and somewhat larger plant size.

Crop water use varies through the season – from the day of emergence to the day of plant physiological maturity. **The highest demands occur during rapid plant growth, usually in June, peaking at silking and tasseling, then slowly decreasing during early grain fill** (solid black historical line in graph on next page). However, in any given year,

<u>daily</u> corn water use can significantly vary from historical norms (i.e., see green line in graph) – higher on hot, windy sunny days of low humidity, or lower on cool, calm, cloudy days of high humidity. On high ET demand days, the root hairs may not be able to concurrently gather soil water at a rate sufficient to keep up with the rate of demand (even in well-watered conditions), which can lead to leaf wilting, rolling or browning on those days. **The upper part of the corn rooting zone supplies approximately 70% of the water it uses.**



Graph of daily corn water use during a growing season on a (A) long-term multiple-year basis, and (B) a single (example) year basis. Source: Kranz, W.L. et al. 2008. Irrigation Management for Corn NebGuide G1850. University of Nebraska-Lincoln Extension.

A great resource for corn producers for estimating current in-season corn ET and corn water use is the Nebraska Agricultural Water Management Network. Estimates for weekly water use, ET and rainfall are available for sites near you (select your county, then select an automated site therein). The daily ET values can be summed over days or weeks to obtain seasonal ET summary. *See:* https://nawmn.unl.edu/ETdata/DataMap.

Generally, irrigation water is used to **supplement** available soil water and effective rainfall. The "water balance" approach for estimating water use would be: Effective Rainfall + Soil Water Removed – Seasonal ET = Irrigation Requirement. Over the season, assuming normal rainfall, corn grown on deep silt-loam soils (with average soil water content) would ordinarily require about **nine inches of supplemental irrigation in Central Nebraska, six inches in Southeast Nebraska and about 14 inches in the panhandle.** These values will vary from year to year depending upon vagaries of within-season weather.

Irrigation management involves a series of decisions concerning **when and how much** water to apply. Each decision needs to be based on the growing stage of the crop, the available water supply, soil water holding capacity – and the amount of water in the soil, weather (atmospheric demand) and, ultimately, the amount of water needed by the crop. Good irrigation management balances current and near future water use while fully utilizing soil water and rainfall. Soil water sensors are available from several sources to help us better understand soil water available to plants. A discussion of their installation and use goes well beyond this brief discussion, but producers should seriously consider adopting them to help them manage their irrigation systems.

A new online UNL website, called **CornSoyWater**, is now available to help irrigated corn producers make better just-in-time-just-the-correct-water-amount irrigation scheduling decisions. See this CropWatch article about the program:

https://cropwatch.unl.edu/2017/cornsoywater-real-time-aid-your-corn-and-soybean-irrigation-decision.

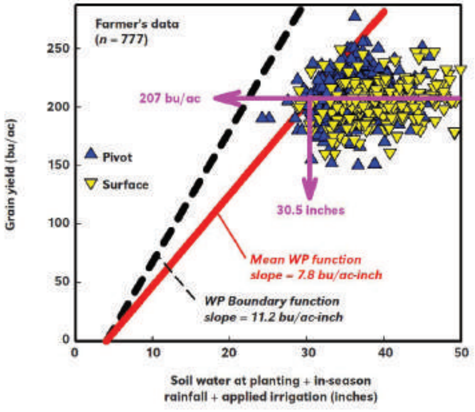
To see videos explain how to use **CornSoyWater,** go to its homepage at:
http://hprcc-agron0.unl.edu/cornsoywater/public_html/Home.php.

IRRIGATION RESEARCH – NE PRODUCER CORN FIELD DATA:

Nebraska producers have a vested interest in water productivity – we need to be able to **maximize profitability** in low rainfall areas and years, **AND preserve our water** resources for future needs. Some of the key questions for irrigated crop producers are:

1) What is the attainable yield for a given total water supply?
2) How much total water does it take to produce a producer-chosen yield goal?
3) How does my water productivity (bushels per inch of the available water supply) compare with those of other irrigated corn producers in Nebraska?

Recent farm-based research from UNL has contributed greatly to understanding how much water is needed to maximize production. Using data collected from hundreds of corn fields across Nebraska on a field-specific basis (i.e., preplant soil water amount, in-season rainfall and irrigation amount and yield), **Nebraska researchers were able to reliably estimate how much water (X) was needed to produce (Y) amount of yield.** The ***theoretical*** maximum boundary limit in Nebraska corn fields, also known as the **Crop Water Productivity** (**WP**) limit (red line in the following chart shown on the next page), is about **11.2** bu./acre per acre-inch change in seasonal water supply (see dashed line in the chart on the next page). But, the ***practical WP*** limit for Nebraska corn fields is (currently) about **7.8** bu./acre per acre-inch of seasonal water supply (see solid red line in the following chart). For Nebraska irrigated corn producers, what the practical **WP** estimate means to you is that with best-practice crop management AND properly scheduled seasonal corn irrigation events (i.e., delivered in a just-in-time-and-just-the-correct-amount manner), **you can expect your corn crop to deliver a 7.8 bu./acre yield increase for each acre-inch of irrigation you apply!**



Reference: P. Grassini et al. (2011) Field Crops Research 120:133–141.

To locate where **your** best corn field might fall in this chart, **go to the left (yield) axis to locate your field's yield, and pencil-draw a *horizontal line rightward***. You will next need to **sum** three critical values: **(1)** total amount of seasonal rainfall your field received, **(2)** total amount of applied irrigation, both of which you likely recorded for this field, plus **(3)** the soil water present in this corn field on the date you planted it. To estimate this third item, go to the next page for help in determining this value. Now, use that sum and go to the chart's **bottom axis to locate your calculated field water supply value, then *pencil-draw a vertical line upward***. Where your horizontal and vertical penciled lines intersect, put an X. If you used best-practice corn and soil nitrogen management, the **X** data point **will typically have a high yield value**, AND if you properly scheduled the irrigation events, the **X** data point **will also fall close to the red WP line.** If so, you will not have over-irrigated a high-yield field, and thus use less water and achieve more net profit!

ESTIMATING PLANT AVAILABLE SOIL WATER AT PLANTING:

Plant Available Water (PAW) is defined as the difference between the Field Capacity (FC) soil water amount and the Permanent Wilting Point (PWP) soil water amount. The below table shows the FC – PWP difference in **units of inches of water present in the zero to 5-foot zone for 13 Nebraska soil series**. You can identify your field's soil series by clicking on the 'Soil Classification Aid' button on the SoyWater web site: http://hprcc-agron0.unl.edu/soywater/, where you can simply type in the street/city address for your field. If your field was at or near FC at planting (often the case in Eastern Nebraska), an AWHC value in the table can be directly used (see previous page) as an item (3) estimate. If your field was not at FC on the planting date, you will have to use the formula in the *Grassini et al. (2012)* ***EC105***.
http://extensionpublications.unl.edu/assets/pdf/ec105.pdf.

Table 1. Plant available soil water holding capacity (AWHC) values in a 0- to 5-foot crop rooting zone, as reported by USDA-NRCS for the below-listed soil series in Nebraska.

Soil Series Name	AWHC (inches)	Soil Series Name	AWHC (inches)
Kennebec silt loam	12.6	Crete silt loam	10.9
Holdrege silt loam	12.2	Aksarben silty clay loam	10.7
Hord silt loam	12.1	Tomek silt loam	10.7
Holder silt loam	11.9	Hastings silt loam	10.4
Moody silty clay loam	11.6	Wymore silty clay loam	9.1
Nora silty clay loam	11.3	Woodly sandy loam	6.4
Yutan silty clay loam	11.1		

Source: Grassini et al. (2012). A PDF is available at:
http://extensionpublications.unl.edu/assets/pdf/ec105.pdf.

CORN INSECTS:

There are some insects that occur in Nebraska that can cause economic damage to the corn crop. There are many others that occasionally cause economic damage, and still many other insects are beneficial in our environment.

The purpose of this guide is to help you identify some of the most common insects which can cause crop damage; however, it would require too many pages to provide pictures and descriptions of all insects. Here are some excellent online sources that can help you identify more insects than this guide covers:

- The UNL Entomology Extension Field Corn main site, with options for further information about types of insects, and insect control recommendations, can be found at: http://entomology.unl.edu/extension/crops/fieldcorn.
- CropWatch is extremely useful to producers, as it highlights current production issues, including current insect pest issues. The archives are also available, and often provide follow-up from past season(s) infestations/treatments, etc. at: http://cropwatch.unl.edu/.
- CropWatch also provides articles of general importance concerning insect resistance management, current reports from UNL Extension personnel, and contacts for getting help directly from them. For a quick reference guide on corn insects, with brief descriptions, damage symptoms, and scouting information, go to: http://extensionpublications.unl.edu/assets/pdf/ec1562.pdf.
- For more insect descriptions and photos, go to: http://extensionpublications.unl.edu/assets/pdf/ec1572.pdf and http://extensionpublications.unl.edu/assets/pdf/ec1573.pdf.

We recommend the purchase of the ***Guide for Weed, Disease and Insect Management – UNL Extension Circular EC130.*** See pages 275, 289-296, & 311-314 in the 2018 **EC130** for **corn insecticide products and information**. It is available in a printed form (or as a PDF) at a cost of $15 for either, or at a discounted cost of $25 for both. You can purchase it at:
https://marketplace.unl.edu/default/ec130.html.

For a current list of corn hybrid **Bt traits**, see:
https://lubbock.tamu.edu/files/2018/11/BtTraitTableNov2018.pdf.

The following corn insect ID section has been arranged in approximate seasonal order of insect appearance from planting/emergence to plant physiological maturity.

SEEDCORN MAGGOT (*Delia platura*):

Description: Pale, yellowish white maggot ¼-inch long. Unlike grubs and caterpillars, maggots lack defined heads and legs. Often found in damaged, rotting kernels.

Seasonal Peak: Planting through May (stages VE-V2).

Tissue Injured: Reduce stands by burrowing into seeds and feeding on the germ, not endosperm, especially in moist, heavily manured/high-residue fields or following cover crops. Usually cause damage when germination and growth are slowed due to cold and wet conditions.

Sampling: Scouting is usually initiated only after poor emergence has been noted. Dig up ungerminated seeds to determine the presence or absence of maggots or puparia. Seed remnants often rot due to secondary fungal infections.

Economic Threshold: No rescue treatments are available. Use of an appropriate rate of seed-applied insecticide is advised if planting or replanting into heavily manured or residue-covered fields. Control with seed-applied insecticides is generally satisfactory. For locations with history of seed corn maggots, order seed with high rates of seed-applied insecticides. Either accept stand loss or replant.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/ec1573.pdf.
http://cropwatch.unl.edu/documents/CW_News/2015/2016-EC130-Insecticide-Guide.pdf.

WIREWORMS (*Agriotes, Limonius, Melanotus* etc., spp.):

Description: Slender, hard-bodied, brownish larvae, ½ to 1 ½ inches long.

Seasonal Peak: April to early June (germination to V4).

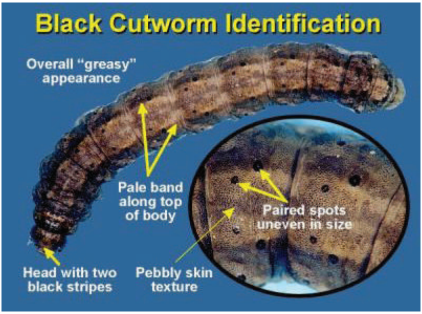
Tissue Injured: Feed on the seed or seedling below ground causing wilting and sometimes plant death, resulting in gaps along row. Their multiyear life cycle may mean that they occur more often in certain areas and certain fields and damage can get worse over the course of their life cycle.

Sampling: Two to three weeks before planting, set up five bait stations in different areas of a field with a suspected infestation. Refer to Purdue Field Crops IPM for technique at: http://extension.entm.purdue.edu/fieldcropsipm.

Economic Threshold: No rescue treatments are available. Seed applied insecticide generally provides good control of low/moderate populations, but no rescue treatments are available. Among early-season seed/root-feeding pests, high populations of wireworms are the most difficult to manage with seed-applied insecticides.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/ec1573.pdf.
http://cropwatch.unl.edu/documents/CW_News/2015/2016-EC130-Insecticide-Guide.pdf.
https://cropwatch.unl.edu/2018/scout-emerging-corn-insects-dont-take-protection-granted.

BLACK CUTWORM (*Agrotis ipsilon*):



Description: Black cutworm colors range from black to pale gray, rough, granular texture on abdominal segments, brown head, ½-inch long in early larval instars and 1 ½ inches long at maturity. Larvae curl up when disturbed.

Seasonal Peak: April through early June (emergence to V5).

Tissue Injured: Typically, larvae live at or just below soil surface and feed on above soil plant parts. Early stages leave "shot-hole" feeding in leaves. Later stages cut seedlings at or below the soil surface.

Sampling: Adults migrate from southern areas to the central states each spring and lay eggs, often in weedy areas. Look for shot-hole feeding on VE and V1 plants, and for plant cutting at V1 and beyond.

Economic Threshold: If 2-4% of plants below ground or 6-8% above ground show feeding/cutting, treatment is warranted if weather is cool and larvae are small. Some Bt transgenes provide partial control. Seed-applied insecticides can provide reasonable control of moderate infestation.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/g1153.pdf.
http://cropwatch.unl.edu/documents/CW_News/2015/2016-EC130-Insecticide-Guide.pdf.
https://cropwatch.unl.edu/2018/scout-emerging-corn-insects-dont-take-protection-granted.

WHITE GRUBS (*Phyllophaga, Cyclocephala* sp.):

Description: Several species of white grubs are native to Nebraska. Some have annual life cycles and others have three-year life cycles. White grubs are white, C-shaped, "fat" larvae typically 1 to 1 ½ inches long, with a well-defined large brown head.

Seasonal Peak: Usually feed on corn at VE to V5 stages in April through early June.

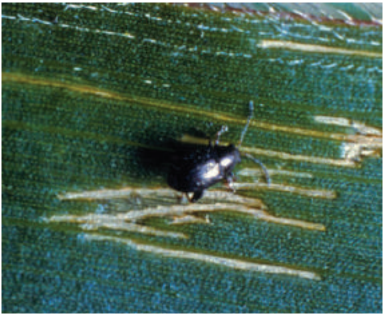
Tissue Injured: Most frequently feed on roots of corn planted after forages or grass sod. Damage is seen as wilting (due to root pruning) and stunting leading to death, leaving dead plants with few remaining roots.

Sampling: Scouting is difficult and depends upon sorting through soil to look for the grubs, which tend to occur in patches. Annual species larvae are found from July through the following May, and will overwinter as larvae. *Phyllophaga sp.* overwinter as either larvae or adults.

Economic Threshold: Rescue treatments are ineffective. Seed applied insecticide gives reasonable level of control. In furrow insecticides (at planting) give the best control when planting into forage or sod.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/ec1573.pdf.
https://cropwatch.unl.edu/2018/scout-emerging-corn-insects-dont-take-protection-granted.

CORN FLEA BEETLE (*Chaetocnema pulicaria*):



Description: Small, shiny black beetle with large hind legs, jump like fleas when disturbed.

Seasonal Peak: Found primarily in Eastern and Southern Nebraska. Feed primarily on small corn, up to V6 in April and May, but they can feed much later.

Tissue Injured: Feeds on leaves, leaving narrow white strips where chlorophyll layers have been eaten. Corn flea beetle vectors bacterial disease, Stewart's Wilt (see guide page 221), which causes early wilt and later, a leaf blight.

Sampling: Scout for plants showing feeding (scraping damage) tracks on the upper leaf surface of lower leaves from V1 to V6. Count beetles on 25 consecutive plants.

Economic Threshold: Corn <3 inches with 30% of tissue damaged. Corn <6 inches with 4 to 5 beetles per plant.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/ec1562.pdf.
http://cropwatch.unl.edu/documents/CW_News/2015/2016-EC130-Insecticide-Guide.pdf.
https://entomology.unl.edu/insecticide-treatment-options-flea-beetles-field-corn.

CHINCH BUGS (*Blissus leucopterus*):

Description: Early stages are wingless, red with white bands, 1⁄16- to 1⁄8-inch long bugs. Adults turn mostly black with a white triangle in the middle section of wings, and become more elongate shaped.

Seasonal Peak: May through September, usually in the southern third of Nebraska. First generation occurs in small grains, migrate into corn as small grains mature. Populations tend to build over successive dry years, drought conditions.

Tissue Injured: Chinch bugs suck sap from plants of all stages, and are generally found behind the leaf sheaths of lower leaves, but can feed on the roots.

Sampling: Check behind leaf sheaths and on lower plant especially near pastures, waterways, wheat stubble. Injury symptoms are stunting of plants, wilting, red feeding marks behind leaf sheaths, yellow streaks and plant death.

Economic Threshold: Reasonable control with seed applied insecticides, difficult to control with insecticides as re-infestation can occur rapidly.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/g806.pdf.

CORN ROOTWORM LARVAE (*Diabrotica* sp.):

Description: Small white larvae, up to ½-inch long, with distinct dark head.

Seasonal Peak: Eggs are laid in mid-to-late summer in soil of corn or bean fields, hatch mostly in late May and June.

Tissue Injured: Feed on roots of corn in June and July, and can tunnel into roots. Root feeding can be severe, cause root lodging and large yield losses.

Sampling: Larval damage sampling is done by digging roots at V8 through R1. Count larvae individually by shaking the roots over a black plastic bag. Larvae can be counted individually to estimate the population, but it is more useful to dig and rate roots for the level of damage observed. Scale: first digit is the number of nodes of roots eaten to within 1.5 inches of the stalk, the second digit is the fraction of a node of roots eaten to within 1.5 inches of stalk, e.g., a 1.4 rating means one node of roots has been eaten, plus 0.4 of roots from the other nodes.

Economic Threshold: A root rating of 1.0 or greater generally will cause yield loss.

References or Informative Websites:
http://cropwatch.unl.edu/unl-documents-shift-corn-susceptibility-rootworms-nebraska.

CORN ROOTWORM – SPECIAL CONSIDERATIONS:

Corn rootworm has a history of chemical control failures, as successive active ingredients worked for a few years, but *Diabrotica* species evolved resistance to them. Primary control, at present, is transgenic Bt genes in hybrids, but in recent years, research has shown **the western corn rootworm capable of developing resistance to known Bt genes** as well. Deploying multiple **Bt** sources of resistance is better than using single genes. New genetic approaches, such as **RNAi** (small RNA molecules that interfere with gene expression) are coming on line, and will help provide stability. It is too soon to know if rootworms will rapidly evolve resistance to **RNAi**. Long-term, an **IPM approach will likely be needed**, which combines crop rotation, resistance gene/source rotation (and stacks), rigorous adherence to refuge requirements, and using chemical approaches only when necessary. For a current table of **Bt** traits, see: https://lubbock.tamu.edu/files/2018/11/BtTraitTableNov2018.pdf.

An excellent online educational series on corn rootworm is available from the UNL Department of Entomology here: http://crweducation.unl.edu/. Multiple modules teach many science-based concepts on the current knowledge of corn rootworm biology, behavior, IPM strategies, resistance management strategies, and population genetics.

EUROPEAN CORN BORER (*Ostrinia nubilalis*) FIRST GENERATION:

Description: Newly hatched larvae are gray with distinct black heads, and grow from about ⅛- to 1-inch long.

Seasonal Peak: Eggs are laid (mid-to-late June, into early July) in "masses" a "whitish, waxy looking set of scales" usually on the bottom side of leaves. Hatch in a few days.

Tissue Injured: European corn borers feed on leaves in whorls and when leaves emerge, feeding "shot-holes" are apparent. As larvae grow they burrow into stalks and continue to feed in the pith and vascular system.

Sampling: Count plants with feeding holes in 100 consecutive plants in several areas of the field.

Economic Threshold: Chemical control is possible when treated before they burrow into stalks. Primary control is by use of Bt genes. Because of the biology, less rigorous refuge adherence has been more effective for European corn borer than for rootworm. However, it is important to adhere to refuge requirements to prevent biotype shifts.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/g1782.pdf.
http://cropwatch.unl.edu/documents/CW_News/2015/2016-EC130-Insecticide-Guide.pdf.
https://cropwatch.unl.edu/2018/scouting-and-treatment-first-generation-european-corn-borer.

CORN LEAF APHIDS (*Rhopalosiphum maidis*):

Description: Corn leaf aphids are very small (about 1⁄16-inch) blue-green insects, and usually without wings. Aphids transmit maize dwarf mosaic virus.

Seasonal Peak: Late June to August.

Tissue Injured: Found in the whorls, they feed on the tender leaves and tassels (by sucking out sugary liquids) before they emerge. Aphids can cause the whorl and emerging leaves to be sticky, causing the tassel glumes not to open, reducing another emergence and pollen shed.

Sampling: Easily observed by examining emerging leaves. High humidity, erect leaves/tight whorls tend to favor aphids. Count five groups of 20 plants in several areas.

Economic Threshold: Very high populations (15 to 30 aphids per plant at 14 to 21 days before tasseling). After tasseling, aphid populations drop, likely due to desiccation and feeding by natural enemies. More often a problem in seed fields, especially the male plant rows.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/ec130.pdf.
http://cropwatch.unl.edu/documents/CW_News/2015/2016-EC130-Insecticide-Guide.pdf.

JAPANESE BEETLE (*Papillia japonica*):

Description: Adults are about ⅓- to ½-inch long, with larvae similar to white grubs. Beetles have greenish heads and thorax, and copper colored wing covers.

Seasonal Peak: Lay their eggs in the soil, overwinter as larvae, which feed on corn roots (V6 to R2) the following spring, causing root pruning similar to white grubs. When present they often occur in "hot spots" in the field and are attracted to plants already being fed on.

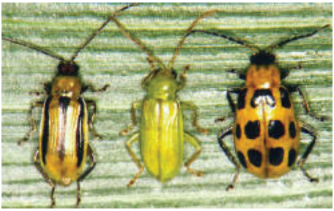
Tissue Injured: Beetles are often found feeding on leaves and whorls, they tend to leave the veins and midrib intact. They also will feed on silks, potentially interfering with pollination if abundant.

Sampling: Examine five groups of 100 plants for presence of skeletonized leaves, and in reproductive stages, look for them on ears.

Economic Threshold: The Japanese beetle is most damaging at silking/pollinating at the rate of three or more per ear and silks are being clipped to within a ½-inch of the husk.

References or Informative Websites:
http://cropwatch.unl.edu/japanese-beetles-emerging-identification-key-management.
https://cropwatch.unl.edu/2018/scout-corn-and-soybean-japanese-beetles.

WESTERN, NORTHERN, AND SOUTHERN CORN ROOTWORM ADULTS (*Diabrotica virgifera virgifera, barberi, undecimpunctata*):



Description: Western females are green or yellow with black stripes, males can be striped to nearly black. Northern are yellowish green. Southern or Spotted species are yellow with 11 black spots.

Seasonal Peak: Adult beetles begin to emerge in July and continue to emerge through August.

Tissue Injured: If corn hasn't yet silked, they will feed on leaves, causing whitish areas. Primary damage is from feeding on/clipping silks, leaving less length to receive pollen grains. This can result in incomplete seed sets.

Sampling: Count adults on five consecutive silks in 10 areas at R1.

Economic Threshold: 10 to 15 per plant on commercial corn, or 8 to 10 with drought stress and silks are being clipped to within ½-inch of the husk; five or more per plant in seed corn fields. Foliar insecticides may be applied to prevent silk clipping if heavy. See guide page 186.

References or Informative Websites:
http://cropwatch.unl.edu/documents/CW_News/2015/2016-EC130-Insecticide-Guide.pdf.
https://lubbock.tamu.edu/files/2018/11/BtTraitTableNov2018.pdf.

EUROPEAN CORN BORER (*Ostrinia nubilalis*) SECOND GENERATION:

Description: See First Generation – guide page 205.

Seasonal Peak: Late July through mid-September.

Tissue Injured: After hatching from egg masses on underside of leaves, larvae feed on pollen caught in leaf axils and ear tips, before moving to leaf sheaths and collars. Later instars bore into stalks, and feed on pith and vascular tissue.

Sampling: Look for egg masses on five groups of 20 plants, under side of leaf, every three or four days as soon as moths begin flying.

Economic Threshold: Chemical control can be effective in non-Bt (non-refuge) with good scouting/timing. Economic thresholds depend on yield potential, other factors. Primary control is presently the use of Bt genes. Refuge areas are essential to prevent shifts of European corn borer to forms resistant to Bt genes.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/g1783.pdf.
https://lubbock.tamu.edu/files/2018/11/BtTraitTableNov2018.pdf.

WESTERN BEAN CUTWORM (*Striacosta albicosta*):

Description: Whitish egg masses (turn bluish-black in 4 to 7 days) laid on upper side of leaves. Early instars are dark brown with faint diamond shapes on their backs. Larger larvae lighter in color, gray to pinkish-brown with three short white stripes on the segment behind the head, shows as two distinct dark rectangles behind orange head.

Seasonal Peak: July to September, whorl to grain filling.

Tissue Injured: Larvae mostly feed on grain in developing ears, often with multiple larvae per ear resulting in large amounts of damage when infestations are significant.

Sampling: Check 20 plants from five or more areas of each field. Look for eggs on upper side of leaves and check tassel for larvae. Larvae often isolated in areas within fields.

Economic Threshold: Five to eight or more percent of plants infested with eggs or larvae. Timeliness in finding egg masses and newly hatched larvae is the key. Not all Bt genes are effective against western bean cutworm.

References or Informative Websites:
http://cropwatch.unl.edu/begin-scouting-western-bean-cutworm-eggs-corn.
https://cropwatch.unl.edu/2016/begin-scouting-western-bean-cutworm-eggs-corn.

http://extensionpublications.unl.edu/assets/pdf/g2013.pdf.

CORN EARWORM (*Helicoverpa zea*):

Description: Color varies from black, green and yellow to pinkish tan. Larvae have alternate light and dark horizontal stripes, orangeish heads. Often confused with western bean cutworm, corn earworm is more widely distributed, often found near tips of corn ears, especially in refugia.

Seasonal Peak: Mid-July through September.

Tissue Injured: Eggs are laid individually on silks and ear tips. Feeding starts at ear tips, then larvae bore through husks into ears, working downward toward butt. Larvae are cannibalistic, so generally only one mature larva is found per ear.

Sampling: Use pheromone traps or clip silks from five groups of 20 plants, count eggs and larvae on black surface.

Economic Threshold: Chemical control is possible, but depends upon carefully scouting silks for eggs and young larvae, with prompt spraying before they penetrate ears. Good control with Bt genes, but the genes vary in their degree of control. Consult your seed supplier for details.

References or Informative Websites:
https://entomology.unl.edu/insecticide-treatment-options-corn-earworm-field-corn.
http://extensionpublications.unl.edu/assets/pdf/ec1572.pdf.

CORN BLOTCH LEAFMINER (*Agromyza parvicornis*):

Description: Adults are a small black fly which lay white, creamy eggs on the bottom side of leaves.

Seasonal Peak: July and August.

Tissue Injured: Larvae hatch, tunnel into the leaf, eating cell layers between the top surface and bottom surface of corn and other grasses. The larvae tunnels leave hollow, clear to whitish areas of the corn leaf. A high population can kill several leaves.

Sampling: Multiple generations per year, from the whorl stage to maturity. Scout fields for leaf tunneling and clear, white leaf regions, note presence of adult flies.

Economic Threshold: None available. Control of corn blotch leafminer by chemicals is difficult, and these have the potential to kill beneficial insects, leading to mite issues and other problems. When damage is noted, the larvae are inside the leaf and thus protected from chemicals, and won't be contacted by sprays, nor will their food source.

References or Informative Websites:
http://cropwatch.unl.edu/unl-cropwatch-july-9-2010-corn-blotch-leafminers-damaging-corn-central-nebraska.

MITES:

Mites are **NOT** insects; instead they are related to spiders and ticks. Mites destroy individual cells by piercing them to suck out contents. Symptoms are yellow spots, webbing on underside of leaves, and leaf death if populations are high, all of which may result in reducing the ability of plants to manufacture sugars. In corn, yield reductions are most severe when mites damage leaves above the ear level, which is where most of the plant photosynthesis occurs. Generally, this occurs during grain filling, resulting in poor grain test weight, too rapid dry-down, and early death and lodging. **Mites are always worse in hot, dry years**.

Two species of mites are common in Nebraska corn, and **correct identification is essential** to control, as some insecticides tend to "flare" populations of two-spotted spider mite, but not Bank's grass mite, and they can differ in sensitivity to chemistries.

<Bank's Grass Mite [BGM] *(Oligonychus pratensis)*

Description: BGM has dark green pigment spots (from their food) that extend along the body and on the edges of their bodies. BGM is more "elongate" than TSM. BGM produces less "spider silk" than TSM, feeding on lower leaves before moving up.

<Two-Spotted Spider Mite [TSM] *(Tetranychus urticae)*

Description: TSM has dark green pigment in two distinct spots located on the front half, one on each side. It produces more "spider webbing" than BGM, and often feeds widely over the entire plant canopy.

MITES (CONT.):

Seasonal Peak: BGM appears earlier in the season, while TSM usually appears in late July and August.

Tissue Injured: Mites pierce cells and suck out plant fluids to get sugars, usually feed on bottom of leaves.

Sampling: First symptoms are fine yellow/white spots on top of leaves. Underside of leaf will have spider webbing. Use a 10x or greater hand lens to see individual mites.

Economic Threshold:
For BGM, treat if mites are present up to the ear leaf.
For TSM, mites will likely be present on all plant leaves; treatment is suggested if 15-20% of leaf area is infested, and if leaf yellowing has begun.

References or Informative Websites:
http://cropwatch.unl.edu/2016/identifying-spider-mite-damage-species-responsible.
https://cropwatch.unl.edu/managing-spider-mites-corn-and-soybean-thresholds-treatments-unl-cropwatch-july-25-2.

NEMATODES (More than 12 species, depending upon soil types, region, crop history, and other factors):


Nematodes are very small, non-segmented round worms that inhabit soil and water, plants and animals. A very few are parasitic, and fewer still are capable of causing crop damage. However, Nebraska has a number of nematodes damaging corn, and nematodes are present in every field, in some number. Damage potential of nematodes depends upon which species and how many are present.

Two of the larger and more damaging species are the sting and the needle nematode, which occur in higher numbers in sandy soil types. Other species, such as the root-lesion nematode dwell inside plant roots of many crops including corn and are smaller and present in most fields.

Description: Not particularly useful, as nematodes usually cause general symptoms that can be caused by several problems.

Seasonal Peak: Damage is usually observed at V6 or earlier.

Tissue Damaged: Plant parasitic nematodes feed on and in root tissue, tending to feed preferentially on fine roots. Feeding generally starts at the seedling stage, and can continue through maturity. Symptoms include uneven patches in fields, yellowing, wilting, stunting, root lesions and root death. Crop injury levels depend on which species are present and in what numbers.

NEMATODES (CONT.):

Sampling: Suspected damaged areas in fields/patches should be sampled. Sampling procedures and timing vary by soil type and current crop. The UNL preferred sampling procedures are explained in an excellent online article that can be found at: https://cropwatch.unl.edu/corn-nematode-sampling.
The below URL contains a video by Dr. Tamra Jackson-Ziems on corn nematode sampling:
https://www.youtube.com/watch?v=zQ0r3p1cz4E.

NOTE that sandy soil fields should be sampled for nematodes between corn emergence and stage V6 for the most accurate results.

Submit your soil samples to the UNL Plant & Pest Diagnostic Clinic for a fee-based determination of the presence of nematodes. For submission details and guidelines – see guide page 7.

Economic Threshold: There are no established economic thresholds for nematodes and damage potential varies greatly by species. The sting nematode, only found in sandy soil, will cause economic damage at a very low population of one per 100 cubic centimeters of soil. This makes careful soil sampling and professional identification essential for nematode control. In many fields in Nebraska, nematodes are likely causing 10 bu./acre (or more) yield loss without any apparent symptoms. Control is by cultural practices (crop rotation to non-host crops for several years is extremely helpful) and nematicides, including seed applied ones.

References or Informative Websites:
https://crops.extension.iastate.edu/nematodes-corn-production-growing-problem.

CORN DISEASES:

We recommend the **Guide for Weed, Disease and Insect Management – UNL Extension Circular EC130**. This publication is available in a printed form (or as a PDF) at a cost of $15 for either, or at a discounted cost of $25 for both. You can purchase it at: https://marketplace.unl.edu/default/ec130.html.

See pages 240-266 in 2018 NE EC130 for corn fungicides and cost per acre information.

For a good UNL summary website offering information on nearly all major Nebraska corn diseases, see:
https://cropwatch.unl.edu/plantdisease/corn

For a list of fungicides that are available for the control of corn fungal pathogens, see:
https://cropwatch.unl.edu/UNL-EC130-Corn-Disease-Trtmt-Tables.pdf.

For a list of videos about major Nebraska corn diseases featuring **Dr. Tamra Jackson-Zeims,** see:
https://www.youtube.com/playlist?list=PLdssrgg38jJ09IFWsfiKJI-ZWNflg5lvZP.

For photographs and brief text descriptions of major NE corn diseases, see these three web sites:
http://extensionpublications.unl.edu/assets/pdf/ec1867.pdf.
http://extensionpublications.unl.edu/assets/pdf/ec1868.pdf.
http://extensionpublications.unl.edu/assets/pdf/ec1901.pdf.

SEEDLING DISEASES (Fusarium, Rhizoctonia, Pythium, and some bacterial species):

Description: Slow growth, wilting, yellow/red discoloration and lesions on roots and/or mesocotyl, pre- or post-emergence death, particularly in wet areas.

Scouting: Look closely at wilting, dying seedlings that often show root rotting, and rotted seed/seedling tissue and lesions on mesocotyl before or after emergence.

Epidemiology: These organisms are abundant in the residue from preceding crops or in soil. They are especially favored when soils are cool (<55° F) and wet for extended periods, when corn germinates and grows slowly, if at all. Soil compaction, heavy rains, and inbred, rather than hybrid seed, increase the risks from seedling diseases.

Management: Modern seed treatments reduce the frequency, and are effective for about two to three weeks, depending upon soil conditions. Two or more classes of fungicide are generally applied, Apron or Allegiance for the Pythium (with motile spores), and Maxim or Dynasty for other fungi. If soils remain cold and wet, and corn has not emerged in 2 or 2 ½ weeks, one should examine fields for this problem.

References or Informative Websites:
http://cropwatch.unl.edu/2016/seedling-diseases-developing-corn.
https://cropwatch.unl.edu/plantdisease/corn.

HOLCUS SPOT (*Pseudomonas syringae*):

Description: Round to oval lesions (up to ¾-inch diameter), water-soaked at first, then turning tan, often exhibiting a brown/red ring, but usually limited to lower leaves. May look like spray drift spots that arise from membrane disrupter herbicides, like Paraquat, or from spray adjuvants.

Scouting: May through July. Often develops during a wet spring, especially with driving rain and subsequent "splash." Watch for round/oval tan spots.

Epidemiology: Bacteria overwinter in soil and crop residue, and development is favored by warm, damp weather.

Management: Economic damage is rare, and cannot be managed with fungicide treatments, as it is a bacterial disease.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/ec1867.pdf.
https://cropwatch.unl.edu/plantdisease/corn.

EYESPOT (*Aureobasidium zeae*):

Description: Small 1⁄16- to 1⁄8-inch tan lesions form on leaves, surrounded brown/purple rings, and often a yellow halo.

Scouting: Typically May and June, but can infect corn throughout the season, particularly in more northern, cooler, damper climates or years. Often found in V4 to V8 corn.

Epidemiology: Fungus overwinters in crop residue (especially no-till), and development is favored by cool, damp weather. When severe, eyespot can continue re-infecting leaves as new leaves appear and cause yield loss if leaf area lost in grain filling period.

Management: Control measures include resistant hybrids and crop rotation. Tillage may help reduce disease severity when practical.

References or Informative Websites:
http://cropwatch.unl.edu/watch-bacterial-diseases-corn.
https://cropwatch.unl.edu/plantdisease/corn.

STEWART'S WILT (*Pantoea stewartii*):

Description: In small plants, about V5 or less, infected plants will develop systemic wilt, and some plants develop an infected cavity in the stem near the soil line. Later season infections are possible, when the disease appears as a foliar blight, with long lesions, brown with wavy margins, similar to those of Goss's wilt and blight.

Scouting: Late May and June, looking for wilted plants with flea beetle feeding "tracks," "water soaked" areas around feeding tracks, long gray/brown lesions.

Epidemiology: This bacterial disease is vectored by flea beetles (see guide page 201). Bacteria overwinter in the gut of flea beetles, which in turn overwinter in plant residue in the soil, especially continuous corn. Cold winters reduce the number of beetles significantly, reducing disease issues.

Management: Insecticides which control flea beetles also affect control of Stewart's wilt. Most sweet corn is quite susceptible to Stewart's, field corn hybrids vary in resistance. Resistant hybrids are likely the best means of control.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/corn/stewarts-wilt.
https://cropwatch.unl.edu/plantdisease/corn.

BACTERIAL LEAF STREAK (Xanthomonas vasicola pv. vasculorum):

Description: Lesions are narrow, between veins, and yellow, brown, to tan in color, ranging in length from ½-inch to many inches long. Lesions may develop on lower leaves initially and spread quickly to the mid and upper canopy and appear yellow when backlit. May cause stalk impacts due to reduction of leaf area during grain-filling.

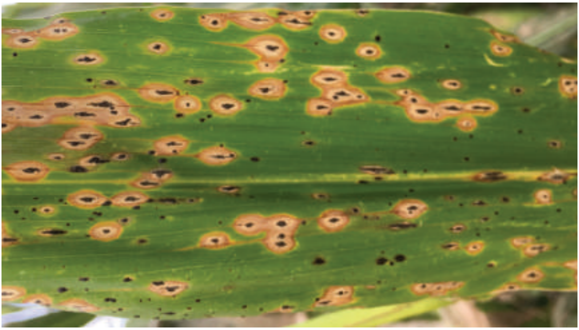
Epidemiology: The bacteria infect through natural openings in leaves and periods of rain and wind storms and high humidity favor infection.

Scouting: Lesions may develop early in V7 corn through August and appear similar to those of gray leaf spot. Look at lesion margins that are more irregular and wavy compared to the smooth, linear margins of gray leafspot lesions.

Management: Hybrid resistance is currently unavailable but varies somewhat. Crop rotation and tillage may help to reduce severity.

References or Informative Websites:
http://cropwatch.unl.edu/bacterial-leaf-streak.
http://extensionpublications.unl.edu/assets/pdf/ec3034.pdf.
https://cropprotectionnetwork.org/download/2550/.
https://cropwatch.unl.edu/plantdisease/corn.

TAR SPOT (Phyllachora maydis and/or Monographella maydis):



Credit: Marty Chilvers, Michigan State University

Description: Observed in eastern NC states but not yet (2018) in NE. Early lesions are black, like splattered tar on leaves and/or husks. Mature lesions are black surrounded by tan to brown rings of dead tissue, as in a "fisheye" appearance. Severe disease may cause early leaf or plant death that can result in weakened stalks and lodging as well as loss of yield and test weight.

Scouting: Disease may begin in the seedling stages on into the remainder of the season. The fungus overwinters in the stomata in infested crop debris.

Epidemiology: The fungus causing tar spot creates the black stromata and releases ascospores during wet or humid conditions. Spores are spread by splashing water and wind. New lesions develop within 2 weeks.

Management: It is unclear yet whether fungicides will effectively manage this disease.

References or Informative Websites/Videos:
https://cropprotectionnetwork.org/library/.
https://www.youtube.com/watch?list=PLnSZYPltjZJ5bfkY8IjWQAwf-BUAQr9yWP&v=uLygYjMkXQE.

PHYSODERMA BROWN SPOT (*Physoderma maydis*):

Description: Infection often results in bands of small chlorotic to brown spots (approximately ⅛-inch) in diameter, midribs often turn brown to purple, also purple spots form on leaves and stalks. Stalks may be infected at multiple points near nodes which may weaken them, often resulting in brittle nodes which break with little pressure.

Epidemiology: This fungus has sporangia which splash or are blown into whorls during storms. Sporangia can live in soil and crop residue for years. They release zoospores which have tails and can swim when water is present in the whorls.

Scouting: Corn is most susceptible at V5 to V9 stage, several days after heavy rains or storms.

Management: Hybrids vary in resistance (though many companies don't rate their hybrids for physoderma brown spot), but it has been seen more often in recent years. It is more common in no-till continuous corn, and crop rotation helps manage it. Foliar fungicides are available, but timing is difficult, and they rarely have yield impact.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/corn/physoderma.
https://cropwatch.unl.edu/plantdisease/corn.

COMMON RUST (*Puccinia sorghi*):

Description: Early lesions tend to be small and circular yellow spots. Common rust quickly forms brick red/brown pustules on both upper and lower leaf surfaces. Mature lesions become more elongated with a yellow halo. Brick red spores will rub off on fingers.

Scouting: Seen most often in late May and June, it requires dew and free moisture on leaves for several hours. Pustules tend to be more sparsely spaced than those of southern rust.

Epidemiology: The causal fungus overwinters in tropical and subtropical areas on Oxalis sp. living plants. Spores blow in from southern areas with spring weather fronts. It is favored by cooler temperatures (61-77° F) than southern rust, and it tends to occur earlier in the season, especially when wet, dewy conditions persist over several days.

Management: Hybrids vary in their resistance, but most hybrids show limited sensitivity. More frequently, this disease is a problem in sweet corn and seed corn fields, because some inbreds are susceptible. Fungicide treatments can be effective, but are rarely needed.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/corn/common-rust.
https://cropwatch.unl.edu/plantdisease/corn.

SOUTHERN RUST (*Puccinia polysora*):

Description: The pustules and spores appear more orange/red to tan in color, and occur mostly on the top surface of the leaves. Initially, the pustules are surrounded by green tissue, but when severe, the leaf area around the pustules turns yellow, then brown. Heavily infected leaves die prematurely, leading to yield loss and stalk rots.

Scouting: July through August and during grain filling. Often, abundant orange spores will discolor clothes when walking through corn.

Epidemiology: Favored by warm temperatures (77-82° F), this rust disease occurs later in the season than common rust. It overwinters on live plants in tropical/subtropical areas, spores blow in during summer.

Management: Hybrids vary in their level of resistance, but none are immune. Cultural practices are ineffective. Fungicide treatments are available, and may be economically justified to prevent severe damage if the disease develops during important grain fill stages.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/g1680.pdf.
https://cropprotectionnetwork.org/download/2546/.
https://cropwatch.unl.edu/plantdisease/corn.

GOSS'S WILT AND BLIGHT (*Clavibacter michiganensis* spp. *nebraskensis*):

Description: Within two weeks of infection the leaf blight phase can be recognized by "water-soaked" lesions with dark "freckles" near the edges, which become gray and tan. These often become glossy with bacterial exudate, lesions becoming long and gray to brown. Systemically infected plants show orange or brown discoloration in vascular tissue, causing wilting and stalk degradation.

Scouting: Usually found June through September, often following storms. Observe fields a week to 10 days following damage.

Epidemiology: The causal bacteria overwinter in crop residue, and usually infect plants via wounds from hail, sandblasting, blowing soil, and high wind.

Management: There is no curative treatment – it is an internal bacterial infection. Hybrids vary in resistance, although none are immune. It is best managed by crop rotation and/or tillage, and choosing resistant hybrids.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/g1675.pdf.
https://cropprotectionnetwork.org/download/5759/.

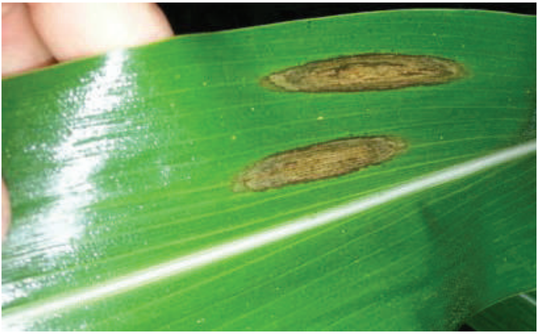
GENERAL NOTE ON LEAF BLIGHTS AND OTHER DISEASES THAT CAUSE DEATH OR LOSS OF LEAF AREA:

Leaf blights and spots are among the most common diseases of corn in Nebraska, as well as across the North-Central U.S. corn belt. It is useful to remember that **it takes all three legs of the "disease triangle"** to result in disease and crop loss: (a) a virulent pathogen (disease inciting organism), (b) a susceptible host, and (c) an environment favorable to the development of the disease.

In this guide, we describe a number of diseases which are capable of causing lesions on the leaves, leading to the destruction of part of the leaf area. Not only can this cause direct yield loss by reducing photosynthesis and grain filling, but **plants often fill grain preferentially while "starving" other plant tissues, notably stalks.** This leads to stalk tissue death, rendering the plants susceptible to attack by many stalk rot pathogens.

A number of fungal and bacterial agents can cause leaf area loss, and most overwinter in crop residue (the pathogens are almost always present, see (a) above). **Most hybrids are not immune** to any of these pathogens, but **tolerance can slow the rate of disease** progress in the field, under "normal" conditions, see (b) above. If weather (and other physical and environmental stress) conditions are favorable for disease development, the disease MAY STILL OCCUR, even in "resistant" hybrids or with application of fungicides, regardless of tillage and crop rotation. Management and good choices, however, may keep disease levels below economic thresholds.

NORTHERN CORN LEAF BLIGHT (*Setosphaeria turcica* syn. *Exserohilum turcicum*):



Description: Elongated oval lesions, (gray to tan) which cross leaf veins, expand into cigar-shaped large lesions, up to eight inches long or larger, and have rounded ends.

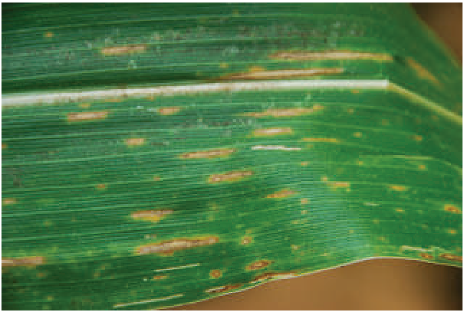
Scouting: June through August. Typically the disease starts on lower leaves during cooler, earlier part of growing season, then spreads upward. More often found on no-till, continuous corn.

Epidemiology: Like other leaf blights, the causal fungus persists in corn residue from previous crops. Cool to moderate temperatures (64-80° F), and cloudy, damp, frequent rainfall conditions favor its development.

Management: Hybrids vary in resistance, although all may show some level of infection. Crop rotation and tillage may help. Fungicides can be effective, and need to be applied before tasseling, and before top four or five leaves become infected (you need these leaves to be fully functional for grain filling).

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/g2270.pdf.
https://cropwatch.unl.edu/2018/differentiating-corn-leaf-diseases.
https://www.youtube.com/watch?v=5eEjDsLu1DQ.
https://cropwatch.unl.edu/plantdisease/corn.

SOUTHERN CORN LEAF BLIGHT (*Cochliobolus heterostrophus* syn. *Bipolaris maydis*):



Description: Tan lesions, rectangular to oval-shaped, ⅛- to ¼-inch wide, ¼- to 1-inch long. Southern corn leaf blight tends to start on lower leaves, and progresses upward on plants. It can resemble early-stage gray leaf spot, but gray leaf spot stays between veins and has yellow halo around tan/brown lesions. Uncommon in hybrids, but often seen in seed production fields.

Scouting: June to August, southern corn leaf blight can infect corn in vegetative and reproductive phases. Look for distinctive tan oblong lesions that can cross leaf veins.

Epidemiology: Overwinters in crop residue, spores are windborne or splashed to new crop leaves. Southern corn leaf blight is favored by warm (75-85° F) humid weather, and spores may travel great distances to be deposited on leaf tissue. It can complete a life cycle in three days, so spreads rapidly.

Management: Choose resistant hybrids (none are immune), especially where disease has been a problem, tillage, crop rotation, and fungicide treatment (properly timed) can be effective. Not often important in Nebraska.

References or Informative Websites:
http://ipm.illinois.edu/diseases/series200/rpd202/.

ANTHRACNOSE LEAF BLIGHT (*Colletotrichum graminicola*):

Description: Initial leaf symptoms (May and June) are small round/oval dark brown lesions on lower leaves. In high humidity conditions, small black specks may appear in lesion centers. Lesions appear in upper leaves later if high humidity prevails. Later in the season, the tops of plants tend to show dieback, while the middle leaves stay green.

Scouting: The leaf blight can develop as early as seedling stages during warm, damp spring conditions. Look for dark brown lesions beginning on lower leaves.

Epidemiology: The fungus overwinters in corn residue, and tends to be more prevalent in continuous corn in wet, warm, humid years. This is an aggressive pathogen that also causes a stalk rot disease.

Management: Best managed by crop rotation and planting hybrids with resistance to both leaf and stalk phase. After severe infections, rotation out of corn for more than one year may be optimal.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/ec1898.pdf.
https://cropwatch.unl.edu/plantdisease/corn.

GRAY LEAF SPOT (*Cercospora zeae-maydis*):

Description: Lesions start as yellow flecks, turning gray/brown, expanding between leaf veins and taking on rectangular or striped appearance. Gray leaf spot is often noted on lower leaves in early July, but can move up in the canopy rapidly in July and August. Larger, irregular lesions can occur on stalks and husks.

Scouting: July and August. Look for rectangular-shaped lesions during warm, humid weather. A lengthy period of high humidity, or free moisture on leaves, is required for spore germination, so gray leaf spot is worse under pivot irrigation.

Epidemiology: The causal fungus overwinters on corn residue; infection generally begins on lower leaves, and progresses upward on the plant given favorable weather. Gray leaf spot is favored by very warm (75-90° F) conditions with high humidity and long dew periods.

Management: Hybrids exhibit a range of susceptibility. Choose less susceptible hybrids for continuous corn and no-till, irrigated production. Fungicide treatments at tasseling and continuing as long as weather conditions are favorable for gray leaf spot development may be economical.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/g1902.pdf.
http://cropwatch.unl.edu/plantdisease/corn/gray-leaf-spot.
https://cropwatch.unl.edu/plantdisease/corn.

CORN LETHAL NECROSIS (two or more viruses):

Description: Starts as viral mottling and chlorosis, moving rapidly to severe chlorosis and tissue death. Corn lethal necrosis will kill susceptible hybrids in 10 days to two weeks. Later infections (V12 through R1) can cause incomplete silking, severe yellowing and stunting, and heavy yield losses.

Scouting: June through August, look for chlorotic, mottled plants, often found in patches. Disease is notably worse in continuous corn.

Epidemiology: Maize chlorotic mottle virus and either wheat streak mosaic virus or one of the strains of maize dwarf mosaic virus are necessary to cause corn lethal necrosis. Maize dwarf mosaic virus is vectored by greenbugs and corn leaf aphids, wheat streak mosaic virus by wheat curl mites, and maize chlorotic mottle virus likely by thrips and corn rootworm beetles (see the insect profiles in this guide for photos and descriptions of these insects).

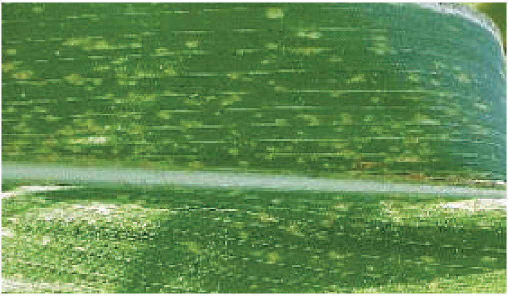
Management: Crop rotation and resistant hybrids are the primary defenses. The reduction in wheat and sorghum acres in the last few decades probably has reduced the number of insect vectors as well.

References or Informative Websites:

http://www.plantpath.k-state.edu/extension/publications/. cornlethalnecrosis.pdf.

https://cropwatch.unl.edu/plantdisease/corn.

http://cropwatch.unl.edu/plantdisease/corn/maize-chlorotic-mottle-virus.



^Maize Chlorotic Mottle Virus

Description: Of the various virus types, the High Plains virus, maize dwarf mosaic virus, wheat streak mosaic virus, or maize chlorotic mottle virus are most frequent but will appear individually, especially in South Central Nebraska.

Scouting: The symptoms of these viruses can be similar, i.e., a mottling, streaking parallel to veins, often combined with yellowing. However, identification of the viral cause is difficult for a layperson. A professional diagnosis is recommended, as a laboratory-based analysis may be required to identify the symptom-causing virus(es). The UNL Plant and Pest Diagnostic Clinic can provide this diagnostic service. See guide page 7 for information on how to submit leaf tissue samples, and forms and fees.

Epidemiology: Depends on the given virus.

Management: Options include tillage to reduce/destroy crop residue, crop rotation, & resistant hybrids. Correct identification of the virus(es) is critical for making good decisions.

References or Informative Websites:

http://cropwatch.unl.edu/plantdisease/corn/maize-chlorotic-mottle-virus.
https://cropwatch.unl.edu/plantdisease/corn.

STALK ROTS – GENERAL CONSIDERATIONS:

Stalk rot is incited by a number of opportunistic organisms, most of them **are not aggressive pathogens** and usually don't attack healthy tissue. These same fungi are responsible for much of the deterioration of the previous year's crop residue, which is beneficial. However, these fungi are also **very effective at attacking dead, dying or stressed stalk tissue.** Stress, from excessively high plant populations, establishing high yield potential followed by nutrient or moisture shortage, reduction of leaf area during grain filling due to hail, high wind, or disease, often results in plants lacking the photosynthetic capacity to both fill ears and keep stalk tissue healthy. If so, stalks can be cannibalized for sugar to fill kernels on the ears.

Most stalk rot fungi digest the pith tissue and weaken the nodal plates, but usually don't rot the vascular tissue. **This leaves the stalk as a hollow tube** with some vascular strands inside, rather than a solid stem, and vulnerable to collapse (just like an aluminum tube with a few gussets and filled with Styrofoam is much stronger than the empty tube itself). When you squeeze the stalks they feel squishy, and will easily "kink" if you try to slightly bend the stalk.

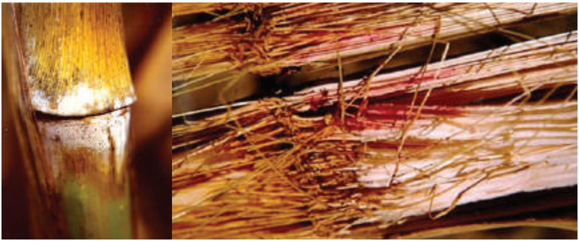
Stalk rots also reduce the flow of sugar and nutrients from the plants to the ears during grain fill, and often result in lower test weight grain and "tip back." Wilting plants and color changes from green to light gray is an early symptom of infected stalks. This leads to premature death of the plant, lodged roots and stalks, unharvested ears, and infected ears if they touch the ground. This not only can result in yield loss, but **loss of grain quality**, and increased risk of ear rot diseases and grain mold diseases in storage.

All of these fungal stalk rots **generally start from the crown of the plant**, infecting dead tissue around the first few nodes. This is usually the first tissue to die naturally, and is subject to invasion by the fungal pathogens in the soil. The fungal spores are abundant in the soil, so are always available for infection. Whether or not fungi spread is often dependent on **whether the rest of the stalk tissue stays alive and well supplied with photosynthate** (sugars). The "stay-green" trait of modern hybrids contributes to stalk health. Stress, defoliation, and anything that interferes with stalk health and vigor will increase stalk rot severity.

Excess N and low K_2O_5 levels increase the likelihood of severe stalk rot, so it is critically important to maintain balanced fertility levels.

For more information, go to the websites listed at the bottom of Gibberella stalk rot page (guide page 238).

FUSARIUM STALK ROT (*several Fusarium species*):



Description: Fungus often infects the root crown, results in grayish green color of early infected plants, contrasted with darker green of healthy neighbors. Early plant death is often followed by whitish fungal growth on the outside of the stalk, and pinkish residue inside – but no black specks (if you slice stalks). Stalks feel spongy, "kink" easily.

Scouting: Late August through harvest. Look for grayish green plants, early plant death. Do "squeeze" test in random spots in fields. Watch for issues in fields with known stress issues from any cause.

Epidemiology: Fungus overwinters as mycelia and spores in infected crop residue. Fusarium infects many plant species, especially grasses. Fungus may enter through roots, insect/hail wounds, or by splashing mycelia on dying stalks. Fungal infection is favored by warm, humid weather during and after grain filling.

Management: Plant hybrids with good late-season health, strong stalks, resistance to fungal stalk rots. Crop rotation helps, as does incorporation of residue where corn follows corn. Avoid excess plant populations, control leaf diseases, and maintain proper balance of N *vs.* K_2O. Planting corn borer resistant (Bt) hybrids reduces incidence by eliminating corn borer entry wounds.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/ec1898.pdf.
http://cropwatch.unl.edu/plantdisease/corn/fusarium-stalk-rot.

GIBBERELLA STALK ROT (*sexual stage of Fusarium* sp.):

Description: Can be difficult to distinguish from Fusarium Stalk Rot, as Gibberella is the sexual stage of *Fusarium graminearum* (which causes scab in wheat), but sliced stalks show more pink/salmon colored residue, and black fungal fruiting bodies on the outside of the stalk (which can be scraped off with a fingernail).

Scouting: Late August through harvest. Look for grayish green plants, early plant death. Do "squeeze" test in random spots in fields. Watch for issues in fields with known stress issues from any cause.

Epidemiology: Fungus overwinters as mycelia and spores in infected crop residue. Fusarium infects many plant species, especially grasses. Fungus may enter through roots, insect/hail wounds, or by splashing mycelia on dying stalks. Fungal infection is favored by warm, humid weather during and after grain filling.

Management: Plant hybrids with good late-season health, strong stalks, and resistance to fungal stalk rots. Crop rotation helps, as does incorporation of residue where corn follows corn. Avoid excess plant populations, control leaf diseases, and maintain proper balance of N *vs.* K_2O. Planting corn borer resistant (Bt) hybrids reduces incidence by eliminating corn borer entry wounds.

References or Informative Websites:
Several excellent bulletins on stalk rots are available:
http://extensionpublications.unl.edu/assets/pdf/ec1898.pdf.
http://cropwatch.unl.edu/plantdisease/corn/fusarium-stalk-rot.
http://cropwatch.unl.edu/stalk-and-crown-rot-diseases-developing- some-corn.

DIPLODIA STALK ROT (*Stenocarpella maydis* syn. *Diplodia maydis*):

Description: Inside the stalk, white/gray fungal mycelium develops, but it distinctively causes small, black structures (pycnidia) on the outside of the stalk, giving the stalks and husks a rough "sandpaper" texture. Infection of husks/silks causes a gray ear rot, often enveloping the whole ear. Diplodia was once the most common stalk rot in the Midwest, but is less common in Nebraska now than others.

Scouting: Late August through harvest. Infection at/near nodes leaves a ring of black pycnidia, soft stalks, dying plants.

Epidemiology: Overwinters as spores in plant residue, no other host known, but stays in soil for years, and re-infects through roots, crown and lower stalks, as well as insect/hail damage. Diplodia *(Stenocarpella)* stalk rot is favored by wet warm weather near corn maturity.

Management: Plant hybrids with good late-season health (stay-green) and strong stalks. Avoid excessive nitrogen rates.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/ec1898.pdf.

CHARCOAL STALK ROT (*Macrophomina phaseolina*):

Description: First symptoms are dying upper leaves. It is called "charcoal" stalk rot because sliced stalk sections show tiny black fungal bodies that look like charcoal dust sprinkled on the tissue, and often appear on rind. Unlike most stalk rots, the vascular bundles are often shredded.

Scouting: Charcoal stalk rot is most often associated with drought and heat stress, followed by better moisture and growing conditions. Look for dying tops of plants, black sclerotia on rind, and split stalk to check stalk, vascular tissue.

Epidemiology: Overwinters as sclerotia in soils, and is a soilborne disease. In hot, dry weather fungi will invade and colonize roots and lower stalks. Favored by drought, intermittent moisture, and high temperatures (>90° F).

Management: Since it affects a wide variety of crops, short crop rotations are generally ineffective. Plant hybrids with good late season health, strong stalks, harvest promptly if a field is significantly affected.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/ec1898.pdf.

ANTHRACNOSE STALK ROT (*Colletotrichum graminicola*):

Description: The fungus causing this stalk rot may also cause leaf blight and top dieback disease (see guide page 231). In addition to rapid top dieback, characteristic shiny, blotchy black lesions appear on the corn stalks, then continue into the rind. It is an aggressive pathogen that can infect dead corn plant tissues at many stages, but in the stalk rot phase, it infects live corn tissue.

Scouting: August and September, particularly if the grain filling period has been cloudy, wet, and warm. Look for top dieback, rather than senescence starting from lower plant. Stalks may also develop large, shiny brown/black lesions on the outer rind and, when cut open with a knife, can be seen to continue into pith tissue. During R4 and R5, systemic infections often lead to death of plant tops, while middle leaves are still green. Premature death and stalk rotting can be severe.

Epidemiology: Reproductive spores are abundant on infected plants and can overwinter via mycelia in crop residue. Infection occurs in both roots and leaf sheaths, via spore-splashing, most notably when warm and wet weather occurs during grain filling.

Management: Plant resistant hybrids (not correlated with resistance to other stalk rot organisms) and hybrids with strong stalks and late-season plant health. Rotate crops and consider tillage in fields known to have severe anthracnose history.

References or Informative Websites:
http://extensionpublications.unl.edu/assets/pdf/ec1898.pdf.

BACTERIAL STALK ROT (*Pectobacterium chrysanthemi pv. zeae* syn. *Erwinia chrysanthemi pv. zeae*):

Description: Dark brown, water-soaked lesions that encompass whole stalk, including rind. Tissue becomes soft, slimy and can almost dissolve the entire stalk at the base of the plant, resulting in a foul odor. Can also affect the tops of plants, rotting out a node, killing leaves above that point. These dead leaves can be detached easily.

Scouting: July to August. Watch areas that were flooded or saturated for more than a few days. Usually found on lower internodes, but can infect nodes from the plant base to the tassel, rapidly leading to complete death and collapse of affected tissue, and tops that pull free of rest of plant.

Epidemiology: The bacteria overwinter in stalk tissue above soil surface and perhaps in surface water. It is more prevalent where overhead irrigation from canals and ponds is used, and areas prone to flooding. Tends to develop midseason, and is favored by high temperatures (>90° F) and high humidity.

Management: Plant hybrids with good plant health, tillage of infected fields, and improve drainage of flood-prone fields.

References or Informative Websites:
http://cropwatch.unl.edu/plantdisease/corn/bacterial-stalk-rot.

EAR ROTS (ARISING FROM A HOST OF FUNGAL SPECIES):

Corn ear rots and grain molds are common wherever corn is grown, and can lead to loss of grain quality and rejection of grain at the elevator. Worse, some **fungi produce mycotoxins**, which can be poisonous to animals and humans that consume the grain. These mycotoxins can be produced on the ear in the field, or in grain storage if the grain is infected in either field or bin, and stored too wet or too long. Drying grain to less than 15% for long-term storage is recommended. Nebraska is fortunate to have generally warm, dry harvest seasons allowing corn to dry well in the field, requiring less artificial drying compared to states to our east.

Ear rots and grain molds are favored by damaged ears and grain, moisture stress, flooding, high moisture storage, and continuous corn production on a field.

Aspergillus tends to produce yellow/green spores, often on ear tips or damaged kernels. Notably, ***A. flavus*** will grow on corn grain at moistures above 13%, temperatures of ≥ 45° F, and produces a mycotoxin that is dangerous to mammals. **Fusarium** produces white/gray fungal mycelia that can be randomly scattered anywhere on ear, while **Gibberella** produces salmon/red molds usually starting on ear tips. Both **Fusarium and Gibberella** can produce carcinogenic toxins in grain, which when fed to animals can result in feed refusal, abortion and other issues.

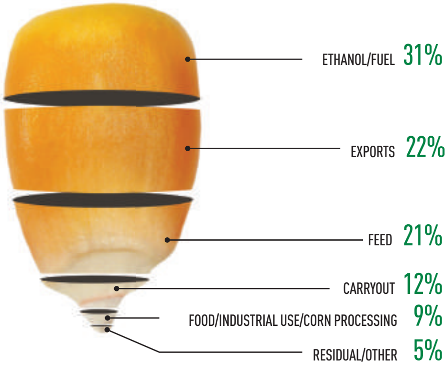
EAR ROTS (CONT.):

Penicillium produces blue/green molds often on ear tips, whereas **Diplodia** produces gray/black molds clear around the ear starting at the butt.

It is highly recommended that producers **keep corn that has high levels of ear rots and molds stored separately from high quality grain**, because attempting to dilute the former by mixing it with the latter carries the risk that an elevator can refuse to accept the entire truck loads that contain mixtures of moldy corn and non-moldy corn. Also, the fungi from the infected kernels can rapidly grow and spread to other corn in the bin.

References or Informative Websites:
If you need to identify a particular ear rot, go to:
http://extensionpublications.unl.edu/assets/pdf/ec1901.pdf.
https://cropprotectionnetwork.org/download/2553/.
https://cropprotectionnetwork.org/download/2555/.
https://cropprotectionnetwork.org/download/4941/.
https://cropprotectionnetwork.org/download/4934/.
https://cropprotectionnetwork.org/download/4926/.

NOTES:



ETHANOL/FUEL 31%
EXPORTS 22%
FEED 21%
CARRYOUT 12%
FOOD/INDUSTRIAL USE/CORN PROCESSING 9%
RESIDUAL/OTHER 5%

SOIL MANAGEMENT – SOYBEAN AND CORN IN NEBRASKA:

In this section of the guide, we provide the reader with some key considerations relevant to effective, efficient, and sustainable soil management for corn and soybean production systems in Nebraska. In a small pocket guide like this, the coverage of most topics is necessarily brief and only key points can be highlighted. **For general information about the availability of many soil science resources, we recommend these two websites:**

http://cropwatch.unl.edu/soils.

http://cropwatch.unl.edu/corn/soilmgt.

For more comprehensive and detailed information about soil nutrient management, we recommend readers go to the **2014 Nebraska Extension EC155 publication titled "Nutrient Management for Agronomic Crops in Nebraska"** at:
http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.
The PDF is free. A print copy can be purchased at:
http://extensionpubs.unl.edu/about/customer-service/.

For Nebraska-specific fertilizer recommendations for **soybean**, see:
https://digitalcommons.unl.edu/extensionhist/1714/.
For **corn,** see:
http://extensionpublications.unl.edu/assets/pdf/ec117.pdf.
https://cropwatch.unl.edu/projectsense.
https://hybridmaize.unl.edu/Maize-N.

For information about using starter fertilizer, see:
http://extensionpublications.unl.edu/assets/pdf/g361.pdf.

SOIL NUTRIENTS – CROP ELEMENTAL COMPOSITION:

A crop nutrient deficiency arises when an essential element is inadequately available. Crops require **18** essential elements. Plants acquire the **three** non-mineral elements of **H**, **C**, & **O** from CO2 and H2O molecules used in **photosynthesis**. The **15** mineral elements are acquired from the soil (exception: legumes can fix atmospheric N2 to acquire N), and **are ranked from high-to-low in Table 1 according to their quantity** (%, ppm, atoms) in corn dry matter. Soybean dry matter would be slightly different. Below table does not show Nickel or Cobalt, but their quantities would be similar to, or less than, the quantity of Molybdenum.

Table 1 - Typical Plant Dry-matter Composition

Element	Amount by mass		Relative number of atoms
	%	ppm	
Hydrogen	6		~All H from H_2O>> 60 000 000
Carbon	45		All C from CO_2>> 40 000 000
Oxygen	45		~1/2 O from CO_2>> 30 000 000
Nitrogen	1.5		1 000 000
Potassium	1.0		250 000
Calcium	0.5		125 000
Magnesium	0.2		80 000
Phosphorous	0.2		60 000
Sulfur	0.1		30 000
Chlorine	0.01	100	3 000
Iron		100	2 000
Boron		20	2 000
Manganese		50	1 000
Zinc		20	300
Copper		6	100
Molybdenum		0.1	1

The above atomic ratio of $C_{40}H_{60}O_{30}$ is close to the ratio of CH_2O (carbohydrate); the skewed C_{40}:O_{30} ratio is due to fewer O atoms in plant lipids. Most of the N atoms are in plant proteins.

Source: Edgar N. Transeau. The accumulation of energy by plants. 1926. Ohio Journal of Science, Vol. XXVI No. 1. See also: http://nzic.org.nz/ChemProcesses/soils/2A.pdf

MACRONUTRIENTS – FUNCTIONS IN PLANTS:

Element	Structural or Metabolic Function
Nitrogen (N)	The most abundant element in a plant after (H, C, and O). Needed for amino acids and thus is present in all structural plant proteins (plant and seed) and all enzymes and coenzymes, and chlorophyll.
Phosphorus (P)	Structural constituent in DNA, RNA, and cell and membrane fatty phospholipids; involved in all cellular energy-storage and transfer metabolism (photosynthesis and respiration), and cell division/elongation/enlargement.
Potassium (K)	Not a structural constituent, but exists at high concentrations in plant tissue; plays a critical role in the regulation of plant cell water (turgidity) and leaf stomatal opening/closing; activates enzymes in key metabolic processes; promotes early root growth.
Sulfur (S)	Structural constituent of the amino acids methionine and cysteine and several other substances/metabolites physiologically required by plants; promotes nodulation in legumes.
Calcium (Ca)	Structural constituent of plant cell walls; activates key enzymes; regulates transport of many nutrients; major role in cell division that occurs in stem/root/floral meristems, and in nitrogen metabolism.
Magnesium (Mg)	Key element in chlorophyll molecule chlorophyll production; activates some critical enzymes, improves mobility and utilization of phosphorus; increases plant iron utilization.

MICRONUTRIENTS – FUNCTIONS IN PLANTS:

Element	Structural or Metabolic Function
Iron (Fe)	Not a structural constituent, but is required for chlorophyll synthesis; essential to photosynthetic and other electron-exchange reactions; coupled with Mo in the nitrogenase enzyme (first step for N-fixation in legumes).
Zinc (Zn)	Plays both a structural and co-factor role in many enzymes and in cell DNA transcription. Essential for plant hormone balance and auxin activity.
Chlorine (Cl)	Essential to photosynthesis and cell ion balance (e.g., osmosis), and thus the turgidity of leaves and stems.
Boron (B)	Plays a role in cell wall deposition, meristem cell division, and cell expansion/ elongation at stem tips; essential for pollen germination; also involved in sucrose transport and amino acid synthesis.
Manganese (Mn)	Required in photosynthesis and in the development of leaf cell chloroplasts.
Copper (Cu)	Required for the synthesis of lignin, which strengthens to cell walls in the vascular parts of stems, petioles, & leaf veins; co-factor for major enzymes, notably in photosynthesis.
Molybdenum (Mo)	Required co-factor in the nitrate reductase enzyme and in the N-fixing nitrogenase enzyme in nodules.
Nickel (Ni)	Required co-factor in the enzyme urease, which converts urea into ammonium ion.
Cobalt (Co)	Now known to be essential for the synthesis of vitamin B12-containing cobalbumin, a co-factor required for leghemoglobin synthesis by Rhizobia in nodules of N-fixing legumes.

Note: Cobalt recently added to plant essential micronutrient list.
Source: https://www.ipni.net/nutrifacts-northamerican.

CROP AVAILABLE FORMS OF THE ESSENTIAL SOIL NUTRIENTS:

Mineral Element	In the Plant †	Plant Absorbed Ionic Form	In the Soil ‡
Nitrogen (N)	Mobile	NO_3^- (nitrate)	Mobile
		NH_4^+ (ammonium)	Immobile
Phosphorus (P)	Somewhat Mobile	$H_2PO_4^-$ (phosphate) HPO_4^{2-} (ortho-phosphate)	Immobile
Potassium (K)	Very Mobile	K^+	Somewhat Mobile
Sulfur (S)	Mobile	SO_4^{2-} (sulfate)	Mobile
Calcium (Ca)	Immobile	Ca^{2+}	Somewhat Mobile
Magnesium (Mg)	Somewhat Mobile	Mg^{2+}	Immobile
Iron (Fe)	Immobile	Fe^{2+} (ferrous) Fe^{3+} (ferric)	Immobile
Zinc (Zn)	Immobile	Zn^{2+}	Immobile
Chlorine (Cl)	Mobile	Cl^-	Mobile
Boron (B)	Immobile	$H2BO_3^{3-}$(borate) H_3BO_3(boric acid)	Very Mobile
Manganese (Mn)	Immobile	Mn^2	Mobile
Copper (Cu)	Immobile	Cu^{2+}	Immobile
Molybdenum (Mo)	Immobile	MoO_4^{2+} (molybdate)	Somewhat Mobile
Nickel (Ni)	Mobile	Ni^{2+} (molybdate)	Somewhat Mobile
Cobalt (Co)	Immobile	Co^{2+} (molybdate)	Somewhat Mobile

Note: Cobalt recently added to the list of 18 plant essential nutrients.

† In the plant, a mobile nutrient can move to newly developing leaves, so older leaves will first show deficiency symptoms. However, when the nutrient is immobile, newer leaves will first show deficiency symptoms.

‡ In soil, mobile ions are not strongly bound to clay particles, and thus can leach when dissolved in the water percolating downward in the soil. In contrast, immobile ions are strongly bound. *Source:* https://nrcca.cals.cornell.edu/soilFertilityCA/CA1/CA1_print.html.

PLANT ABSORPTION OF SOIL NUTRIENTS:

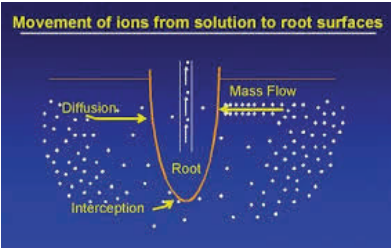
Nutrients move from the soil into plants by various mechanisms that can only be briefly noted here. For more detail, see: http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Mass flow is the movement of dissolved nutrients. See below graphic. Root hairs absorb water to replace transpirational water loss, leading to dissolved **mobile ions** (e.g., NO_3^- and SO_4^{2-}) **flowing** with the water moving to the root hairs. Fertilization increases a mobile ion concentration, thus making it more available to plants.

Diffusion is the net movement of a nutrient from high-to-low concentration in the soil. Nutrient ions present in soil water absorbed at root hair surfaces are rapidly depleted, and replaced by the **diffusion** of ions from non-depleted soil regions. However, the rate of **diffusion** is dependent on nutrient mobility (see guide page 250). To increase the concentration of slow-diffusing **immobile ions** (e.g., K^+ and $H_2PO_4^-$ and HPO_4^{2-}), fertilizer must be placed in the root zone.

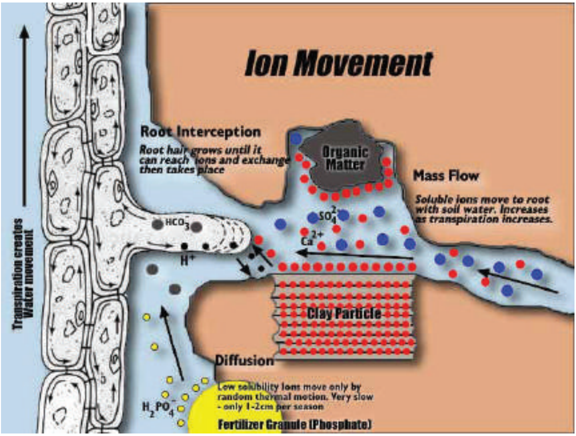
Interception of the colloidal surfaces by elongating root hairs readily leads to the absorption of the macro- and micronutrient **cations** present on those colloidal clay and organic matter surfaces, notably, NH_4^+, Ca^{2+}, and Mg^{2+}.

Soil colloids are defined as extremely small particles of clay (<0.001mm) and organic matter, whose mostly negatively charged surfaces attract positively charged ions known as cations. See guide page 273 for information about soil cation-exchange capacity (CEC).



PLANT ABSORPTION OF SOIL NUTRIENTS (CONT.):

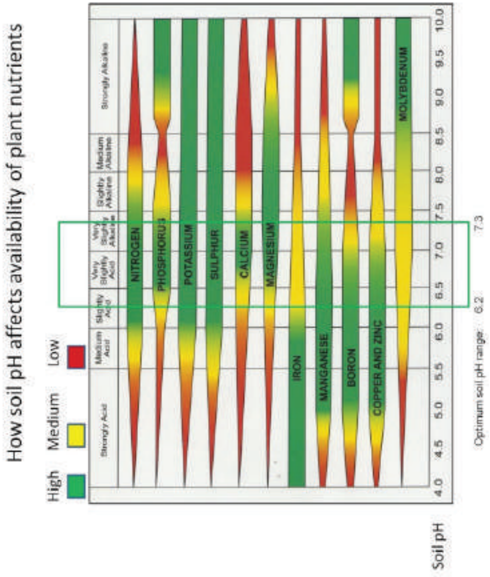
The below graphic illustrates the **migration of nutrient ions to the surface of a water-absorbing root hair:**



Nutrient ion acquisition by plant root hairs is not complete until the ion enters the root endodermis cell cytoplasm and is subsequently loaded into the root xylem where water is moving to the leaf to replace transpired water. To overcome a **low-to-high (soil-to-endodermis) difference in ion concentration,** plant energy must be expended to actively acquire the nutrient, typically via cell membrane-embedded carrier proteins. For an inverse **high-to-low (soil-to-endodermis) difference in ion concentration,** no energy is theoretically needed, even though carrier proteins are still used for the rapid transfer of an ion across a membrane.

CROP NUTRIENT AVAILABILITY *VS.* SOIL SOLUTION PH:

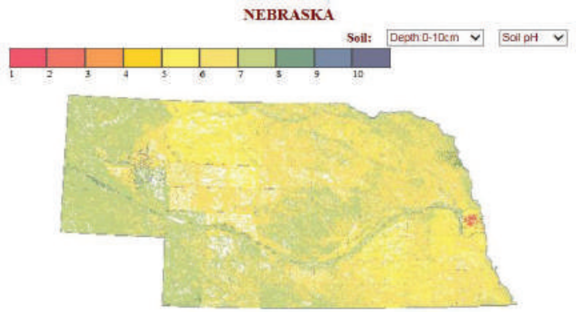
Soil **pH** is a measure of the concentration of the hydrogen ions (H^+), ranging from **1** highly acidic to **14** highly alkaline. Non-carbonated pure water has a (neutral) pH of **7**. In Nebraska, the soil water pH ranges from **5** to **8** (see next page maps). For corn or soybean production, a pH of about **6.2**-**7.3** is considered optimal (see below). Outside of this pH range, **N**, **K**, **S**, and especially **P**, **Ca**, **Mg**, and **Mo**, are less available in low pH (**more acidic**) soils, whereas **Fe**, **Mg**, **B**, **Cu**, and **Zn** are less available in high pH (**more alkaline**) soils.



Source: This figure originated (essentially) from research first conducted by Emil Truog and published in SSSA Proceedings 11:305-308 (1946). During the past 70 years this figure has been updated and repeatedly redrawn for use in plant nutrient guides.

CROP NUTRIENT DEFICIENCY – ACID OR ALKALINE SOILS:

In Nebraska, the surface soil pH gradually rises from east to west. Acid soils are commonly associated with high annual rainfall regions, most notably where rainfall and irrigation exceed evapotranspiration, which leads to leaching of soil nutrients (e.g., nitrate). Conversely, alkaline soils are commonly associated with low rainfall regions.



Source: Wang et al (2010)
https://beaumont.tamu.edu/SoilData/SoilStateMap.aspx?index=2_14_0_30&name=NEBRASKA.

Soil acidification is an inevitable consequence of modern crop production **due to gradual over time decrease in soil pH arising from:** (**1**) routine (and in-excess) applications of ammonia (NH_3) based fertilizer, or elemental sulfur (**S**), that form strong inorganic acids [i.e., nitric acid (HNO_3) & sulfuric acid (H_2SO_4)], and (**2**) excess applications of organic nutrient sources (i.e., swine/poultry manures). Some originally alkaline western Nebraska cropland soils, now acidic after a century of crop production, may require liming. See:
http://extensionpublications.unl.edu/assets/pdf/g1503.pdf.
http://extensionpublications.unl.edu/assets/pdf/g1504.pdf.
Lowering pH in a calcareous alkaline soil is difficult, due to the continuous dissolution of limestone into carbonates. Elemental sulfur applications may help if soil pH ≥ 8, but this is seldom practical for agronomic crops. See guide page 276 for details on liming.

CROP NUTRIENT DEFICIENCY SYMPTOMS:

Photos of corn and soybean plants or leaves exhibiting macro- or micronutrient deficiency symptoms are provided here, but are not necessarily decisive indicators, because symptom features can vary significantly among differing crop production systems. **Thus, if you observe a symptom that is suggestive of a nutrient deficiency (but not a root injury due to soil compaction, insect, disease), TAKE tissue samples** of both affected and non-affected leaves and **soil samples** in those affected and non-affected field areas to submit to a soil/tissue testing laboratory for professional diagnosis: http://cropwatch.unl.edu/plantdisease/unl-diagnostic-clinic-lincoln. http://cropwatch.unl.edu/nebraska-soil-testing-laboratories-unl-cropwatch-sept-21-2012.

For more comprehensive information about soil nutrient management, consult the **2014 Nebraska Extension EC155 publication titled "Nutrient Management for Agronomic Crops in Nebraska,"** especially Chapter 10 for **corn** (pages 73-81) or Chapter 16 for **soybean** (pages 116-120) in this 150-page document, which is freely available as a PDF at: http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

If you suspect a nutrient deficiency symptom, and wish to make an "initial" judgement call as to which nutrient might be the cause (prior to consulting a professional), try the step-by-step nutrient deficiency "symptom identification key" approach (with photos) described at these two CropWatch websites:

Corn: http://cropwatch.unl.edu/soils/keysnutrientdef.
Soybean: http://cropwatch.unl.edu/soils/soybean-nutrients.

For additional corn/soy nutrient deficiency info/photos, see: http://www.extension.iastate.edu/Publications/IPM42.pdf. https://soil.msu.edu/wp-content/uploads/2017/11/Micros-for-Soybean-in-the-NC-Region.pdf.

CROP NUTRIENT DEFICIENCY SYMPTOMS (CONT.):

Macronutrients:

NITROGEN (N) – See Chapter 1 in: http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Conditions Favoring Crop N Deficiency in Corn:

- Excessive leaching from rooting zone.
- Water-saturated soil, causing denitrification.
- Cold, wet soil during early crop development.
- Sandy, low organic matter soil.
- Temporary immobilization due to large amounts of crop residue that is high in C but low in **N**.
- Any factor (e.g., dry soil) limiting **N** supply or **N** uptake.

Characteristic N Deficiency Symptoms:

Corn:

- Yellowish green, stunted, spindly plants, bottom old leaves often "fire," even without drought.
- V-shaped yellowing of older (lower) leaves along mid-rib, starting at leaf tips; leaves eventually wither and turn brown.
- Symptoms first occur and are more severely expressed on lower leaves – as is the case with mobile nutrients.

Conditions Favoring Crop N Deficiency in Soybean:

- In soybean, little or ineffective nodulation.
- Planting non-inoculated soybean seed in fields where soybeans haven't been grown for five years or more.
- Low organic matter soils.
- Low pH soils, especially those with low **Mo** levels.

Soybean:

- Pale green plants with pale yellow to brown older leaves.
- Ineffective (or very few) **N**-fixing nodules. Photo shows nodulated (left) *vs.* non-nodulated plants.

Note: Soybean seedlings do not commence **N**-fixation until stage **V3** (see guide page 49) and may exhibit **N** deficiency symptoms if any of the four conditions listed above occur before **V3**. **Leaf yellowing** will be observed in **late April–early May planted fields** when abnormally **cool spring soil and air temperatures** (common in no-till fields heavily covered with corn residue) **delay the onset of V3.** Microbial decomposition of high C/low **N** corn residue will lead to **N** immobilization and less availability of nitrate **for not yet N-fixation-capable pre-V3 seedlings.**

Soybean effectively uses residual **N** leftover from a prior crop and soil organic matter **N** mineralization. However, **N-fixation may be insufficient as N source** when: (**1**) the soil has low pH, low organic matter, low residual **N**, or large amounts of prior crop residue, or (**2**) the field has a >75 bu./acre yield potential that may not be realized due to **N**-fixation and residual **N** not providing the needed total **N**. However, profitable response to applied **N** is unlikely if **N** deficiency symptoms are not observable.

PHOSPHORUS (P) – See Chapter 2 in: http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Conditions Favoring Crop P Deficiency:

- Soil with a Bray P1 soil test of <12 ppm for soybeans, 17 for corn following soybeans, 25 for corn following corn.
- Cold soil, either too wet or too dry.
- Poor root growth arising from soil compaction, chemical damage or insect feeding.

Characteristic P Deficiency Symptoms:

Corn:

- Dark green to bluish-green leaves, with red-purple leaf margins (note: a few hybrids exhibit purpling when not **P** deficient); slow growth; symptoms more generally observed in early spring, but the crop often fully recovers without a **P** application.
- Twisted ears; irregular kernel rows; imperfect ear tips.

Soybean:

- Symptoms of **P** deficiency are not always well-defined; leaves initially become dark green or bluish green; spindly plants, with small leaflets, exhibit retarded growth.
- In the absence of definitive leaf symptoms in stunted plants, an analysis of leaf **P** content may be needed to correctly diagnose a soybean **P** deficiency.

POTASSIUM (K) – See Chapter 3 in: http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Conditions Favoring Crop K Deficiency:

- Soil with <80 ppm exchangeable **K**.
- Sandy, low organic matter soil.
- A wet, compacted soil that limits root growth.
- A previous crop (e.g., silage or alfalfa) that removed large amounts of **K**.

Characteristic K Deficiency Symptoms:

Corn:

- Yellowing begins at tips of lower leaves, but moves along the leaf margins, progressing inward to become necrotic brown; leaf blade near mid-rib stays green.

- Tendency to wilt, even with adequate soil water, especially with full sunlight.
- Ears are small and exhibit partially filled, pointed tips.
- Increased incidence of stalk diseases and lodging.

Soybean:

- Green plants with yellow (older) leaf margins that may advance inward if **K** deficiency is severe, at which point newly emerged leaves will also show the yellowing margin symptoms.
- Small leaflets; slow growth; spindly seedlings/plants.

SULPHUR (S) – See Chapter 5 in: http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Conditions Favoring Crop S Deficiency:

- Low organic matter (especially sandy) soils.
- Repeated removal of crop residue and no manure.

Characteristic S Deficiency Symptoms:

Corn:

- Stunted, light green plants with upper light green leaves that may look similar to an **N** deficiency – see guide page 256.
- Yellow interveinal stripes, retarded growth rate, delayed maturity if **N** is also deficient.

Soybean:

- Pale yellow to light green leaves (top photo) compared to normal leaves (bottom photos, without prominent color differentiation between veins and interveinal areas.
- Leaves and plants are smaller than normal; stems are generally thin, hard, and elongated between nodes.

CALCIUM (Ca) – See Chapter 4 in:
http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Conditions Favoring Crop Ca Deficiency:

- Very low (<5.5) pH soils.
- Soils with very high **K** and **Mg**, but low **Ca** levels.

Characteristic Ca Deficiency Symptoms:

Corn:

- Very rare in Nebraska-grown corn.
- New leaves on stunted plants exude a gelatinous-like substance that causes a leaf tip to "stick" to a lower leaf (photo).

Soybean:

- Because **Ca** is a mobile nutrient, deficiency symptoms would be expected to appear in the lower leaves first.
- Soybean **Ca** deficiency symptoms may mimic **N** deficiency symptoms (as described on guide page 257).

*[No photo of soybean **Ca** deficiency symptoms is available.]*

NOTE: Nebraska Extension soil specialists have not documented (to date) a demonstrable case of **Ca** deficiency in a Nebraska soil. If you strongly suspect that you have a case of **Ca** deficiency in a corn or soybean field, please contact a Nebraska Extension soil specialist – see guide page 374.

MAGNESIUM (Mg) – See Chapter 4 in: http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Conditions Favoring Crop Mg Deficiency:

- Extremely sandy soil, with high pH or excessive applications of calcitic lime.
- Sandy soils with very high **K** levels.

Characteristic Mg Deficiency Symptoms:

Corn:

- Younger plants tend to show dark yellow interveinal chlorosis on oldest leaves, becoming a rust/brown.
- Older leaves may become reddish/purple, with dead leaf tips and margins.

Soybean:

- Symptoms are similar to **Zn** deficiency (see guide page 264) - with pale green plants; leaves exhibit interveinal pale yellow mottling that can become necrotic.
- **Mg** deficiency can inhibit N-fixation.

NOTE: Nebraska Extension soil specialists have observed **Mg** deficiency symptoms that briefly appear, but these soon disappear in waist-high corn. In such cases, no yield response has been observed with added **Mg**. If you strongly suspect that you have a **Mg** deficiency in your corn or soybean field, please contact a Nebraska Extension soils specialist – see guide page 374.

Micronutrients:

Plants require nine nutrients in low amounts, seven as positively charged **cations** and two as negatively charged **anions** (see quide page 245). Deficiencies of Boron (**B**), Chlorine (**Cl**), Copper (**Cu**), Manganese (**Mn**), and Molybdenum (**Mo**), Nickel (**Ni**), and Cobalt (**Co**) have not been observed (to date) in a Nebraska corn or soybean field by NE extension soil specialists. However, Iron (**Fe**) or Zinc (**Zn**) deficiency symptoms are frequently observed in Nebraska fields.

IRON (Fe) – See Chapter 6 in
http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.
http://extensionpublications.unl.edu/assets/pdf/g1830.pdf.

Conditions Favoring Crop Fe Deficiency:

- Calcareous (high pH) alkaline soils that have high levels of calcium carbonate and soluble salts.
- Wet, poorly drained river/creek bottomland soil.
- An iron-chlorosis susceptible soybean variety (photo).

Characteristic Fe Deficiency Symptoms:

Corn:

- Interveinal yellow striping (green veins) along leaf length, mainly upper leaves.
- Spotty pattern in fields.

Soybean:

- Interveinal chlorosis/necrosis (yellow/brown); green veins.
- Spotty in some fields (especially those with eroded hillsides); but crop may be yellow across the entire field in bottomland areas.
- Leaf yellowing is greater when the (within) row soybean plant density is low (e.g., narrow rows).

ZINC (Zn) – See Chapter 6 in
http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.
http://extensionpublications.unl.edu/assets/pdf/g1830.pdf.

Conditions Favoring Crop Zn Deficiency:

- Calcareous soils in which the pH > 7.3.
- Eroded, terraced or leveled soil, particularly where topsoil was removed.
- Very sandy, low organic matter soils.
- Wet, cold soils, especially when high amounts of phosphate have been applied.

Characteristic Zn Deficiency Symptoms:

Corn:

- Pale green plants; white to pale yellow bands in lower leaf that later become a pale brown or gray necrotic color; tips of leaves remain green.
- Stunted plants with short internodes.
- The corn stalk, when split open with a knife, may show brown/purple coloration at the stalk nodes.

Soybean:

- Pale green plants; interveinal mottling between green veins in older leaves, which may take on a gray, bronzy look.
- Fewer flowers; pod development abnormal; early leaf drop; and delayed maturity may be observed.

CROP NUTRIENT DEFICIENCY SYMPTOMS (CONT.):

BORON (B) – See Chapter 6 in http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Conditions Favoring Crop B Deficiency:

- Dry sandy soils; highly weathered soils low in organic matter; over-liming a low organic matter sandy soil.
- In excessive rainfall years, leaching of **B** may occur.

Characteristic B Deficiency Symptoms:

Corn:

- Internodes fail to elongate; bushy look; brittle, crinkled leaves curl in a spiral; small dead spots.
- Barren ears/stalks, short bent cobs, poor kernel; symptoms mimic those mediated by drought.

Soybean:

- Necrosis and death of growing points (i.e., apical meristem); short internodes, yellow-red upper leaves.
- Limited flowering, poor seed quality.

NOTE: A boron deficiency has not been observed to date in any corn or soybean field by a NE Extension soils specialist. If you strongly suspect that you have a **B** deficiency in your corn or soybean field, contact a Nebraska Extension soil specialist – see guide page 374. Keep in mind that the difference between adequate and toxic levels of **B** is small, so be careful if you do apply **B**!

MANGANESE (Mn) – See Chapter 6 in http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Conditions Favoring Crop Mn Deficiency:

- Depressions in fields with a high organic matter content sands, peats, or mucks.
- Over-liming of a high pH soil that (before liming) may have had naturally low **Mn.**

Characteristic Mn Deficiency Symptoms:

Corn:

- Light green/olive interveinal chlorosis.
- Upper leaves will continually exhibit light yellow/olive green striping.

Soybean:

- Leaf interveinal area becomes yellow to light green, but veins stay dark green.
- Eventually, mottled interveinal chlorosis becomes dark brown necrosis.
- Symptoms can resemble **Fe** deficiency symptoms (see guide page 263).

NOTE: Nebraska Extension soil specialists have not documented (to date) a demonstrable case of **Mn** deficiency in a Nebraska soil. If you strongly suspect that you have a **Mn** deficiency in your corn or soybean field, please contact a Nebraska Extension soil specialist – see guide page 374.

MOLYBDENUM (Mo) – See Chapter 6 in http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Conditions Favoring Crop Mo Deficiency:

- **Mo** is the only micronutrient (of the seven – see guide page 249) that becomes deficient at pH <6.0.
- Observed in acid prairie soils (such soils exist in the eastern U.S., but not so much farther west in Nebraska).

Characteristic Mo Deficiency Symptoms:

Corn:

- Rarely observed in corn.
- Short longitudinal chlorotic streaks in upper third of older leaves when **Mo** deficiency is severe (photo).

Soybean:

Soybean **Mo** deficiency symptoms will mimic **N** deficiency symptoms (see page guide 252), because **Mo** is an essential cofactor of two enzymes: (1), the **nitrogenase enzyme in nodules** that fixes N2 and (2) the **nitrate reductase enzyme in leaves** that reduces NO3- to NO2- . Both enzymes are first steps in different processes that lead to the production of the NH(sub)2 component of amino acids.

NOTE: Nebraska Extension soil specialists have not documented (to date) a demonstrable case of **Mo** deficiency in a Nebraska soil. If you strongly suspect that you have a **Mo** deficiency in your corn or soybean field, please contact one of those scientists – see guide page 374.

COPPER (Cu) – See Chapter 6 in http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Conditions Favoring Crop Cu Deficiency:

- Organic peat soils (these soils are rare in Nebraska).
- Cereal crops (e.g., wheat) are more vulnerable, particularly with excessive applications of **P** fertilizer.

Characteristic Cu Deficiency Symptoms:

Corn:

- Pale young leaves.
- A **Cu** concentration of <2 ppm in the ear leaf at silking is considered to be the critical level below which deficiency symptoms might become apparent.

Soybean:

- Seed development and quality more impacted than vegetative development.
- Terminal dieback (i.e., necrosis of meristem), delayed flowering; low pollen viability, few pods develop.
- A **Cu** concentration of <5ppm in a (pale) topmost trifoliolate at flowering is the critical level below which deficiency symptoms would become evident.

*[No NE photo of soybean **Cu** deficiency symptoms is available.] See:* https://soil.msu.edu/wp-content/uploads/2017/11/Micros-for-Soybean-in-the-NC-Region.pdf.

NOTE: Nebraska Extension soil specialists have not documented (to date) a demonstrable case of **Cu** deficiency in a Nebraska soil. If you strongly suspect that you have a **Cu** deficiency in your corn or soybean field, please contact one of those scientists – see guide page 374.

CHLORINE (Cl) – See Chapter 6 in http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Conditions Favoring Crop Cl Deficiency:

- Rare in U.S. except in high rainfall areas of leached sandy soils derived from low **Cl** parent material.
- Cereal crops (e.g., wheat) are more sensitive to low **Cl**.

Characteristic Cl Deficiency Symptoms:

Corn:

- Cell extension is impaired in **Cl** deficient plants; short lateral roots form, and the highly branched root system exhibits "stubby" appearance.
- Plants wilt readily due to the restricted root system.
- Leaves may exhibit a bronzing appearance.

*[No NE photo of corn **Cl** deficiency symptoms is available.]*

Soybean:

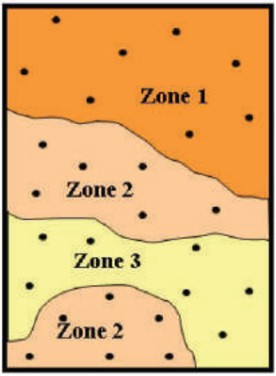
- **Cl** deficiency symptoms rarely observed in legumes.
- If observed, young leaves are chlorosis-mottled.

*[No NE photo of soybean **Cl** deficiency symptoms is available.]*

NOTE: UNL soil scientists have not documented (to date) a demonstrable case of **Cl** deficiency in a Nebraska soil. If you strongly suspect that you have a **Cl** deficiency in your corn or soybean field, please contact one of those scientists – see guide page 374.

SOIL SAMPLING FOR NUTRIENT AND PH ANALYSIS:

A soil sample is taken to quantify an area of interest for soil fertility management. Each sample should be a composite of several sub-samples (multiple cores), mixed together to create one representative sample for a given area. Important considerations when taking samples are: amount of acreage to be represented by each sample, the number of sub-samples, sample soil depth, subsequent mixing/handling/shipping of the samples, and frequency of sampling over time.



Sample Area Size:

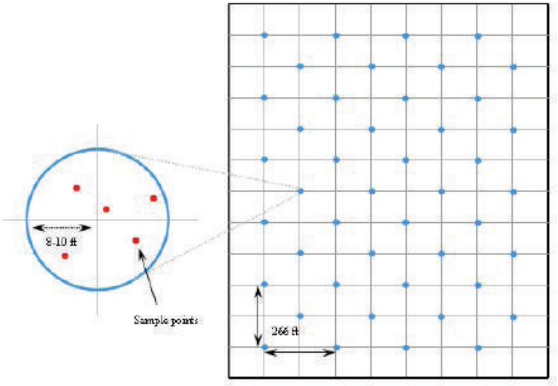
Select an area based on how much information you want to acquire and how you intend to manage that area. **A single soil sample should be representative of no more than 40 acres,** and preferably less than that if there are zones in the field you want to separately manage (see right).

Sub-Samples per Sample:

For fields divided into zones for management, a sample should be a composite of (up to) 15 cores (about 1 inch diam.) taken in the zone using a random zigzag collection pattern.

SOIL SAMPLING FOR NUTRIENT AND PH ANALYSIS (CONT.):

For good quality grid-based soil sampling, a **single sample** normally represents an area of about 2.5 acres or less. In the 44-acre field shown below, **blue dots** are grid intersection points to be sampled, and **red dots** are soil cores randomly taken within an 8-10 foot radius extending from the grid point.



In fields that received a broadcast fertilizer application, take five or more sub-sample soil cores around a tight 8- to 10-foot radius to serve as one soil sample representative of that area (i.e., see left side of above figure). **In fields that received a banded application of fertilizer,** take only one sub-sample purposely centered on a band for every 20 sub-samples taken between bands and composite the 21 samples to serve as the representative grid area sample.

Sample Soil Depth:

Collect soil core samples from a **0 to 8 inch soil depth** because UNL fertilizer recommendations were developed based on many soil test results in that surface soil zone. Sampling a 0 to 24-inch soil depth is recommended to be able to credit residual soil nitrate-N in the determination of fertilizer N rate for corn.

Post-Collection Handling of the Soil Samples:

Crush the individual soil cores in the collection bucket and thoroughly mix the resultant fragments and particles. Draw a **one-pint sample** of the mixture to represent sampled area. Do not contaminate the sample with other soil, or with fertilizers, manures, ashes or pesticides. If shipped to a soil testing lab within a day or two, moist samples do not need to be dried. Exception: water-saturated soil samples should be air-dried or oven-dried (<120° F) before shipping. If samples must be stored for a lengthy time period before shipping, either air-dry the soil samples, or store them in refrigerator/freezer, to limit any N mineralization that can occur in warm moist sample.

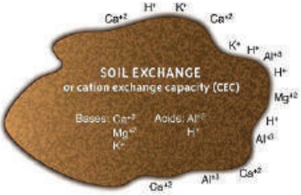
Frequency and Time of Sampling:

Some of Nebraska's Natural Resource Districts (NRD) require an annual deep soil sample near the date of corn planting for soil N management. Soil samples taken every 4-5 years for a given field should otherwise be sufficient for monitoring long-term changes in pH and fertility. If you decide to implement a significant change in soil management, taking soil samples prior to that change will establish baseline data that can be used to evaluate the later-year impact of that change. Soil pH and nutrient levels can vary within a season (i.e., peaks and lows), so to avoid confounding of the seasonal variance with long-term tracked values, collect different year samples in the same month.

For more details on soil sampling methods and guidelines, *see:*
http://extensionpublications.unl.edu/assets/pdf/g1740.pdf.
http://extensionpublications.unl.edu/assets/pdf/ec154.pdf.

CATION EXCHANGE CAPACITY:

Cation Exchange Capacity (CEC) is a measure of the **ability of a soil to hold "positively charged" nutrient ions,** including the hydrogen ion H^+ that governs soil pH. The larger the CEC value, the greater the ion-holding capacity and the greater the resistance to soil pH changes. **CEC essentially is a reflection of the number of exchangeable cations held in a per unit quantity of dry soil at a given pH and exchangeable with other ions present in the soil water solution.** The CEC measurement unit is milliequivalents (meq) per 100 grams of soil (i.e., meg/100g). As the clay and organic matter content of a soil increases, so does the CEC value (as can be seen in the below table). CEC also increases if the soil pH is boosted from 4.0 to 7.0 by liming.

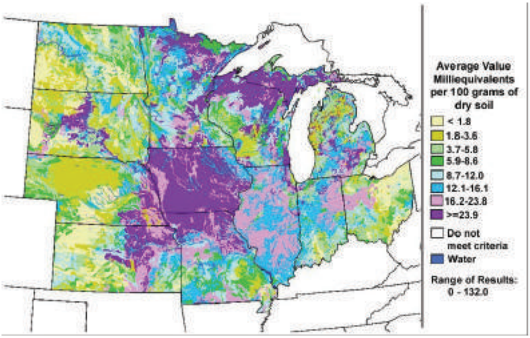


Approximate CEC Values for Soil pH Values of 5.4-6.0	
	CEC Value
Soil Texture	/100g
Sand	3 to 5
Coarse loams & silt loams	10 to 12
Fine-textured loams & silt loams	15 to 25
Clay loams & clays	28 to 35

Source: https://www.extension.purdue.edu/extmedia/ay/ay-238.html.

CATION EXCHANGE CAPACITY (CONT.):

As was evident in the prior table, the CEC value varies with the soil texture type. Below is a map of soil CEC values in the 12 states in the North Central U.S. Note **the low CEC values in the Nebraska sand hills region** and **the high CEC values in eastern Nebraska silty clay soil regions.** See guide page 14 for just the Nebraska map of soil texture.



Source: National Resource Conservation Service STATSGO Database. https://chemistry.beloit.edu/Rain/copy/Cec1.jpg.

Factors of importance of CEC relative to soil fertility and pH management are indicated in the below table.

	Soil Cation Exchange Capacity	
Relevant Factor	**High CEC: 11-50**	**Low CEC: 1-10**
Clay content	Higher	Lower
Capacity to hold NH4+, K+, Ca2+, and Mg2+	Greater; leaching of key nutrients is minimal	Smaller; leaching of key nutrients is more likely
Amending a specific low soil pH with lime	More lime required to correct the pH	Less lime required to correct the pH

LIMING ACID SOILS TO SUSTAIN CROP PRODUCTION:

Soil acidity is gradually increasing in Nebraska because of: (1) **repeated use of ammonium-based acid-forming fertilizers,** (2) **leaching of nitrate-N from the crop root zone,** and (3) **loss of plant-absorbed cations absorbed by the crop in the harvested grain.** Plant-absorbed cations present in the crop residue will be eventually returned to the soil upon decomposition of that residue, but NOT if some or much of that residue is removed by the producer. Note that all but the last-listed fertilizer in the below table acidifies the soil. Take note of the pounds of lime that would be needed to neutralize each pound of **N** applied.

Lime required to neutralize the soil acidity produced by the below fertilizers if all ammonium-N is converted to nitrate-N

Nitrogen Source	N-P-K-S	Lime Required (lb. $CaCO_3$/ lb. N)
Anhydrous ammonia	82-0-0	1.8
Urea	46-0-0	1.8
Ammonium nitrate	34-0-0	1.8
Ammonium sulfate	21-0-0-24	5.4
Monoammonium phosphate	10-52-0	5.4
Diammonium phosphate	18-46-0	3.6
Triple super phosphate	0-46-0	0.0

Source: NebGuide G1504
http://extensionpublications.unl.edu/assets/pdf/g1504.pdf.

For example, **applying 200 pounds of N per acre** in continuous corn for **four successive years** would require about a **ton of lime per acre** to neutralize the resultant increase in acidity. Soil pH can also be reduced by some phosphate fertilizers that have acidic properties. Consideration of **N application rates** and other acidifying sources will help you anticipate long-term lime needs as the soil pH declines.

Lime takes time to neutralize soil acidity. A significant post-liming change in soil pH change may not even be observed until six months (or a year) later. For that reason, you should **consider the cost of liming** to improve the 6-8 inch deep soil pH to be a long-term **investment**. The return (i.e., higher pH) is not going to be realized in one year, but **will gradually accrue over a 5-10 year timeframe.** Obviously, the responsibility for the cost of liming must be negotiated between producer and landowner in land rental leases.

The effectiveness of liming acid soils is determined by the:
(1) Neutralizing value of the lime source. The excess of hydrogen (H^+) ions in a low pH soil can be neutralized by creating hydroxyl (OH^-) ions that lessen the H^+ concentration when both react to form water (i.e., $H^+ + OH^- >> H_2O$). Adding the calcitic type of lime (mostly calcium carbonate) to the soil will create those OH^- ions (i.e., $CaCO_3 + H_2O >> Ca^2+ + HCO_3^- + OH^-$). The dolomitic type of lime contains both calcium and magnesium carbonate, but $MgCO_3$ is less soluble in water. In Nebraska, the most available lime type is the calcitic form.
(2) Particle size. The greater surface area available in a smaller particle is advantageous relative to: (a) exposing more of the particle's $CaCO_3$ to the soil solution, and (b) no-till systems in which only surface lime application (not tillage incorporation) is desired. Finer particles lying on surface will be more effective than larger particles in that scenario. However, fine particles of lime are poorly controlled during application.

Note: Aluminum (Al) toxicity may occur in very low pH soils (<5). A soil solution high in Al inhibits root uptake of Ca and Mg, and reduces P availability, leading to symptoms that mimic Ca, Mg or P deficiencies, along with stunted plants, yellow-brown short-thick roots and laterals that have few root hairs at the root tips.

LIMING ACID SOILS TO SUSTAIN CROP PRODUCTION (CONT.):

The neutralization of soil acidity by applied lime is quite slow. When surface applied without incorporation, it may **require three years to amend each one-inch increment of soil depth.** If lime is applied to untilled land, rates in excess of three tons/acre should be split-applied. A repeat application may be needed after two to four years. Do not apply more than 8 tons/acre of lime in a single year to soils with very low pH values. Then examine the pH change two to four years later.

In Nebraska, a profitable crop response to a lime application can be reasonably expected when the **0-8 inch zone soil pH reaches a threshold** of **5.6 to 5.8** in corn-soybean, or **5.0 to 5.2** in continuous corn. The below table indicates the amount of lime needed to improve soil pH for three differing soil textures that have differing CEC values and buffer pH values. **For each 0.1 buffer pH unit below 7.0, 1.0 to 1.2 tons/acre of lime should be applied.** The $CaCO_3$ content of irrigation well water can be high (test it). Contact a NE extension specialist (see guide page 374) for advice on choosing a suitable lime rate for your low pH field.

Soil Texture	CEC	Soil pH	Buffer pH	Lime required
	Meq. /100g			tons/acre
Loamy sand	6	5.6	6.8	1
Silt loam	14	5.5	6.6	2
Silty clay loam	24	5.6	6.2	4

For more details on soil pH and liming, see these publications:

http://extensionpublications.unl.edu/assets/pdf/ec705.pdf.
http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.
http://extensionpublications.unl.edu/assets/pdf/g1503.pdf.
http://extensionpublications.unl.edu/assets/pdf/g1504.pdf.
http://corn.agronomy.wisc.edu/Management/pdfs/a3671.pdf.

Crops absorb and accumulate substantial quantities of nutrients from the soil from germination to physiological maturity. See below tables for estimates of how much **N**, **P**, **K**, **S**, and **Zn** are removed by a soybean and corn crop.

Soil Nutrient	Plant Part	Nutrient Removal at *Soybean* Yields (bu./acre):				
		80	70	60	50	40
		Pounds of Nutrient Removed per Acre				
N	Grain	260	228	195	163	130
	Residue	88	77	66	55	44
P_2O_5	Grain	58	51	44	37	29
	Residue	20.0	17.5	15	12.5	10.0
K_2O	Grain	94	83	71	59	47
	Residue	80	70	60	50	40
S	Grain	14.4	12.6	10.8	9.0	7.2
	Residue	13.6	11.9	10.2	8.5	6.8
Zn	Grain	0.08	0.07	0.06	0.05	0.04
	Residue	0.27	0.23	0.20	0.17	0.13

Soil Nutrient	Plant Part	Nutrient Removal at *Corn* Yields (bu./acre):				
		260	220	180	140	100
		Pounds of Nutrient Removed per Acre				
N	Grain	174.2	147.4	120.6	93.8	69
	Residue	117	99	81	63	45
P_2O_5	Grain	91	77	63	49	35
	Residue	41.6	35.2	28.8	22.4	16.0
K_2O	Grain	65	55	45	36	25
	Residue	286	242	198	154	110
S	Grain	20.8	17.6	14.4	11.2	8.0
	Residue	18.2	15.4	12.6	9.8	7.0
Zn	Grain	0.26	0.22	0.18	0.14	0.10
	Residue	0.48	0.40	0.33	0.26	0.18

Source: These tables were adapted from IPNI data. Actual nutrient removal in your soybean or corn field will NOT be identical (due to many factors too numerous to list here). But, if that point is kept in mind, the generality and relativity of these tabulated approximations can still be useful when coupled with your field soil test data.

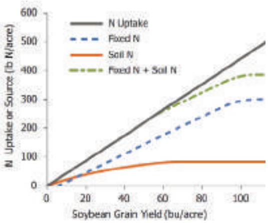
For much more comprehensive information about UNL recommendations about fertilizing soybean and corn (more than we could include in this small guide), we recommend the reader consult the UNL publications cited at the end of each following section.

Soybean Fertilization Information:

Nitrogen:

Well-nodulated soybean plants fix atmospheric N_2 in addition to effectively using residual soil nitrate and nitrogen mineralized from soil organic matter. Of the total plant N uptake at maturity, **the soil-supplied N fraction *vs.* the N_2-fixation N fraction** has been shown to range from 25 vs. 75% to 75 vs. 25%. However, seedlings are completely dependent on soil nitrate prior to stage **V3**, when N_2-fixation finally commences – see guide pages 49 & 63, and thus may be yield responsive to starter N in fields planted in late April-early May in cold no-till heavy residue fields. UNL trials indicated no significant yield response to soybean starter fertilizer in later plantings. In fields that have a high-yield potential, the supply of N from both soil and nodules may be insufficient for the crop to realize (i.e., capture) that yield potential. Application of fertilizer N to soybean can enhance iron deficiency on calcareous soil. See NebGuide G859 and EC155 - Chapter 16 for perspective and advice of UNL soil scientists with regard to this issue: http://extensionpublications.unl.edu/assets/pdf/g859.pdf. http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Nitrogen (cont.):



A scientific review of 108 publications reporting research on yield response of **N**-fixing soybean to supplemental soil applied **N** revealed that an economically significant response was not likely to be observed unless the field soybean yield potential reached 75 bu./acre. *Source: Above figure adapted from the data of Salvagiotti et al. (2008).* https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1133&context=agronomyfacpub.

Producers with a field that routinely generates (each year) yields of 75 bu./acre or more might consider collaborating with a UNL soil scientist to conduct on-farm tests to determine if **N** fertilizer via fertigation after pod set can produce an economical response. For more information, see: http://cropwatch.unl.edu/farmresearch.

Phosphate: Recommended P_2O_5 fertilizer rates.

Phosphorus Soil Test		"Relative" Level	P_2O_5 rate to apply
Bray-1 P	Olsen-P		
ppm			pounds/acre
0-5	0-3	Very low	60
6-10	4-5	Low	20
11-15	6-7	Somewhat Low	0
16-24	8-24	Medium	0
>24	>14	High	0

Source: Table 16-1 (page 118) in Nebraska EC155
http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

For information on calculating fertilization rates, see:
https://pubs.ext.vt.edu/424/424-035/424-035.html.

SOYBEAN FERTILIZATION INFORMATION (CONT.):

Potassium: Recommended K_2O fertilizer rate.

Potassium Soil Test (exchangeable K)	"Relative" Level	K_2O rate to apply
ppm		pounds/acre
0-40	Very Low	60
41-74	Low	40
75-124	Medium	20
>124	High	0

Source: Table 16-2 (page 118) in Nebraska EC155
http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Sulfur: A yield response to **S** fertilizer is unlikely in Nebraska.

Zinc: Recommended **Zn** fertilizer rate.

DTPA-Zn Soil Test	"Relative" Level	Soil is Calcareous	Soil is not Calcareous
ppm		Zinc to apply (lbs./acre)	
0.0-0.4	Low	Row (1 lb.) Broadcast (10 lb.)	Row (1 lb.) Broadcast (5 lb.)
0.4-0.8	Medium	0	0
>0.8	High	0	0

Source: Table 16-3 (page 119) in Nebraska EC155
http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Iron: Iron chlorosis is common in the calcareous soils of Nebraska and in the Platte, Elkhorn, and Republican River Valleys. Varieties tolerant to **Fe**-chlorosis should be used in those soils. Planting 12 seeds per foot within a row (no matter the row width) has been shown to lessen the severity of the chlorosis. **Applying an iron-chelate (i.e., Fe-EDDHA) to the seed at planting** (1-4 pounds/acre) is consistently a more effective treatment than using foliar applications (see page 120 in Nebraska EC155) at http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

CORN FERTILIZATION INFORMATION:

Nitrogen:

Nitrogen Soil Test (2-foot deep sample)		Expected Yield (bushels/acre)									
		60	80	100	120	140	160	180	200	220	240
ppm	"Relative" Level	N to apply (pounds/acre) if soil has 3% soil organic matter									
3	Low	60	75	90	105	120	135	150	165	185	200
6	Low	35	50	65	80	95	110	125	145	160	175
9	Medium	0	25	40	55	70	90	105	120	135	150
12	Medium		0	15	35	50	65	80	95	110	125
15	High			0	0	25	40	55	70	85	100
18	High					0	15	30	45	65	80
21	High						0	0	25	40	55
24	Very high								0	15	30
27	Very high									0	0

Source: Table 10-1 (page 75) in Nebraska EC155.

Nitrogen (continued):

Nitrogen Soil Test (2-foot deep sample)		Expected Yield (bushels/acre)									
		60	80	100	120	140	160	180	200	220	240
ppm	"Relative" Level	N to apply (pounds/acre) if soil has 2% soil organic matter									
3	Low	65	85	105	120	140	160	175	195	215	230
6	Low	40	60	80	95	115	135	155	170	190	210
9	Medium	20	35	55	75	90	110	130	145	165	185
12	Medium	0	15	30	50	70	85	105	125	140	160
15	High		0	0	25	45	60	80	100	115	135
18	High				0	20	40	55	75	95	110
21	High					0	15	35	50	70	90
24	Very high						0	0	25	45	65
27	Very high								0	20	40

Source: Table 10-1 (page 75) in Nebraska EC155.

CORN FERTILIZATION INFORMATION (CONT.):

Nitrogen (continued):

Nitrogen Soil Test (2-foot deep sample)		Expected Yield (bushels/acre)									
		60	80	100	120	140	160	180	200	220	240
ppm	"Relative" Level	N to apply (pounds/acre) if soil has 1% soil organic matter									
3	Low	75	95	115	140	160	180	200	225	245	265
6	Low	50	70	95	115	135	155	180	200	220	240
9	Medium	25	50	70	90	110	135	155	175	195	215
12	Medium	0	25	45	65	85	110	130	150	170	195
15	High		0	20	40	65	85	105	125	150	170
18	High			0	20	40	60	80	105	125	145
21	High				0	15	35	60	80	100	120
24	Very high					0	15	35	55	75	95
27	Very high						0	0	30	50	75

Source: Table 10-1 (page 75) in Nebraska EC155.

Nitrogen (Estimated N Credit – prior year legume crop):

A prior year legume crop typically improves the soil **N** supply to a corn crop because legume crop residues decompose faster than cereal crop residues, resulting in less soil **N** and fertilizer **N** immobilization and tie-up. Thus, the corn **N** fertilizer recommendations (prior page) can be reduced by the **N** credit values listed for these prior crops.

Legume Crop	Medium & Fine-Textured Soils	Sandy Soils
	N Credit (pounds/acre)	
Soybean	45	35
Dry Bean	25	25
Alfalfa (70-100% stand; <4 plants/ft^2)	150	100
Alfalfa (30-69% stand; 1.5-4 plants/ft^2)	120	70
Alfalfa (0-68% stand; <1.5 plants/ft^2)	90	40
Sweet clover or Red clover	80% of the credit allowed for alfalfa	

Source: Table 10-2 (page 76) in Nebraska EC 155
http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Nitrogen (Estimated N Credit – Nitrate in Irrigation Water):
Irrigation water may contain nitrate (test it). To compute the N credit, use this formula: **N Credit (pounds/acre) = Irrigation water nitrate (ppm) x Net Irrigation (in) x 0.225.** Example: 35 ppm x 9 inches x 0.225 = 70 pounds **N**/acre. Ignore values <10 lbs./acre); drop credit for post-July water applications.

Reference: Table 10-3 (page 76) in Nebraska EC 155
http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

CORN FERTILIZATION INFORMATION (CONT.):

Nitrogen (Estimated N Credit – manures and other wastes):

Dry Materials	N pounds per ton	Liquid Materials	N pounds per 1000 gallons
Beef feedlot manure	4-5	Swine, liquid pit	10-15
Dairy manure	3	Swine, lagoon	2-5
Sheep manure	5	Beef, liquid pit	10-12
Poultry manure	12-17	Beef, lagoon	1-2
Composted Beef feedlot manure	10-14	Dairy, liquid pit	7-8
Sewage sludge	2-3	Dairy, lagoon	1-2
Horse manure	3	Cheese whey	1-2

Source: Table 10-4 (page 76) in Nebraska EC 155
http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

For manure in particular see: http://water.unl.edu/manure.

Phosphate: Recommended P_2O_5 fertilizer rates.

Phosphorus Soil Test		"Relative" Level	P_2O_5 rate to apply	
Bray-1 P	Olsen P		Broadcast	Band*
ppm			pounds per acre	
0-5	0-3	Very low	80	40
6-15	4-10	Low	40	20
16-24	11-16	Medium	0	**
25-30	17-20	High	0	**
>30	>20	Very high	0	0

*Source: Table 10-5 (page 77) in Nebraska EC 155 (same above URL). **Applied in a pre- plant band, or beside the row at planting. **Applying 10-20 pounds P2O5/acre with 5-10 pounds N/acre in a band at planting may boost early corn growth – see NebGuide G361 at:*
http://extensionpublications.unl.edu/assets/html/g361/build/g361.htm.

Potassium: Recommended K_2O fertilizer rate.

Potassium Soil Test*	"Relative" Level	K_2O to Apply (pounds per acre)		
ppm		Broadcast		Band**
0-40	Very low	120	+	20
41-74	Low	80	+	10
75-124	Medium	40	or	10
125-150	High	0		0
>150	Very high	0		0

Source: Table 10-6 (page 78) in Nebraska EC 155
http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.
*Exchangeable K.
**Banded next to the seed furrow; not with the seed.

Sulfur: Recommended S fertilizer rate for low S sandy (and other low S) soils.

Sulfur Soil Test *	Annual Sulfur Application Rate (pounds per acre)	
ppm	Soil Organic Matter <1%	Soil Organic Matter <1%
Irrigation water sulfate concentration <6 ppm SO4 - S		
<6	10 row** or 20 Broadcast	5 row**
6-8	10 row** or 20 Broadcast	0
Irrigation water sulfate concentration > 6 ppm SO4 - S		
>6	5 row** or 10 Broadcast	0
6-8	5 row** or 10 Broadcast	0
>8	0	0

Source: Table 10-7 (page 78) in Nebraska EC 155 (same above URL).
*Sulfur test is $Ca(H_2PO_4)_2$ extraction.
**Banded next to the seed furrow; not with the seed.

Zinc: Recommended **Zn** fertilizer rate.

DTPA-Zn Soil Test	"Relative" Level	Soil is Calcareous	Soil is not Calcareous
ppm		Zn to apply (lbs. per acre)	
0-0.4	Low	2 row or 10 broadcast	2 row or 5 broadcast
0.41-0.8	Medium	1 row or 5 broadcast	1 row or 3 broadcast
>0.8	High	0	0

Source: Table 10-8 (page 79) in Nebraska EC 155
http://extensionpublications.unl.edu/assets/pdf/ec155.pdf.

Iron: Iron chlorosis is common in the calcareous soils of Nebraska and in the Platte, Elkhorn, and Republican River Valleys.

Use corn hybrids tolerant to **Fe**-chlorosis in fields that have calcareous soils. Current research has shown that the most effective treatment for correcting high pH chlorosis corn is an at-planting seed-row application of 100 to 150 pounds of ferrous sulfate heptahydrate ($FeSo_4 \cdot 7H_20$) per acre (see page 79 in Nebraska EC155: http://extensionpublications.unl.edu/assets/pdf/ec155.pdf).

USING STARTER FERTILIZER FOR CORN AND SOYBEAN:

The primary benefit of starter fertilizer is to increase early growth and crop uniformity. Early planted no-till fields often have cooler soil temperatures due to increased residue cover. In fact, corn yield response to starter fertilizer is typically observed more in no-till and reduced-till systems (especially in sandy or high pH soils) than in tilled systems.

Starter nitrogen (**N**) often has the most impact on **no-till corn,** but phosphorus (**P**) in the starter can also result in corn yield responses, particularly on soils with low **P** levels (<15 ppm Bray-P1). Corn yield increases on sandy soils can arise from including sulfur (**S**) in the starter fertilizer. Band application of starter fertilizer can be in the seed furrow, either injected two inches to the side of the seed row, or placed on the surface over the seed row if precautions are taken to avoid salt damage. If zinc (**Zn**) and sulfur (**S**) are needed, starter **S** application can be a convenient and efficient placement system.

Yield responses of soybean to starter **N** fertilizer have only been infrequently observed in Nebraska field trials. But, with Nebraska soybean producers planting much earlier, see: https://cropwatch.unl.edu/data-show-nebraskans-planting-soybeans-earlier-each-year into colder no-till fields with heavy corn residue, it may be time to re-visit this topic (see note on guide page 257). Starter **P** fertilizer for soybean is suggested when Bray P1 is <10 ppm.

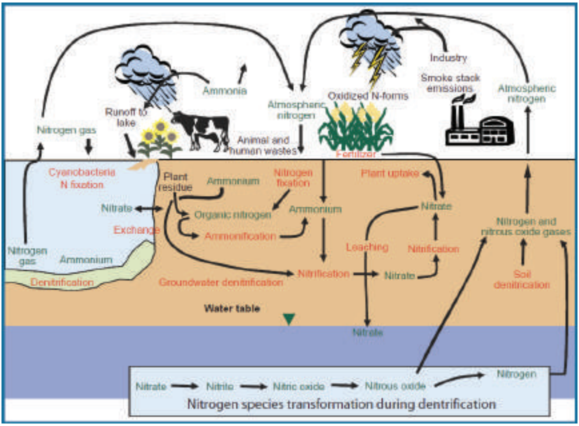
For more information/advice about starter fertilizer, see: http://extensionpublications.unl.edu/assets/pdf/g361.pdf.

COMPOSITION OF COMMON FERTILIZERS:

Fertilizer & Formula	N	P_2O_5	K_2O	S
Nitrogen				
Anhydrous Ammonia NH_3	82	0	0	0
Aqua Ammonia $NH_4OH\ H_2O$	16-25	0	0	0
Ammonium Nitrate NH_4NO_3	Varies 33-34	0	0	0
Ammonium Sulfate NH_4SO_4	21	0	0	24
Nitrogen Solutions (UAN)	Varies 28-32	0	0	0
Urea $CO(NH_2)_2$	46	0	0	0
Phosphate				
Single Superphosphate $Ca(H_2PO_4)_2CaSO_4$	0	Varies 18-20	0	12
Triple Superphosphate (TSP) $Ca(H_2PO_4)_2$	0	46	0	0
Potash				
Muriate of Potash or Potassium Chloride KCl	0	0	Varies 60-62	0
Sulfate of Potash or Potassium Sulfate K_2SO_4	0	0	50	18
Sulfate of Potash-Magnesia K_2SO_4+2$MgSO_4$ (11% Mg)	0	0	22	22
Multiple Nutrients				
Ammoniated Superphosphate	3-6	Varies 18-20	0	12
Ammonium Polyphosphate	10-11	Varies 34-37	0	0
Diammonium Phosphate (DAP) NH_42HPO_4	16-21	Varies 48-53	0	0
Monoammonium Phosphate (MAP) $NH_4H_2PO_4$	10-11	Varies 48-55	0	0
Potassium Nitrate KNO_3	13	0	44	0

NITROGEN FERTILIZER USE EFFICIENCY:

The below graphic illustrates several elements and processes in what is commonly known as the Nitrogen Cycle.



Source: http://extensionpublications.unl.edu/assets/pdf/rp189.pdf.

For profitable and sustainable **N** management, a key goal is the **optimization of crop N uptake,** but with concurrent **minimization of N loss to either the atmosphere or groundwater.** The **efficiency** of crop capture of applied and/or residual **N** is **lessened** when soil available nitrate ion (NO_3-) – see the graphic - is **reduced** due to: (1) its leaching below the crop root zone on into the ground water, (2) its denitrification, a process (see light blue box) that occurs in the soil, groundwater, & surface water, releasing both N_2 gas and the (key greenhouse gas) nitrous oxide N_2O into the atmosphere, (3) its immobilization, and (4) its nitrification to ammonium ion (NH4+). The availability of the ammonium ion can also be reduced by its immobilization, or by its volatilization to ammonia (NH3) gas. For more detail on the effect of management practices on **N** loss: http://extensionpublications.unl.edu/assets/pdf/g2249.pdf.
To optimize your corn N fertilization rate, see: https://water.unl.edu/documents/Section%20E.pdf.

ENHANCED EFFICIENCY FERTILIZERS (EEF):

EEF is a term applied to **N** fertilizer additives that were formulated to **inhibit nitrification**, to **inhibit urease**, or to **slow the release of N** via a physical barrier (coating) or via a chemical-mediated decrease in solubility. For more information about the nature/function of EEFs, see: https://efotg.sc.egov.usda.gov/references/public/UT/EnhancedEfficiencyFertilizers.pdf.

Table 1. Enhanced Efficiency Nitrogen Fertilizers Available in USA

Chemical or Compound	Common Product Name*	Process Inhibited or Slowed
Dicyandiamide (DCD)	Guardian®	Nitrification
2-chloro-6 (trichlormethyl) pyridine (Nitrapyrin)	N-Serve®, Instinct®	Nitrification
N-butyl-thiophosphoric triamide (NBPT)	Agrotain®	Volatilization Urease
NBPT and N-(n-propyl) thio-phosphoric triamide [NPPT]	Limus®	Urease
Malic+ itaconic acid co-polymer with urea	Nutrisphere®	Nitrification, Volatilization
Polymer-coated urea (PCU)	ESN®, Polyon®, Duration®	Rapid Release
Sulfur-coated urea (SCU)	SCU	Rapid Release
Polymer + SCU	Tricote, Poly-S®	Rapid Release
Urea formaldehyde	Nitroform®	Rapid Release
Methylene urea	Nutralene®, CoRoN®, NFusion®	Rapid Release
Triazone	N-Sure®	Rapid Release
NBPT + DCD	Agrotain®Plus, SuperU®	Nitrification, Volatilizaton
Methylene urea + triazone	Nitamin®, NFusion®	Rapid release
Triazone + NBPT	N-Pact®	Rapid release, Volatilization

**Mention of these products implies NO endorsement by UNL.*

Note: Product effectiveness has been found to vary when tested.

ASSESSING RISK OF N LOSS RELATIVE TO POTENTIAL N MANAGEMENT RESPONSE USING ENHANCED EFFICIENCY FERTILIZERS:

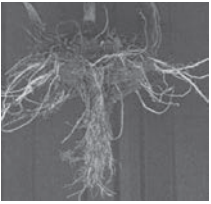
The fertilizer products* listed on the previous page may be of value with respect to the below situations and the potential corresponding **N** loss risk. However, **most of these products have not undergone much unbiased third-party testing**, so producers should do their own on-farm research strip testing to evaluate the economic value of any product. For assistance in conducting a suitably designed strip trial on your farm, go to: http://cropwatch.unl.edu/farmresearch.

Situation	Risk	Approach
Fall application to silt loam or poorly drained clay loam soil	Denitrification, leaching	NH_3 injection with nitrapyrin
Pre-plant application to silt loam or poorly drained clay loam soil	Denitrification, leaching, runoff, volatilization	NH_3 with nitrapyrin; PCU: Urea with NBPT; Methylene urea
At-planting with a no-till surface application	Volatilization, runoff, denitrification	Urea with NBPT; PCU: Methylene urea; UAN with NBPT
Side-dress application or fertigation	Wet weather preventing timely application	Pre-plant or at-planting application, using inhibitors or slow/controlled release formulation

SOIL COMPACTION – HOW IT IMPACTS ROOT SYSTEMS:

Soil compaction often appears as:

- Reduced/irregular plant height.
- Slower seedling emergence and early growth.
- Areas/strips of standing water.
- Roots spread sideways above or between compacted layer(s), not angling downward.
- **N**, **P**, or **K** deficiency symptoms.

(Left) Roots grow to right, away from tire-track-compacted area; (Right) Hard pan above subsoil shank slot (operated when soil was too wet to fracture restrictive layer).


(Left) Lighter green rows suggest wheel-track compaction; (Right) Soil cutaway shows rooting confined to shallow depth plus subsoil shank slot:

Soil characteristics to look for

- Coarse “cloddy” structure in topsoil.
- Plate-like structure below surface.
- Horizontal root growth at tillage pan layer(s).

SOIL COMPACTION – DIAGNOSIS METHODS:

The root growth pattern can indicate if soil compaction is a problem. Soil compaction MAY be a possible cause when **poor emergence, slow and/or irregular early growth, a nutrient deficiency, or early drought symptoms** tend to parallel each other, particularly if soil moisture has been adequate, and no herbicide issues are present.

Potential Diagnostic Tools:

1. **Soil Probe.** Probe the soil in multiple areas of the field, and push it into the soil several times, moving a few inches at a time, on and between rows of the previous crop. Try to detect changes in force required to move the probe downward at each spot.

2. **Soil Penetrometer.** This instrument is very similar to a soil probe, but measures the downward force necessary to insert the tip into the soil. One can get relative readings of the force required in different areas.

3. **Tile Spade.** Carefully dig next to the plants to observe pattern of root growth.

4. **Knife Blade Probing.** Dig a hole about 2 feet in diameter and 2 feet deep. Then use a knife blade to probe the exposed soil about every 2 inches to see if resistance or the soil structure changes. If a crop is currently growing, **dig a small trench to check on root distribution.**

Note: **Pressure readings are affected by soil moisture**, especially when using probes and penetrometers. Make comparisons among similar soils at similar moisture contents on the same day, and areas which have used the same tillage systems for the past few seasons.

SOIL COMPACTION – HOW TO MINIMIZE IT:

The use of **heavier equipment**, multiple field operations, **operating on wet soil** due to time constrictions, and fewer (primarily row crops) crops used in a rotation, all provide elements for "**more extensive and deeper compaction**" according to UNL research.

A loaded 12-row combine will have an axle weight of about 52,000 pounds; a loaded 1200 bushel grain cart will be 70 to 80,000 pounds. UNL research has shown that such axle weights can compact soils to 3 feet or more, below the reach of deep ripping tools, or freeze/thaw cycles, that might be able to remedy the compaction.

The best option is to AVOID compaction whenever possible.

Tillage can contribute to compaction, primarily via its degradation of soil aggregation. No-till methods (increased surface residue) are helpful, as long as other operations are not performed when soil is excessively moist. Controlled traffic patterns help, as 80-85% of compaction is done on the first pass. Avoid enlarging the “area” of compaction in a field by keeping wheel travel in the same rows over multiple operations, year after year. During wet falls, try to delay harvest until the soil will support the combine. It helps to reduce the effective load by not completely filling combine bins and grain carts to full capacity before unloading. Keep grain trucks on roads near the fields or at the sides of fields as much as possible unless soil is dry. If ruts are made during harvest in wet falls, avoid tilling until the soil is dry at least to the depth of the ruts, or the compacted areas will not shatter.

For more information, see:
http://cropwatch.unl.edu/avoiding-compaction-harvest.
http://extensionpublications.unl.edu/assets/html/g896/build/g896.htm.

MANAGING CROP RESIDUE:

Wind and water erosion, especially the not easily seen sheet erosion, are serious threats to the sustainability of Nebraska agriculture. Maintaining crop residue cover by use of no-tillage and conservation tillage is one of the most effective means of erosion control. Effective management requires, at harvest, leaving much of the aboveground crop residue (as feasible) attached, while uniformly spreading the detached residue, then maintaining that residue through the winter and into the following growing season. Weather and microbes degrade crop residue, but tillage, residue harvest, and field operations have the biggest impact.

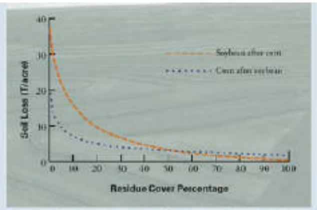
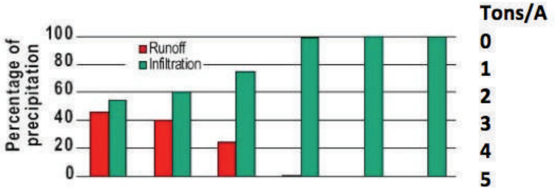


Figure 1. Soil loss due to water erosion in relation to percent residue cover for Iowa, based on the Universal Soil Loss Equation.

Not only does soil residue decrease the impact and erosion from raindrops, it also increases infiltration rate of precipitation (see chart) and reduces evaporation from the soil surface, thus allowing the crop to capture and store rainfall in the soil, reducing irrigation needs as well.

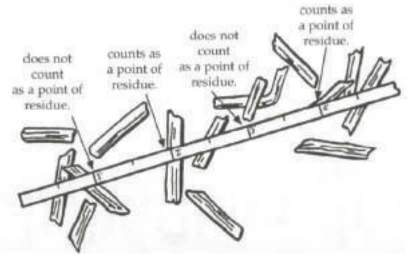


Source of Graph: http://www.fao.org/docrep/009/a0100e/a0100e08.htm.

See:
http://cropwatch.unl.edu/conserving-soil-and-water-no-till-and-crop-residue-unl-cropwatch-april-5-2013.
http://cropwatch.unl.edu/tillage/residue.

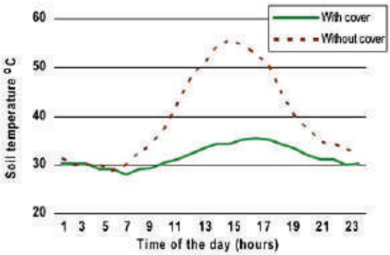
Estimating Residue Cover Remaining on Soil Surface:

The "line-transect" method is an easy and accurate way to determine percentage residue coverage. A 100-foot measuring tape or a knotted rope or cord will work. For convenience you need 100 easily visible marks. To use the method, stretch the tape diagonally across the rows on a section of the field. Check for presence of a piece of crop residue directly under the mark. By counting the number of marks that are directly over a piece of residue (use only one edge of the tape) you can directly determine the percent residue coverage (e.g., 57 marks on residue equals 57% coverage. Choose several representative areas of the field and average the results. To count, a piece of residue must be large enough to dissipate the energy of a rain drop hitting it.



See: http://extensionpublications.unl.edu/assets/html/g1931/build/g1931.htm.

Heavy crop residue will slow soil warming and drying the following spring. No-till reduces field trips, so Nebraska producers have not suffered major planting delays waiting for soils to warm to suitable temperatures.



Graph: http://www.fao.org/docrep/009/a0100e/a0100e08.htm.

MANAGING CROP RESIDUE (CONT.):

Planter attachments designed to move residue (not soil) away from the planted row will help that soil warm faster in cold springs. Some producers use **fall and spring "strip till" equipment** to facilitate drying of the row area to enable earlier spring planting (*vs.* no-till). Tracking soil temperature in no-till *vs.* strip-till early planted soybeans showed that **soil under no-till residue stays colder during sunny days after planting, whereas the soil in a plant row with no residue cover warms up quickly each day**. See: http://cropwatch.unl.edu/tracking-air-and-soil-temperatures-soybeans-planted-april-29-unl-cropwatch-may-2013.

Harvesting Residue:

Crop residue can be used as roughage to feed to animals with DDGS from ethanol plants, and as an additional revenue source when grain prices are low. However, corn & soybean crop residues do have intrinsic **value to the producer. First**, in-place residue provides the **benefits of** reducing erosion and increasing water infiltration as noted earlier. **Second, maintaining** or increasing soil carbon (organic matter) **is essential to soil productivity and fertility over the long term. Keep in mind** that removed residue contains valuable nutrients, so those lost nutrients **may need replacing by fertilizers**. **Grazing corn stalks leaves the nutrients in** the field as manure, **but** soil residue coverage still decreases and grazers can cause soil compaction. A ton of corn residue contains about **17 lbs. of N, 4 lbs. of P_2O_5, 50 lbs. of K_2O, and 3 lbs. of S. A ton of soybean residue contains about 10 lbs. of N, 4 lbs. of P_2O_5, 30 lbs. of K_2O, and 3 lbs. of S**. Removing 3 or 4 tons of corn stalks per acre (= 5 or 6 round bales) can remove \$60 to \$100 of soil nutrients. **Soybean residue per acre is less, but nutrients are of value to the next corn crop**. *Be sure to offset harvested residue value against removed nutrient value.*

For more details on crop residue removal, see:

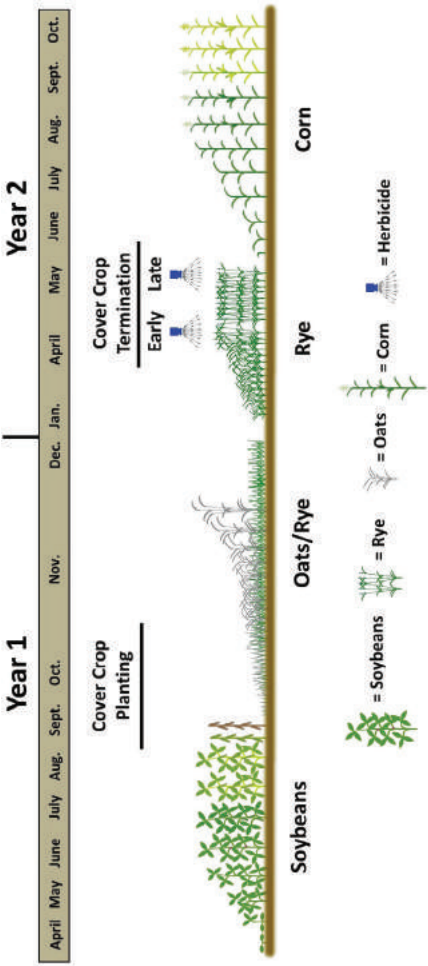
http://extensionpubs.unl.edu/publication/9000016365924/harvesting-crop-residues/.
http://cropwatch.unl.edu/harvesting-crop-residue-whats-it-worth.
https://cropwatch.unl.edu/2018/what-value-soybean-residue.
http://cropwatch.unl.edu/grazing-corn-residue-win-win-crop-and-cattle-producers.

COVER CROPS:

In recent years, cover crops (CCs) have become more common in the NE landscape. More farmers are using CCs to reduce soil erosion, capture excess soil Nitrate, suppress weeds, & provide an additional forage source. These benefits tend to increase with increases in fall and spring CC biomass, and can be of great value in a soybean/corn cropping system. It can be challenging to (1) **establish a CC crop immediately after the fall harvest** of a soybean or corn crop, and (2) **determine when to terminate a CC crop for spring planting** of the following crop. **See next page graphic timeline.** To best **establish** a CC, it must be planted early enough in the fall to allow the CC to form sufficient shoot & root biomass before winter conditions halt CC growth. Early fall CC planting is not difficult after harvest of short-season crops like wheat, silage, and seed corn. However, in a **soybean/corn rotation**, early fall CC planting is more difficult due to the cash crop's lengthy growing season.

Potential solutions include a timely broadcast of CC seed into the main crop before its harvest, or using a slightly shorter-season corn hybrid or soybean variety, although rain or irrigation must occur just before or soon after CC seeding to ensure germination & seedling establishment. Water stress is mitigated in **irrigated** fields, so using a slightly shorter-season soybean may not incur much of a yield penalty. In **rainfed** fields, early-maturing soybean varieties are more yield-vulnerable to August drought than late-maturing varieties, so rainfed producers tend to use the latter to mitigate drought risk (guide pages 26 & 86). For yield data on a range of short- to long-season corn hybrids in irrigated/rainfed fields, see: https://cropwatch.unl.edu/OnFarmResearch/2018%20On-Farm%20Protocol%20RM%20Corn%20Hybrids_v1.pdf.

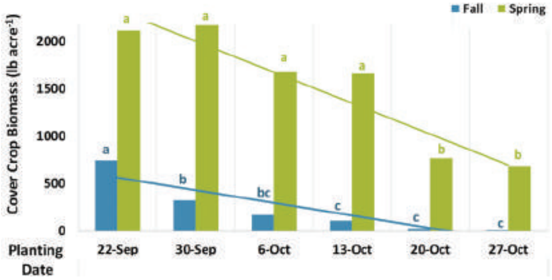
COVER CROPS (CONT):



Graphic provided by Justin McMechan.

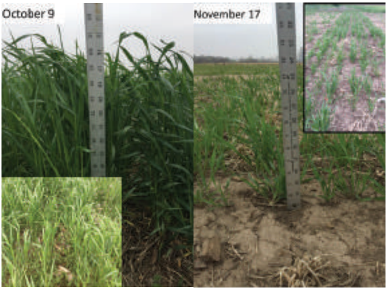
Shown at left is a 2-yr time frame of a soybean / corn rotation with a cover crop used **from** the end of a 1st year cash crop **to** the start of a 2nd year cash crop. The **Fall CC planting date choice** is critical for establishing a CC that can produce an end-of-year biomass goal. A **Spring CC termination date choice** impacts the duration of the production of CC biomass after the CC resumes its spring growth in mid-March until the summer cash crop must be planted.

As shown in the prior page graphic, cover crop planting typically ranges from mid-September (if a CC broadcast seeding option is used before main crop harvest) to early/mid-November (if the CC seeding occurs after the main crop harvest). Nebraska research shows that fall planting date is the key critical factor governing CC biomass production, as shown in the below chart provided by Chris Proctor when cereal rye was the CC. The CC biomass produced by Nov 17 (blue bars), and subsequently produced by Apr 11 (green



bars), clearly declined when fall CC planting was delayed after September 22. A CC biomass is often desired prior to a spring CC termination date.

Photos taken on May 10 show the cereal rye biomass difference generated with an October 9 versus a November 17 plant date.



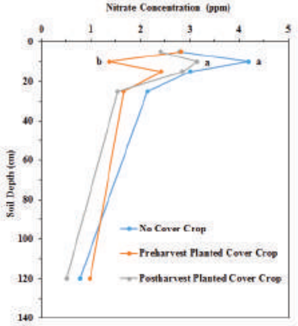
COVER CROPS (CONT):

As shown in the guide page 301 graphic, a cover crop (CC) must be terminated by a herbicide just before the planting or emergence date of the next crop. Selecting a CC **termination** date requires weighing the positive value of an increase in CC biomass that occurs per day of termination delay ***versus*** the negative value of the decrease in yield potential that occurs per day of delay in planting the summer crop – for late planting yield penalties, see soybean guide pages 29-30, 51-52 & 64, and corn guide pages 151-153, 157-159 & 167. See also: https://cropwatch.unl.edu/2018/timing-cover-crop-termination-and-related-factors.

Late CC termination leads to greater CC biomass, *but excessive residue* can impact germination, emergence, and early growth of the main crop, because it can: (1) keep the soil temperature cooler, (2) create a soil surface physical barrier when compressed, (3) tie up key nutrients needed by main crop seedlings, (4) transpire soil water in the CC soil root zone that, in low-rainfall springs, would need to be replaced by a timely rainfall or irrigation event before the planted main crop can germinate, (5) serve as a refuge for insects/pathogens that may harm the main crop, and (6) exhibit an alleleopathic effect (i.e., release of substances by the CC species that inhibits germination & seedling growth of the main crop species). All of these items should be considered when selecting a suitable CC termination date, though the most critical one may be the CC crop creating dry soil layers that prevent soybean seedling taproot extension (guide page 41). For more information on CCs, see:
https://cropwatch.unl.edu/cover-crops.
http://mccc.msu.edu/.
https://www.sare.org/Learning-Center/From-the-Field/North-Central-SARE-From-the-Field/2017-Cover-Crop-Survey-Analysis.

Small-grain cereals are particularly effective CCs for suppressing weeds prior to planting of the main crop. Most studies indicate that ~2 tons/acre of CC biomass present at the CC termination date will result in near-complete weed suppression (see guide page 298), but even lesser amounts are still effective in delaying weed emergence, resulting in fewer, smaller weeds being present in the main crop. This delay allows for greater flexibility in choosing herbicides for the main crop and extending the optimal window for herbicide application.

Soil nutrient loss can be a significant issue in some Nebraska soybean/corn areas. Use of fall-seeded cereal rye CC on a sandy field in north-east Nebraska reduced nitrate leaching, especially in the top foot (30 cm) of soil.



Hail and storm damage occur somewhere in NE every year. If a very late season hail storm destroys your summer cash crop, the only replant option may be a forage crop that can be used to graze animals. See: http://beef.unl.edu/double-cropped-cool-season-annuals.

Herbicide "plant back" intervals restrictions must be coordinated with the species chosen for CC seeding. Many corn and soybean herbicides have a four-month "no plant back" interval, but others have much less. For more details, see:

http://cropwatch.unl.edu/corn-and-soybean-herbicide-options-planting-cover-crops-forage-fall.

WEED CONTROL – SOYBEAN AND CORN PRODUCTION:

Comprehensive information on all weed control topics cannot be provided in this small pocket guide. For detailed coverage of all aspects of weed control relative to Nebraska soybean and corn production systems, we strongly recommend that readers purchase the current ***Guide for Weed, Disease and Insect Management – UNL Extension Circular EC130***. This annually updated publication is available in an 8.5 x 11 printed format, or as a PDF you can download to your computer or smart phone. The cost is $15 for a printed copy or PDF, or at a discounted cost of $25 for both. To purchase online, please visit: https://marketplace.unl.edu/extension/ec130.html.

Note: A copy is provided to those who register for and attend one of the annual Crop Production Clinics held at sites across Nebraska.

Weed identification is first step consideration relative to all weed control decisions. Photos of Nebraska weeds are provided in this easy-to-carry pocket guide for convenient use by producers walking/scouting fields. For a listing of online available UNL weed-related extension publications (PDFs) that also contain weed photos, go to:
http://extensionpubs.unl.edu/search/?keyword=weed+&page_number=2.

A Nebraska Department of Agriculture publication with photos of common Great Plains weeds can be purchased for $25 at:
http://www.nda.nebraska.gov/forms/nw11.pdf.

For photos of 54 weeds common to the 12 North-Central U.S. States, go to:
http://soybeanresearchinfo.com/pdf_docs/weedID_NCR607.pdf.

Many weed photos also can be found at these websites:
https://weedid.missouri.edu/.
https://www.weedalert.com/search-by-region-results.php?region=2.

Smartphone Weed ID apps are also available:
https://cropwatch.unl.edu/university-missouri-offers-weed-id-app.
https://itunes.apple.com/us/app/id-weeds/id559906313?mt=8.
https://play.google.com/store/apps/details?id=com.extension.idweeds&hl=en_US.

INTEGRATED WEED MANAGEMENT – KEY ELEMENTS:

Integrated Weed Management (IWM) is an approach aimed at developing an effective and efficient weed management plan that enables crop production systems to be both profitable and sustainable. **In practical terms, IWM involves using a combination of preventative cultural, mechanical, and chemical practices that are mutually supportive with regard to weed control.** Keep in mind that (1) complete eradication of weeds from a field is never possible, and (2) the few weeds that do escape from being killed by ANY single control measure (chemical or not) will have a high probability of possessing biological characteristics that will enhance their ability to adapt to that same control measure if it is used the following year (or repetitively). With IWM, the goal is to minimize that probability by using a wider range of weed control practices.

The primary key principles of IWM include the following:

Weed Prevention: It is often noted that "an ounce of prevention is better than a pound of cure." Keeping weeds and their seeds from infesting a field is a key first step to weed control. Weeds growing in non-planted field edges (i.e., fence lines and road sides) can generate huge amounts of weed seed that can contaminate fields and thus should be controlled. Patches of weeds that suddenly appear in a field should be immediately removed (these are likely to be herbicide-resistant). Relative to field sanitation, be sure to clean combines before moving from field to field.

Crop-Weed Competiveness: To enhance the ability of the crop to compete with (or suppress) weeds, consider (a) narrowing the row spacing or (b) earlier planting for faster crop canopy closure (see guide pages 30 and 35 for soybean and 157 and 158-159 for corn). Cover crops can also mitigate winter and spring annuals prior to planting a cash crop (see guide pages 300-304). For organic corn or soybean production, propane-fueled flame weeding is an option for non-chemical control. See page 16 in 2018 **EC130**:
https://marketplace.unl.edu/extension/ec130.html.

Mitigation of Weed Adaptation: By using a variety of weed control methods, a producer can mitigate the known ability of weeds to quickly adapt to any given single weed control method. Crop rotation and using different herbicide groups (site of action) will mitigate weed adaptation. Shifting from continuous corn to a corn-soybean rotation is thus useful, BUT not for glyphosate-resistant weeds if the rotated soybean variety and corn hybrid are glyphosate-tolerant and volunteers of the prior crop occur in the current crop. (For glyphosate-resistant weed control options in this specific case, see page 21 in 2018 **EC130**): https://marketplace.unl.edu/extension/ec130.html.

Herbicide Application Decisions: Economic thresholds constitute the core of any integrated pest management (IPM) control decision (weeds, like diseases and insects, are pests). Simply stated, for IWM, a **decision** to apply an herbicide should be based on whether the known or expected return per acre (i.e., yield advantage of treatment (spraying or not) surpasses known expense cost per acre (i.e., herbicide and its application). To base a spray decision on economic weed thresholds, see pages 11-14 in 2018 **EC130**: https://marketplace.unl.edu/extension/ec130.html.

Making a sound herbicide choice decision requires (a) annual documentation to record long-term field weed histories, **(b)** weekly scouting to assess at each crop stage which weeds are present or emerging, their density and growth stage, and **(c)** recognition of the cost of delaying weed control – see figure 1 (corn) and figure 2 (soybean) on page 13 in 2018 **EC130**.

HERBICIDE-RESISTANT (HR) WEEDS IN NEBRASKA:

As of 2018, on a global basis, 496 unique cases of herbicide-resistant (**HR**) weed biotypes have now been detected in 255 weed species (148 dicots and 105 monocots). These **HR** weed biotypes are resistant to at least one (or more) of 23 of the 26 recognized herbicide site of action groups (see guide page 310). Mutant **HR** biotypes of each weed species spontaneously occur naturally, but only at very low frequencies. Year-after-year use of the same herbicide (example: glyphosate), or even different herbicides that STILL have the same site of action, will ONLY control non-**HR** weed biotypes. NOTE, however, that **because the HR biotype is NOT controlled, its frequency rapidly increases to the point that it becomes the dominant weed in a field!** Examples are shown in the photos of a glyphosate-resistant biotype of common water hemp in a corn field and a soybean field.

Nine weed species with an HR biotype have NOW been detected in 92 crops in 70 NE counties (see next page). **Six** of those NE weeds (i.e., common ragweed, giant ragweed, common waterhemp, marestail, kochia, and Palmer amaranth) **are glyphosate resistant**, and four of those are also resistant to other herbicide classes. This should be of great concern to any producer of no-till corn and no-till soybean who has repetitively used glyphosate for post-emergence weed control. **NOTE: If <u>YOU</u> fail to rotate herbicide classes for weed control, you can count on <u>YOUR</u> fields to soon look like the fields shown in the above photos.**

HERBICIDE-RESISTANT WEEDS IN NEBRASKA (CONT.):

Herbicide Resistant Weeds Present in Nebraska		
Weed Species	**Resistant to this Herbicide Site of Action Group #**	**Common Brand Name Herbicides**
Common Waterhemp	Glyphosate (9); HPPD (27); ALS (2); Triazine (5); Growth Regulators (4); PPO (14)	Roundup, Touchdown; Callisto, Laudis, Impact; Armezon; Pursuit, Classic; Aatrex; 2,4-D
Kochia	Glyphosate (9); ALS (2); Triazine (5); Growth Regulators (4)	Roundup, Touchdown; Glean; Aatrex; 2,4-D, dicamba
Palmer Amaranth	Glyphosate (9); HPPD (27); ALS (2); triazine (5); Photosystem-II (6)	Roundup; Callisto, Laudis, Impact, Armezon; Pursuit, Classic; Aatrex; Buctril
Marestail	Glyphosate (9); ALS (2); PPO (14)	Roundup, Touchdown; FirstRate
Common Ragweed	Glyphosate (9)	Roundup, Touchdown
Giant Ragweed	Glyphosate (9)	Roundup, Touchdown
Redroot Pigweed	Triazine (5)	Aatrex
Shattercane	ALS (2)	Accent, Beacon, Option
Johnsongrass	ALS (2)	Accent/Zent, Pursuit

Reference: See 2018 Nebraska Extension Circular **EC130** (pages 18-20) and:
http://agronomy.unl.edu/documents/EC%201278.pdf.
http://cropwatch.unl.edu/multiple-herbicide-resistant-weeds-and-challenges-ahead.
https://cropwatch.unl.edu/documents/Corn%20and%20Soybean%20Herbicide%20Chart.pdf.

HERBICIDE SITE OF ACTION GROUPS:

Repetitive use of herbicide(s) with the same site of action (below table) increases the frequency of weeds resistant to that herbicide. Be wise, rotate herbicides!

Herbicide Type	Group Number and Site of Action		Chemical Family
Lipid Synthesis Inhibitors	1	Acetyl CoA Carboxlase (i.e., ACCase) Inhibitors	Aryloxyphenoxypropionate; Cyclohexanedione
Amino Acid Synthesis Inhibitors	2	ALS Inhibitors	Sulfonylurea; Imidazolione; Triazoloyrimidine
	9	ESPS Synthesis Inhibitor	NA (glyphosate)
Growth Regulators (Synthetic Auxins)	4	Specific Site Not Known	Phenoxy; Benzoic Acid; Carboxylic Acid
	19	Auxin Transport	Semicarbanzone
Photo-synthesis Inhibitors	5	These 3 groups are all Photosystem II Inhibitors but differ in binding	Triazine; Triazinone
	6		Nitrile; Benzothiadiazole
	7		Ureas
Nitrogen Metabolism Inhibitor	10	Glutamine Synthesis Inhibitor	NA (glufosinate)
Pigment Inhibition	13	Diterpene Synthesis Inhibitor	Isoxazolinone
	27	HPPD Inhibitors	Isoxazole; Triketone
Cell Membrane Disrupters	14	PPO Inhibitors	Diphenylether; N-phenylph-thalimide; Aryl triazinone; Trifluoromethyl uracils
	22	Photosystem I Electron Diverter	Bypyridilium
Seedling Root Growth Inhibitors	3	Microtubule Inhibitors	Dinitroaniline
Seedling Shoot Growth Inhibitors	8	Non-ACCase Lipid Synthesis Inhibitor	Thiocarbamate
	15	Long-Chain Fatty Acid Inhibitors	Chloroacetamide; Oxazolinone; Oxyacetamide

Do you know what site of action group number a brand name herbicide falls into? If you don't, see pages 8-10 in Nebraska 2018 **EC130**.

WEED IDENTIFICATION – BROADLEAF SPECIES:

To identify broadleaf weeds using a graphical key, see: https://extension2.missouri.edu/IPM1007.

Common Ragweed (*Ambrosia artemisiifolia*)**

True leaves are deeply lobed, may be hairy. Cotyledons are rounded, thick, and short. Stem is rough to the touch.

A biotype with **glyphosate resistance (group 9) is now present in Nebraska (see guide page 309).

Giant Ragweed (*Ambrosia trifida*)**

True leaves are slightly hairy with three to five lobes. Cotyledons are oval to spatulate, and thick and fleshy. Stem is coarse and hairy.

A biotype with **glyphosate resistance (group 9) is now present in Nebraska (see guide page 309).

Palmer Amaranth (*Amaranthus palmeri*)**

Similar in appearance to redroot pigweed and common waterhemp. Leaves are diamond- to ovate-shaped with petioles much longer than leaf blades. Leaf watermarks vary in intensity (barely visible in some cases). Plant lacks hairs on stems and leaf surfaces.

A biotype with **glyphosate resistance (group 9) is now present in Nebraska (see guide page 309).

Common Waterhemp (*Amaranthus Rudis*)**

Similar in appearance to pigweed and Palmer amaranth. Plants lack hairs and have long (3-6”) ovate-to lanceolate-shaped leaves with short petioles.

A biotype with **glyphosate resistance (group 9) is now present in Nebraska (see guide page 309).

Redroot Pigweed (*Amaranthus retroflexus*)**

True leaves are rough with prominent veins and a notched tip. Stems are reddish, erect, and rough. Cotyledons are lanceolate.

A biotype with **triazine resistance (group 5) is now present in Nebraska (see guide page 309).

Marestail [Horseweed] (*Conyza canadensis*)**

Leaves are alternate, linear, and simple with entirely or slightly-toothed margins. Mature plants have leaves with no petioles.

A biotype with **glyphosate resistance (group 9) is now present in Nebraska (see guide page 309).

Kochia (*Kochia scoparia*)**

Alternating leaves are narrow with short or no petioles; multi-branch stems that can be green, red-tinged, or red.

A biotype with **glyphosate resistance (group 9) is now present in Nebraska (see guide page 309).

Russian Thistle [Tumbleweed] (*Salsola tragus*)

Seedling leaves are needle-like; multi-stem plant takes on an oval shape and stem becomes brittle and breaks; high winds lead the weed to tumble across fields, disbursing its seeds in a streak pattern appearing when those seeds germinate.

Velvetleaf (*Abutilon theophrasti*)

True leaves are heart-shaped and covered with short, velvety hairs. Stem is covered with short, velvety hairs. Cotyledons are round and heart-shaped at base.

Common Lambsquarters (*Chenopodium album*)

Leaves are slightly toothed and coated with a white, mealy substance, especially on young plants.

Jimsonweed (*Datura stramonium*)

True leaves are ovate with unevenly toothed edges. Cotyledons are long and narrow. Strong odor when crushed.

Eastern Black Nightshade (*Solanum ptycanthum*)

True leaves alternate, shallow-lobed edges, pointed at tip. Stem is smooth. Underside of leaf is violet in color.

<u>Common Sunflower (*Helianthus annuus*)</u>

True leaves are ovate to lanceolate, and alternate. Stem and leaves are rough textured.

Pitted Morning Glory (*Ipomoea lacunosa*)

True leaves are heart-shaped on a twining vine. Cotyledons are deeply indented.

Ivyleaf Morning Glory (*Ipomoea hederacea*)

True leaves are hairy, alternate, and have three lobes. Cotyledons have a butterfly shape – similar to tall morning glory.

Tall Morning Glory (*Ipomoea purpurea*)

True leaves are heart-shaped and alternate. Cotyledons are butterfly-shaped, similar to those of ivyleaf morning glory.

Common Cocklebur (*Xanthium strumarium*)

True leaves are triangular in shape with three main veins from base. Cotyledons are long, narrow, and fleshy. Stem is spotted and rough.

Venice Mallow (*Hibiscus trionum*)

True leaves have 3-7 lobed segments. Cotyledons rounded to heart-shaped with long petioles.

Downy Brome (*Bromus tectorum*)

Plants up to 2 feet tall. Leaf sheaths, blades, and nodes covered with soft hairs. Leaves twist clockwise. A membranous ligule is present where leaf blade and sheath meet.

Field Pennycress (*Thlaspi arvense*)

Erect, branched, or simple stems up to 2.6 feet tall. Alternating leaves form a basal rosette. Leaves have coarsely toothed margins (lower ones have blunt tips; upper ones have projected leaf tips).

Henbit (*Lamium amplexicaule*)

Plants up to 1 foot tall found in cultivated areas and roadsides, with squared (green then purplish) stems. Leaves are opposite, clasping the stem's top portion, with crenate and lobed leaf margins.

Tansy Mustard (*Descurainia pinnata*)

Plants up to 2.9 feet tall found in fields and roadsides could be 0.3 to 2.9 feet tall with simple or branched stems. Leaves are segmented in a narrow pattern.

WEED IDENTIFICATION – SEDGE SPECIES:

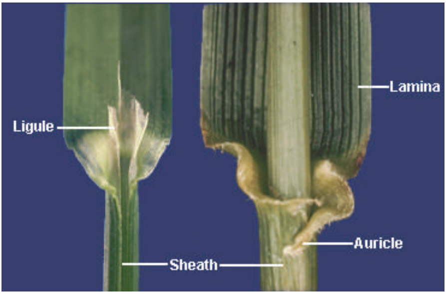
Note: A sedge is a monocot, but is not a true grass.

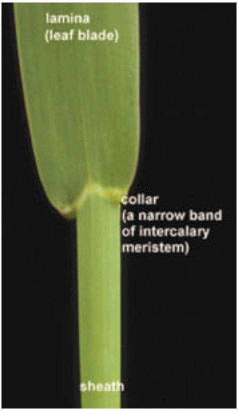
Yellow Nutsedge (*Cyperus esculentus*)

Stems and leaves are arranged in threes, making a triangular cross-section. It is a perennial, reproducing by seed and tubers. Flowers arranged in narrow spikes.

Grass Weed Structure Key:

Grasses are distinguishable based on the below structures:





Collar: Junction of the leaf blade with leaf sheath.

Auricle: Small appendages that project from the leaf blade base and appear to partially or completely wrap around the stem.

Lamina (Blade): The expanded portion of the leaf.

Sheath: The lower portion of the leaf that encircles the stem and younger leaves.

Ligule: A projection of the base of the leaf blade that may be membranous or just a tuft of hair.

Node: A joint on stem where a leaf is attached.

UNL Reference on Grass Weeds:
http://extensionpubs.unl.edu/publication/9000019100747/identification-of-grass-weeds-commonly-found-in-agronomic-crops-in-nebraska-ec3020/.

WEED IDENTIFICATION – GRASS SPECIES (CONT.):

Johnsongrass (*Sorghum halepense*)**

Sheath: Slightly round.

Ligule: Membranous, tall, jagged.

Blade: Smooth, prominent mid-vein.

Auricles: None.

A biotype with **ALS resistance (2) is now present in Nebraska (see guide page 309).

Shattercane (*Sorghum bicolor*)**

Sheath: Somewhat round.

Ligule: Membranous, tall, jagged.

Blade: No hairs.

Auricles: None.

A biotype with **ALS resistance (2) is now present in Nebraska (see guide page 309).

UNL Reference on Johnsongrass and Shattercane:
http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1847&context=agronomyfacpub.

Giant Foxtail (*Setaria faberi*)

Sheath: Round.

Ligule: Fringe of hairs.

Blade: Short, stiff hairs.

Auricles: None.

Green Foxtail (*Setaria viridis*)

Sheath: Round.

Ligule: Fringe of hairs.

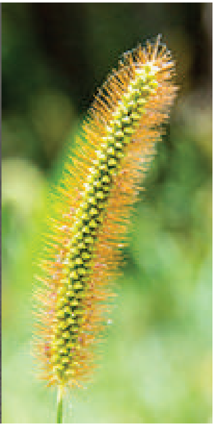
Blade: No hairs.

Auricles: None.

A biotype with **ALS resistance (2)** is now present in Nebraska (see guide page 309).

UNL Reference on Johnsongrass and Shattercane:
http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1847&context=agronomyfacpub.

Yellow Foxtail (*Searia pumilia*)



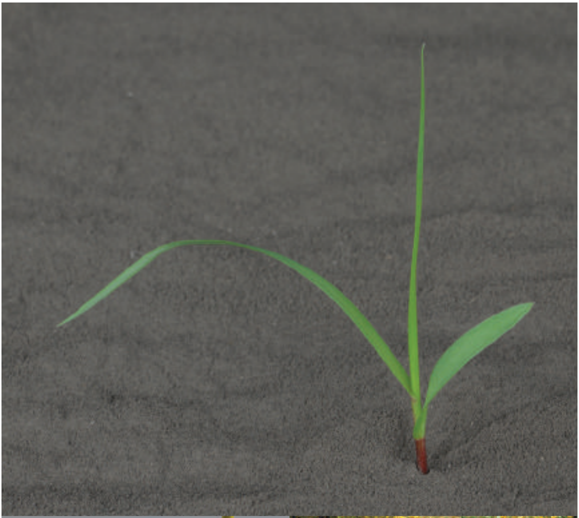
Sheath: Flat.

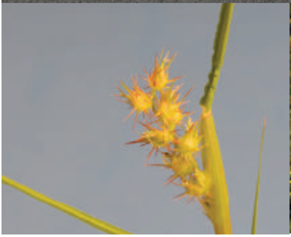
Ligule: Fringe of hairs.

Blade: Long hairs near base.

Auricles: None.

Field Sandbur (*Cenchrus pauciflorus*)





Sheath: Round.

Ligule: Fringe of hairs.

Blade: No hairs, folded.

Auricles: None.

<u>Barnyardgrass (*Echinochloa crus-galli*)</u>

Sheath: Flat.

Ligule: None.

Blade: No hairs.

Auricles: None.

Fall Panicum (*Panicum dichotomiflorum*)

Sheath: Round.

Ligule: Fringe of hairs.

Blade: Smooth, prominent mid-vein.

Auricles: None.

Large Crabgrass (*Digitaria sanguinalis*)

Sheath: Compressed.

Ligule: Membranous.

Blade: Hairy.

Auricles: None.

WEED IDENTIFICATION – GRASS SPECIES (CONT.):

Wooly Cupgrass (*Eriochloa villosa*)

Sheath: Round.

Ligule: Fringe of hairs.

Blade: Has flat, distinctive crinkle on one side.

Auricles: None.

CROP HERBICIDE INJURY – KEY CONSIDERATIONS:

It can be quite difficult to correctly match an observed crop injury symptom with the specific causal herbicide.

If you suspect a crop injury you observed to be herbicide-caused, you should first try to objectively rule out other possible causes for the observed symptoms, including soil mineral nutrient deficiency/ toxicity, pH, low organic matter sandy soils, clayey soil field depressions, or a disease or an insect. Abnormally warm or cool temperatures can lead to crop injury due to a more rapid herbicide uptake or a slower herbicide detoxification. Corn hybrids and soybean varieties may differ in sensitivity to the herbicide or the spray adjuvant. **A crop herbicide injury typically is due to:** (1) **an intended but faulty application** or (2) **an unintended off-target drift.** These two can be distinguished by the pattern of crop injury that is observable across a field. **Crop injury from a faulty field application** will usually have a straight-line pattern related to the direction of the application equipment (i.e., a defective nozzle; sprayer boom-end overlap, or field-end turn-around overlap). Sprayer tank contamination, tank-mix order or incompatibility, or improper spray additive choice can lead to crop injury (for advice on these items, see pages 30 and 62-65 in 2018 **EC130** https://marketplace.unl.edu/extension/ec130.html).

Crop injury from off-target drift (of a particle or vapor type) will not have a straight nor rectangular pattern, and will invariably extend well beyond the field itself into fencerows, roadsides, or waterways. In fact, non-crop plant (including weed) injury in those non-field areas is strong evidence of herbicide drift, so be sure to examine (and photograph) injury observed in **both cropped and non-cropped areas**. Keep in mind that crop injury could arise from the carryover of a herbicide applied last year or this spring. For a listing of herbicides with this potential, see:

https://www.ag.ndsu.edu/weeds/weed-control-guides/nd-weed-control-guide-1/wcg-files/15-CO.pdf.

CROP HERBICIDE INJURY – REDUCING DRIFT:

Always read/follow label instructions for drift mitigation. **The label is the law.** Failure to follow label directions could incur a liability if herbicide off-target drift leads to a monetary loss:

http://cropwatch.unl.edu/2016/neighbor-neighbor-communication-key-avoiding-drift-damage.

Off-Target Drift Types: **Particle drift** occurs when small **spray droplets** are blown by wind from a target site to adjacent or distant fields. **Vapor drift** occurs when the herbicide active ingredient changes from a liquid to **vapor** state (i.e., volatilizes), and the vapor then moves from the target site. Note that **vapor** movement occurs even at very low wind speeds, and some herbicide active ingredients are very volatile, particularly at temperatures of 80-90° F.

Drift Mitigation: Monitor wind speed and temperature before, during, and after applications. In general, low wind speeds of 3-7 MPH are preferable, and are most common during dawn or dusk; temperatures are coolest at dawn. **Do NOT START and immediately STOP spraying when wind exceeds 10 MPH**. Beware of spraying during dusk-to-dawn no wind "**temperature inversions**," when light warm air rises and heavy cool air settles near the ground. Spray droplets suspended in a concentrated mass move upward and can subtly move (in bulk) to distant off-target sites!

A handheld digital wind speed and temperature device purchasable online for less than $25 is a negligible cost *versus* the cost of a potential liability incurred for off-target drift damage.

Drift potential can be reduced by: (**1**) using a boom height just sufficient for proper nozzle-to-nozzle spray fan coverage; (**2**) using nozzles generating a coarser (larger) spray droplet (≥400 µm), but note that too large of a droplet size may hinder the effectiveness of contact herbicides; (**3**) using a lower pressure to generate larger droplets, but if using a rate controller, recalibration/ adjustment of ground speed will be required; (**4**) using drift retardants, but make sure your retardant choice is compatible with a drift-reducing nozzle type you have also chosen.

CROP HERBICIDE INJURY – *EX POST FACTO* THOUGHTS:

Producers who observe a crop injury symptom that they suspect might be herbicide-caused will often ask if that suspicion can be confirmed by submitting a sample of the injured tissue for a laboratory analysis. **However, if that tissue sample was NOT collected (and dried immediately to stop tissue metabolism) within a few hours after an off-target drift or sprayer tank contamination event, it will be very difficult to detect in the plant tissue the causal herbicide.** Plants also quickly break down or metabolize most herbicide active ingredients (particularly the synthetic plant growth regulator ones). Moreover, several days may elapse before an herbicide-induced injury becomes visible if just meristematic growing points or leaf primordia are the site of action targets of the misapplied herbicide. Lab-mediated tissue analyses may thus not be able to identify the injury-causing herbicidal active ingredient.

If an injury arising in this year's crop is suspected to be due to carryover of an herbicide applied to that field last year or due to burndown herbicide applied earlier in the year, consider doing a do-it-yourself bioassay. *Reference:* http://extensionpublications.unl.edu/assets/pdf/g1891.pdf.

Some commercial laboratories offer soil sample testing service for herbicide carryover analysis and a few are listed on pages 29-30 of the 2018 Nebraska Extension Circular **EC130** at: https://marketplace.unl.edu/extension/ec130.html.
More labs are listed on page 108 of this North Dakota State University publication at: https://www.ag.ndsu.edu/weeds/weed-control-guides/nd-weed-control-guide-1/wcg-files/15-CO.pdf.

In any event, if you suspect a crop injury was caused by an herbicide, we strongly recommend that you first contact a UNL Research and Extension weed scientist who can provide you with professional advice (see guide page 374).

PRIMARY MODES OF ACTION OF COMMON HERBICIDES:

For an up-to-date listing of the brand name herbicides currently available for use in corn and soybean fields, consult the annual version of Nebraska Extension Circular **EC130**, which can be found at: https://marketplace.unl.edu/extension/ec130.html.

For weed responses to fall burndown or spring burndown, and soil-applied or foliar-applied brand name herbicides, see 2018 **EC130** pages 72-79 for corn and pages 118-124 for soybean. **For details on brand name product rates, application times, and approximate cost per acre,** see **EC130** pages 80-90 for corn & pages 125-131 for soybean.

To mitigate the increase in herbicide-resistant weed biotypes that will inevitably result from repetitious application of the same active ingredient (ai), be sure to consult pages 8-10 of 2018 **EC130** to make sure that you are aware of the **ai** in herbicides that you use each year on the same field on which you grow a corn or soybean crop.

Nearly all herbicides are classified into groups according to their mode of action, a classification system developed by the Weed Science Society of America to be helpful when assessing crop herbicide injury. A detailed documentation of injury symptoms you observed (take photos) will help you and a professional make an initial call as to the most likely causal **ai**. First, rule out any **ai** that could not have caused the observed injury symptoms. Consider carryover – see: https://www.ag.ndsu.edu/weeds/weed-control-guides/nd-weed-control-guide-1/wcg-files/15-CO.pdf. A contemporaneous record of your herbicide applications and those you witnessed being applied near your fields will also be useful. On the following pages, we present each known **herbicide group** and **classification number** assigned to the site of action, and the **active ingredients** (not all are listed herein; for a complete listing see pages 8-10 in 2018 **EC130**). We also provide photos (if available) showing typical corn and soybean injury symptoms for each group.

LIPID SYNTHESIS INHIBITORS (GROUP 1):

Action: Known as ACCase inhibitors, this herbicide mode of action is active only on the grass species (i.e., broadleaf plants are tolerant), whether the grass is an annual or perennial. Major activity is from post-emergence applications, though sensitivity varies, e.g., johnsongrass is more sensitive than quackgrass, with shattercane, giant foxtail and volunteer corn more sensitive than crabgrass, yellow foxtail or green foxtail.

Injury: Grasses stop growing, begin to turn red to purple, and growing points decay. The plant may outwardly seem to still be alive, but the top leaves can be easily pulled from the whorl to reveal a dead and rotten growing point. The nodal meristem tissue will also be dead and disintegrating in the stem (and also in perennial grasses, the underground rhizomes). Corn whorl leaves will whiten.

Rotation Carryover Risk: Always read the label; mostly minimal for corn after soybean.

Active Ingredients (ai): (1) clethodim, fluazifop, quizalofop, sethoxydim

Corn Injury Photo: quizalofop (1)

Soybean Injury Photo: quizalofop (1)

AMINO ACID SYNTHESIS INHIBITORS (GROUPS 2, 9):

Action: The herbicides in this group, known as ALS (**2**) or EPSP Synthetase (**9**) inhibitors, are effective on both broadleaf and grass weed species, preventing plants from producing essential amino acids, slowly killing them. Glyphosate (**9**) is nonselective (kills all but crop tolerant plants); other active ingredients (**2**) are selective.

Injury: Plants stop growing but stay green for several days before the final death color (golden in grasses; flay green in broadleaves). Injury to corn from carryover of Group **2** herbicides may include one or all of the following symptoms: stunted plants, interveinal chlorosis, purpling, red-purple veins on undersides of lower leaves, and reduced root systems (bottle-brush). Post-emergence misapplications may cause stunting, chlorosis, and possible malformation of corn leaves (stacking of nodes and a rippling effect) and ears (ear pinching). Glyphosate (**9**) may cause leaf reddening/banding in non-tolerant corn hybrids.

Active Ingredients (ai): (**2**) chlorimuron, cloransulam, flumetsulam, halosulfuron, imazamox, imazaquin, imazethapyr, metsulfuron, nicosulfuron, primisulfuron, rimsulfuron, thifensulfuron, tribenuron; (**9**) glyphosate.

Rotation Carryover Risk: Always read the label; carryover risk may be greater in soils with: (a) a low pH when using imidazolinones or (b) a high pH when using sulfonylureas.

Corn Injury Photos: imazethapyr (2), nicosulfuron (2)

Soybean Injury Photos: chlorimuron (2), thifensulfuron (2)

SEEDLING GROWTH INHIBITORS (GROUPS 3, 8, 15, 16, 19):

Action: These herbicides include inhibitors of root microtubule (**3**), shoot non-ACCase lipid synthesis (**8, 16**), long-chain fatty acid (**15**), and auxin transport (**19**). These inhibitors stop pre-emergence root and/or shoot growth.

Injury: Symptoms are expressed in either the roots or the shoots. Active ingredients that affect the root system usually do not cause any visible damage to the shoot (other than stunting or discoloring the foliage), while those that affect the shoot usually cause no root damage.

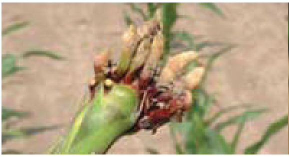
Rotation Carryover Risk: Root pruning is common, as is the inhibition of secondary roots. Roots may be swollen or club-shaped. Stem just below the ground surface will be thickened/shortened and may not fully emerge. Soybean stems may be brittle at soil surface line (easily breaking), and leaves will be heart-shaped ("drawstring" effect).

Active Ingredients (ai): (**3**) pendimethalin, trifluralin.

Shoot Injury Symptoms: Corn shoots appear twisted with leaves tightly rolled. Stems can rupture with new growth protruding from ruptured tissue. Soybean leaves are dark green, crinkled, and/or leaf tips are flattened. Leaves may fail to unfold from buds. Root damage may also occur.

Active Ingredients (ai): (**8**) butylate; (**15**) acetochlor, alachlor, dimethenamid-P, s-metolachlor, pyroxasulfone; (**16**) benzofurane; (**19**) diflufenzopyr.

Rotation Carryover Risk: Always read the label; carryover risk is generally viewed as relatively low.



Corn Injury Photo:
pendimethalin (3)

Soybean Injury Photo:
acetochlor (15)

GROWTH REGULATORS (GROUP 4):

Action: These herbicides are synthetic auxins (**4**) applied post-emergence for direct leaf uptake, but pre-plant treatments are also used in reduced or no-till systems.

Injury: Leaf uptake leads to shoot damage but usually not much root damage. Absorption from soil can injure both. Plants turn dark green; dicamba injury is more severe than 2,4-D or 2,4-DB at equal rates. Soybean stems bend/twist (epinasty) with leaf strapping (feathering); 2,4-D but not dicamba lengthens petioles; corn stems may be brittle ("green snap") or be "goose-necked" or have a "buggy whip" (onion leaf) appearance. Dicamba drift produces upwardly cupped soybean leaves at the same stem node(s) in every plant in an off-target drift zone. The claim that all soybeans in a field will self-produce a "natural" upwardly cupped leaf is not correct. **There is NO scientific evidence whatsoever supporting such a claim!**

Active Ingredients (ai): (4) 2,4-D, clopyralid, dicamba, diflufenzopyr, fluroxypyr, picloram, triclopyr, naptalam, diflufenzopyr.

Rotation Carryover Risk: Always read the label; carryover risk is generally viewed as relatively low, except for certain auxins that have high levels of soil persistence.

Corn Injury Photos: 2,4-D (4), dicamba (4)

Soybean Injury Photos: dicamba (4) *vs.* 2,4-D (4)

PHOTOSYNTHESIS INHIBITORS (GROUPS 5, 6, 7):

Action: These herbicides include three classes of photosystem II inhibitors that differ in how each class binds. They are generally soil-applied, absorbed by plant roots, and move with the upward flow of water in the stem to the foliage. When used post-emergence, action is by contact and requires thorough wetting of foliage, usually with adjuvants. These herbicides halt photosynthesis and thus will not work until the leaves are green after emergence.

Injury: Older leaves turn yellow between the veins from the tip toward the leaf base and from the leaf margins to the leaf center. Leaf speckling and blotching often occurs. In soybean, dying leaves drop from the plant, leaving only a stem with an apical bud.

Active Ingredients (ai): Soil-applied: (**5**) atrazine, simazine, metribuzin; (**7**) diuron, linuron; Post-Emergence-applied: (**6**) bentazon, bromoxynil.

Rotation Carryover Risk: Always read the label; carryover risk is generally viewed as relatively low, except for triazines (atrazine) and uracils.

Corn Injury Photos: atrazine (5), bromoxynil (6)

Soybean Injury Photos: atrazine (5), bentazon (6)

NITROGEN METABOLISM INHIBITORS (GROUP 10):

Action: This herbicide blocks the key plant enzyme glutamine synthetase, causing a lethal build-up of phytotoxic ammonia. The mode of action is nonselective, so it affects nearly all weed species, plus any corn hybrids or soybean varieties that do not have a tolerance gene.

Injury: Injury shows up quickly (especially in hot weather) and initially appears as spots where the herbicide droplets first contacted the leaf surface. New growth will appear chlorotic or water-soaked, sometimes between the leaf veins, and these areas quickly turn necrotic. Corn injury will initially appear as pale green and become chlorotic in the newest growth, with necrosis occurring in the older leaves and leaf tips.

Active Ingredients (ai): (**10**) glufosinate.

Rotation Carryover Risk: Always read the label; carryover risk is generally viewed as relatively low.

Corn Injury Photos:
Glufosinate (10)

Soybean Injury Photos:
Glufosinate (10)

PIGMENT INHIBITORS (GROUPS 12, 13, 27):

Action: These herbicides include inhibitors of phytoene desaturase (**12**), diterpene synthesis (**13**), and HPPD (**27**) which block the synthesis of carotenoids. They are applied as pre-plant or pre-emergence treatments. Carotenoid pigments protect chlorophyll from light-mediated destruction (i.e., photo-oxidation), and if not present, chlorophyll content declines in affected leaves, more rapidly in full sunlight and high humidity conditions.

Injury: The primary injury to crops is the bleached-white appearance of new leaves that then turn yellow and finally brown. Strapping of soybean leaves is a common symptom. In some cases, the affected areas of soybean leaves will have pink to red margins.

Active Ingredients (ai): (**12**) fluridone; (**13**) clomazone; (**27**) isoxaflutole, mesotrione, tembotrione, topramezone.

Rotation Carryover Risk: Always read the label; under certain conditions, these herbicides may persist long enough to affect the next rotational crop.

Corn Injury Photos: clomazone (**13**), mesotrione (**27**), isoxaflutole (**27**)

Soybean Injury Photos: mesotrione (**27**)

CELL MEMBRANE DISRUPTORS (GROUPS 14, 22):

Action: This group includes the protoporphyrin oxidase (PPO) (**14**) and Photosystem I (**22**) inhibitors applied as post-emergence contact herbicides. Foliage must be thoroughly covered with spray. Toxicity increases with high temperatures and no-cloud full sunshine. Incomplete coverage or spray particle drift results in leaves that exhibit scattered spots or zones of dead tissue.

Injury: Symptoms include desiccation of leaf tissue (leaf burn) caused by disruption of cell membranes. Reddish-bronze spotting correlates with droplet size. Applications to soybeans may also cause crinkling of new growth similar to s-metolachlor injury.

Active Ingredients (ai): (**14**) acifluorfen, carfentrazone, flumiclorac, flumioxazin, fomesafen, lactofen, saflufenacil, sulfentrazone; (**22**) paraquat.

Rotation Carryover Risk: Always read the label; carryover risk is generally viewed as relatively low.

Corn Injury Photos: carfentrazone **(14)**

Soybean Injury Photos: mesotrione **(27)**, acifluorfen **(14)**, actophen **(14)**

CALIBRATING A SPRAYER:

How to Determine the Application Rate Per Acre:

There are two basic ways used to calibrate sprayers:
(1) the ounce-based and (2) the formula-based methods. With the ounce-based calibration method, you simply spray **1/128th of an acre (= 340.3125 sq. ft. test area)**, and collect liquid sprayed on that area. You then divide the collected fluid ounce amount by **128 (number of fluid ounces in a gallon)** to determine the number of gallons of herbicide applied per acre. Note that this method requires you to collect the spray from all nozzles on the boom.

With the **formula-based calibration method**, you collect the spray liquid from a single nozzle* during one minute of travel at the chosen ground speed. You then use formulas to compute the gallons per acre applied.

(*NOTE: Technically, all nozzles should be checked in this method to ensure that any "bad" nozzles are replaced!)

First, convert your ground speed from MPH to feet/min.:
(Note: 1 MPH = 5,280 ft. / 60 min. = 88 ft./min.)

mph	6	7	8	9	10
ft/min	528	616	704	792	880
mph	11	12	13	14	15
ft/min	968	1056	1144	1232	1320

Second, what is your sprayer nozzle spacing (NS) - in feet?
30 inches (2.5 ft.); 20 inches (1.67 ft.); 15 inches (1.25 ft.)

Third, calculate the area covered by a nozzle (NS = 30-inch spacing) during one minute of travel at 6 MPH:

Formula: Area Covered = NS x ft./min (see above table)

Example: Area Covered = 2.5 feet x 528 feet/minute = 1320 total square feet of area covered by this nozzle, which is
1320 ÷ 43560 = 0.0303 acre covered per minute.

Fourth, measure the spray liquid (in fluid ounces) collected from the single nozzle during one minute of 6 MPH travel. Divide that collected amount by 128 (ounces per gallon). For example, **if the collected amount was 40 fluid ounces, then 40 ÷ 128 = 0.3125 gallons were applied to the 0.0303 acre covered by that nozzle. This translates into 0.3125 ÷ 0.0303 = 10.31 gallons of herbicide applied per acre at this ground speed.**

Note that the same above formulas can be rearranged to calculate the nozzle flow rate if you specify the ground speed, nozzle spacing, and the number of gallons of herbicide you want to apply per acre.

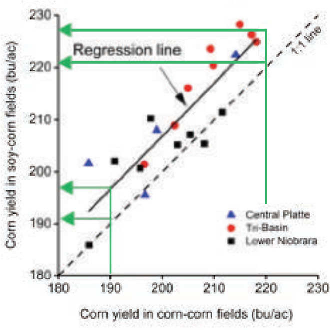
Keep in mind that nozzle size is important. The below table of nozzle color codes is from detailed table on pages 32-44 in 2018 **EC130**. Finer sizes reduce droplet size, which is good for contact herbicide applications, but not so good from small particle drift standpoint. Pressure (psi) also plays a role. The nozzle flow rate (gpm) varies with the psi in a non-linear way, (e.g., a doubling in the flow gpm requires a pressure increase from 10 to 40 psi). See **EC130** for more information on nozzle size and gpm.

Nozzle Category	Symbol	Color
Extremely Fine	XF	Purple
Very Fine	VF	Red
Fine	F	Orange
Medium	M	Yellow
Coarse	C	Blue
Very Coarse	VC	Green
Extremely Coarse	XC	White
Ultra Coarse	UC	Black

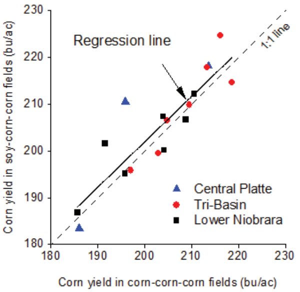
For sprayer calibration protocols and a list of herbicides with required or recommended nozzle sizes, see pages 45-50 and pages 37-39 in 2018 Nebraska Extension Circular **EC130** at: https://marketplace.unl.edu/extension/ec130.html.

SOYBEAN-CORN CROPPING SEQUENCES – NEBRASKA YIELD DATA:

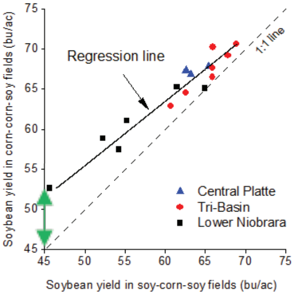
On most Nebraska rainfed farms, soybeans and corn are usually rotated, but on irrigated fields, the rotation sequence tends to shift to more years of corn before a soybean year, and in some cases, corn is grown year after year (see maps on guide page 23). In the below chart, the left axis is corn yield in a soybean-corn (S-**C**) rotation, whereas the bottom axis is corn yield after a prior year of corn (C-**C**). The dashed 1:1 line denotes equality in yields if corn IS NOT impacted by a previous year's crop. However, the chart's solid line shows that, on average, actual Nebraska corn yield WAS INDEED impacted – **6.4 bu./acre higher following soybean than following corn** across the low-to-high (190-220 bu./acre) yield range in central Nebraska (see paired sets of green arrows). The corn yield bump was higher in the Tri-Basin NRD (**9.6 bu./acre)** but lower in the Lower Niobrara NRD (**3.2 bu./acre).**



Source: Dr. B. Farmaha and Dr. P. Grassini of UNL. See:
https://dl.sciencesocieties.org/publications/aj/pdfs/108/6/2313.
Note: The colored symbols denote the yields of corn in hundreds of fields surveyed per data point year in three Nebraska NRDs during the years 2006 to 2013. For more detail, consult the above reference.



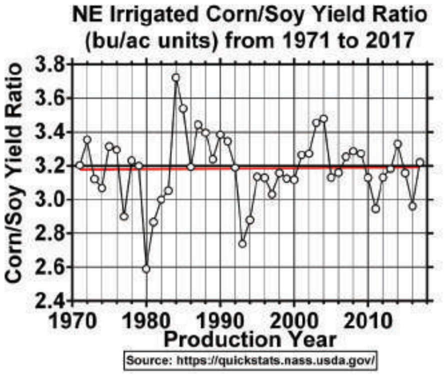
Using the same survey data, only a negligible **1** bu./acre corn yield benefit was detected when corn was grown in the third year of a S-C-**C** sequence *vs.* the third year of a C-C-**C** sequence (left chart). The **6.4** bu./acre corn yield boost in corn yield following soybean disappears if soybean **IS NOT** the prior year crop. Keep in mind that in a S-**C**-S-**C** rotation sequence, the corn yield boost occurred despite a lower N fertilization of corn (soy N credit; guide page 285).



The yield of **soybean** was higher following two prior years of corn (C-C-**S**) compared to one prior year of corn (S-C-**S**). BUT the solid line did not parallel the 1:1 line, thus revealing that the yield advantage diminished in more productive fields. For example, soybean yields were **52 bu./acre** for C-C-**S** *vs.* **45 bu./acre** for S-C-**S** (second chart arrow), but at higher yields, just **67 bu./acre** *vs.* **65 bu./acre**. The reason for this is not clear, though the yield bump was greater in the Lower Niobrara NRD. In Illinois, yield after 11 corn years was **5.7 bu./acre** greater *vs.* C-**S** [*Reference: Fox et al. Crop Science (2013)*]. These data suggest that **IF** a given year corn/soybean price ratio favors increasing your irrigated soybean acreage, you might want to **interrupt a long C-C-C-etc. sequence with a soybean crop to take advantage of the soybean yield boost as well as the favorable price!**

NE IRRIGATED CORN / SOYBEAN YIELD RATIOS:

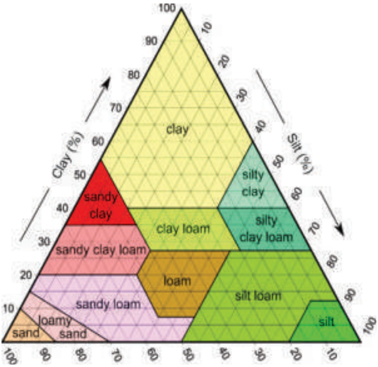
The predominant crop sequence system in Nebraska is a rotation of 2-year corn-soybean, or 3-year corn-corn-soybean - see guide page 23 that shows the percentage acreage splits of these two crops on a per county basis. What is not well known is that the long-term statewide **Irrigated Corn-Soybean Yield Ratio** has averaged nearly **3.2** over a 47-year period from 1971 to 2017 (i.e., red line in below chart). Although there have been growing seasons more favorable for **corn (>3.2)**, or more favorable for **soybean (>3.2)**, a long-term **C/S yield ratio of 3.2** is remarkable.

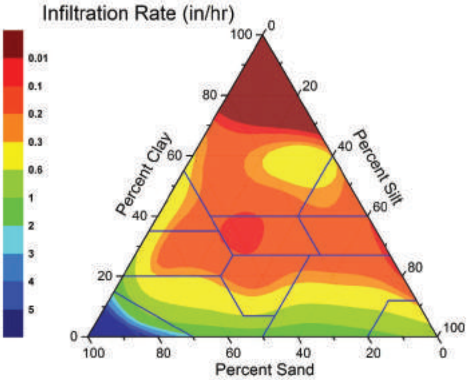


What this long-term average irrigated C/S yield ratio of **3.2** implies is that if you produce 240 bu./acre corn, then you should be able to produce 75 bu./acre soybean (i.e., 240 ÷ **3.2** = 75). Other **3.2** C/S ratio equivalents include: 256/80, 288/90, 320/100, & 352/110. Also note that the current NE irrigated annual improvement rate of 2.169 bu./acre for corn and 0.678 for soybean (see the respective guide pages 138 & 20) have a **C/S yield ratio of 2.169 ÷ 0.678 = 3.2**. Apparently, as NE irrigated producers continue to adopt new genetic & agronomic technologies, they can expect each 3.2 bu./acre increase in corn yield to be <u>matched</u> by a 1.0 bu./acre increase in soybean yield. *Reference:* Specht et al. (2014).

SOIL WATER AND SOIL TEXTURE – SOME CONSIDERATIONS:

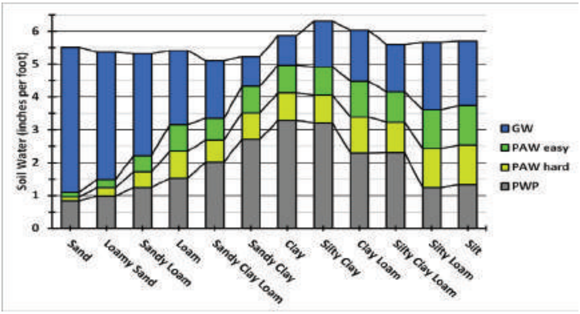
Soil texture plays a major role in the rate of infiltration of water into soil. The well-known soil texture triangle shown here can be converted to a similar triangle (below) that shows the rate of infiltration for water entering the soil. The rates are shown as a gradient across the triangle for the 12 soil textures. The infiltration rate varies from very fast (blue) in a sandy soil to very slow (brown) in a mostly clay soil. Infiltration is a key consideration in irrigation application rates.





SOIL WATER AND SOIL TEXTURE – CONSIDERATIONS (CONT.):

The amount of water a soil can hold is also a function of soil texture. The below stacked graph shows the total amount of water (about 5.1 to 6.3 inches) when it is saturated, but much of that water cannot be held in the soil against gravity and this gravitation water (GW, **blue** bar portion) drains away within hours or a few days.



Reference: Adapted from Suat Irmak (2015) ***EC2009 Figure 2****. See:* http://extensionpublications.unl.edu/assets/pdf/ec2009.pdf.

At 100% field capacity (FC, top of upper **green** bar), a soil is holding as much water as it can against gravity. This is the soil's water-holding capacity amount, and it varies among soil texture types (e.g., one inch in a sand soil *vs.* five inches in a clay soil). At the permanent wilting point (PWP, top of gray bar portion), the water is held so tight by the soil that the plant root hairs cannot extract it. The soil water amount between FC and PWP is called plant available water (PAW, the sum of the two green bar portions), because that water can be extracted from the soil by plant root hairs. However, only about half (100% to 50% FC, upper **green** bar portion) of that total PAW amount is "easy" to extract, and that half is typically called readily available water, RAW); the other half (50% to 0% FC, lower **yellow-green** bar portion) is "harder" to extract. [See the next page for the tabulated values displayed in the above chart.]

Tabulated values for the saturation, GW, FC, PWP, PAW, and RAW (see definitions on next page) for the 12 texture types in the soil triangle. Values here were calculated using the procedures outlined by Saxton et al. (1986) and Saxton and Rawls (2006). *Reference: Adapted from Suat Irmak (2015)* ***EC2009 Table 2***. *See:* http://extensionpublications.unl.edu/assets/pdf/ec2009.pdf.

Soil Texture Type	Saturation Point Water	Gravitational Water	Field Capacity	Permanent Wilting Point	Plant Available Water (PAW)*	Readily Available Water (RAW) – 50% of PAW**
	Acre-Inches of Water per foot of Soil Depth					
Sand	5.50	4.41	1.10	0.83	0.27	0.14
Loamy Sand	5.36	3.87	1.49	0.99	0.50	0.25
Sandy Loam	5.30	3.11	2.20	1.24	0.96	0.48
Loam	5.41	2.26	3.15	1.53	1.62	0.81
Sandy Clay Loam	5.10	1.76	3.34	2.02	1.32	0.66
Sandy Clay	5.22	0.90	4.32	2.70	1.62	0.81
Clay	5.86	0.90	4.96	3.28	1.68	0.84
Silty Clay	6.31	1.39	4.91	3.20	1.71	0.86
Clay Loam	5.59	1.44	4.15	2.30	1.85	0.93
Silty Clay Loam	6.02	1.55	4.48	2.28	2.20	1.10
Silty Loam	5.66	2.06	3.60	1.24	2.36	1.18
Silt	5.69	1.96	3.73	1.33	2.40	1.20

***Plant Available Water is the water available in a soil between 100% Field Capacity and the Permanent Wilting Point (PWP = 0% Field Capacity).**

****About 50% of the total Plant Available Water is generally assumed to be Readily Available Water (i.e., RAW = water between 100% FC and 50% FC).**

Soil Water Terms – Definitions:

- **Saturation** is defined a soil condition in which all pores in the soil are completely water-filled. In most cases, however, some air bubbles are typically present even in very wet soils, so 100% saturation is a rare occurrence.
- **Field Capacity (FC)** is defined as the amount of water held in a soil "against" gravity. Rain or irrigation water entering a soil layer that is already at 100% FC will respond to gravity by moving downward to the next lower soil layer(s) until reaching any lower layer that is not at 100% FC (or water table). This downward moving **Gravitational Water** (GW) in any soil layer is temporary, existing in a soil layer only during the brief transit time it takes for that water to drain to the next layer. Note that plant root hairs can absorb the gravitational water in a given layer during the transit time period.
- The **Permanent Wilting Point (PWP)** is defined as a soil water content that is so low that the crop's root hairs cannot extract sufficient water from the soil to keep the crop plant cells turgid, even if the plant leaf stomates are tightly closed.
- **Plant Available Water (PAW)** is defined as the difference between the FC soil water content and the PWP soil water content. **PAW is essentially the total plant-available water-holding content.** In theory plant root hairs could conceivably extract all of the soil water available between FC and PWP; however, when the soil layer water content declines from an 100% FC to a 0% FC (i.e., PWP), the extraction of water from that soil by root hairs declines from being "very easy" to "very difficult." In reality, root hairs located in a lower (more moist) soil layer will commence water extraction well before root hairs located in a higher (drier) soil layer encounter difficulty in extracting water upon the approach to PWP.
- **Readily Available Water (RAW)** is thus a more useful parameter for scheduling timely irrigation events, and is defined as 50% of the total plant available water (PAW = FC - PWP). Thus, for a given soil texture, **RAW is the difference in the amount of plant available water at 100% FC and the amount at 50% FC (i.e., 100% - 50% FC).** But, because crop water stress symptoms can begin to occur when 50% of the PAW is withdrawn by a crop, it may be necessary to permit only a **40%** or even a **33%** PAW withdrawal to occur before "triggering an irrigation event" (at least during the most water-sensitive crop developmental stages), though a 50% trigger is useful when the crop approaches physiological maturity.

Average, Common, and Range of Statewide Production Operation Costs in Nebraska Soybean and Corn Systems

Operation (cost/acre; unless otherwise stated)	Average	Common	Range	Number of Reports
Vertical or turbo tillage	15.50	15	12-25	21
Strip tilling	18.73	20	12-25	30
Seeding grass seed (cover crop)	18.92	20	12-29	13
Planting row crops (soybean or corn)	19.70	20	13-30	39
Raking cornstalks	8.09	10	2-16	11
Large round bailing of cornstalks (cost per bale)	15.63	15	11-21	23
Dry fertilizer broadcast application	6.43	5	3-10	26
Liquid fertilizer application	8.25	7	5-15	31
Anhydrous ammonia, knife with coulters	15.18	15	9-25	10
Spraying weed control by boom	6.84	7	5-10	55
Combining irrigated corn	38.22	35	18-95	101
Combining rain-fed corn	34.82	30	14-90	123
Combining soybean	35.40	35	20-66	140
Hauling grain <20 miles to elevator (cost per bu./mile)	0.13	0.10	0.05-0.25	61
Closing pivot tracks (cost per hour)	75.50	100.00	25-100	10

*For many more statewide & district operation costs per acre (or per bushel), see Table 1 in Nebraska Extension Circular **EC823** at:* http://extensionpublications.unl.edu/assets/pdf/ec823.pdf.
For NE soybean or corn crop budgets, see **EC872** at: https://cropwatch.unl.edu/Economics-Real-Estate/2019-nebraska-crop-budgets.pdf.

MEASUREMENT UNIT CONVERSION:

CONVERSION FACTORS				
Acres (Ac.)	x	0.4046863	=	Hectares (Ha)
Acres	x	43,560	=	Square feet
Acres	x	4,046.825	=	Square meters
Acres	x	0.0015625	=	Square miles
Acres	x	4,840	=	Square yards
Bushels	x	2,150.42	=	Cubic inches
Bushels	x	1.2472	=	Cubic feet
Bushels	x	0.04606	=	Cubic yards
Bushels	x	0.3524	=	Hectoliters
Bushels	x	35.24	=	Liters
Bushels	x	64	=	Pints
Bushels	x	32	=	Quarts
Bushels (corn)	x	0.0254	=	Metric tons
Bushels (soy)	x	0.0272	=	Metric tons
Corn Bu./Ac. (56 pounds/bu.)	x	62.767665	=	Kilograms/hectare Corn
Soybean Bu./Ac. (60 pounds/bu.)	x	67.251069	=	Kilograms/hectare Soybean
Centimeters	x	0.0328	=	Feet
Centimeters	x	0.3937	=	Inches
Centimeters	x	0.01	=	Meters
Centimeters	x	10	=	Millimeters
Cubic centimeters	x	0.061	=	Cubic inches
Cubic centimeters	x	0.000001	=	Cubic meters
Cubic centimeters	÷	3,785	=	Gallons
Cubic centimeters	x	0.001	=	Liters
Cubic centimeters	x	0.0338	=	Ounces (fluid)
Cubic feet	x	0.80176	=	Bushels
Cubic feet	x	1,724.137	=	Cubic inches
Cubic feet	x	0.0283	=	Cubic meters
Cubic feet	x	0.03704	=	Cubic yards
Cubic feet	x	7.4805	=	Gallons
Cubic feet	x	28.32	=	Liters
Cubic feet	x	59.84	=	Pints (liquid)
Cubic feet	x	62.422	=	Pounds of water
Cubic feet	x	25.71	=	Quarts (dry)
Cubic feet	x	29.92	=	Quarts (liquid)
Cubic inches	÷	2,150.42	=	Bushels

MEASUREMENT UNIT CONVERSION (CONT.):

Cubic inches	x	16.39	=	Cubic centimeters
Cubic inches	÷	1,724.137	=	Cubic feet
Cubic inches	÷	61,023	=	Cubic meters
Cubic inches	÷	46,656	=	Cubic yards
Cubic inches	x	0.0164	=	Liters
Cubic inches	x	0.554	=	Ounces (fluid)
Cubic inches	x	0.02976	=	Pints (dry)
Cubic inches	x	0.0346	=	Pints (liquid)
Cubic inches	x	0.03613	=	Pounds of water
Cubic inches	x	0.0149	=	Quarts (dry)
Cubic inches	x	0.0173	=	Quarts (liquid)
Cubic inches (dry)	x	0.00372	=	Gallons
Cubic inches	x	0.00433	=	Gallons of water
Cubic meters	x	1,000,000	=	Cubic centimeters
Cubic meters	x	35.31	=	Cubic feet
Cubic meters	x	61,023	=	Cubic inches
Cubic meters	x	1.308	=	Cubic yards
Cubic meters	x	264.2	=	Gallons
Cubic meters	x	1,000	=	Liters
Cubic meters	x	1,000,000	=	Megaliters
Cubic meters	x	2,113	=	Pints (liquid)
Cubic meters	x	1,057	=	Quarts (liquid)
Cubic yards	x	21.71	=	Bushels
Cubic yards	x	27	=	Cubic feet
Cubic yards	x	46,656	=	Cubic inches
Cubic yards	x	0.7646	=	Cubic meters
Cubic yards	x	202	=	Gallons
Cubic yards	x	1,616	=	Pints (liquid)
Cubic yards	x	807.9	=	Quarts (liquid)
Cups	x	236.5	=	Milliliters
Cups	x	8	=	Ounces (fluid)
Cups	x	0.5	=	Pints
Cups	x	0.25	=	Quarts
Cups	x	16	=	Tablespoons
Cups	x	48	=	Teaspoons
° Celsius	x 1.8 + 32		=	° Fahrenheit
° Fahrenheit	-32 ÷ 1.8		=	° Celsius
Feet	x	30.48	=	Centimeters
Feet	x	12	=	Inches
Feet	÷	3,281	=	Kilometers
Feet	÷	6,086	=	Knots

MEASUREMENT UNIT CONVERSION (CONT.):

Feet	x	0.3048	=	Meters
Feet	÷	5.280	=	Miles
Feet	÷	16.5	=	Rods
Feet	x	0.33333	=	Yards
Feet/minute	x	0.01667	=	Feet/second
Feet/minute	x	0.01136	=	Miles/hour
Feet/second	x	60	=	Feet/minute
Feet/second	÷	1.467	=	Miles/hour
Feet/second	÷	88	=	Miles/minute
Gallons	x	3.785	=	Cubic centimeters
Gallons	x	0.1337	=	Cubic feet
Gallons (dry)	x	269	=	Cubic inches (dry)
Gallons of water	x	231	=	Cubic inches (liquid)
Gallons	x	0.003785	=	Cubic meters
Gallons	÷	202	=	Cubic yards
Gallons	x	3.785	=	Liters
Gallons	x	3,785	=	Milliliters
Gallons	x	128	=	Ounces (fluid)
Gallons	x	8	=	Pints (liquid)
Gallons	x	4	=	Quarts (liquid)
Gallons (Water)	x	8.3453	=	Pounds (Water)
Gallons/Acre (Water)	÷	27,154.28	=	Inches/Acre (Water)
Grams	x	15.43	=	Grains
Grams	x	0.001	=	Kilograms
Grams	x	1,000	=	Milligrams
Grams	x	0.0353	=	Ounces
Grams	x	0.0022	=	Pounds
Grams/liter	x	1,000	=	Parts/million
Hectares	x	2.471044	=	Acres
Hectares	x	10,000	=	Square meters
Hundredweight (cwt.)	x	100	=	Pounds
Inches	x	2.54	=	Centimeters
Inches	x	0.08333	=	Feet
Inches	x	0.0254	=	Meters
Inches	x	0.02778	=	Yards
Inches/Acre (Water)	x	3.94	=	Megaliters/Ha (Water)
Kilograms	x	1,000	=	Grams
Kilograms	x	2.205	=	Pounds

MEASUREMENT UNIT CONVERSION (CONT.):

Kilograms	x	0.01594	=	Tons
Kilograms/hectare	x	0.0159318	=	Corn Bu./Ac. (56 lb.)
Kilograms/hectare	x	0.0148697	=	Soy Bu./Ac. (60 lb.)
Kilograms/hectare	x	0.8929	=	Pounds/acre
Kilometers	x	3,281	=	Feet
Kilometers	x	1,000	=	Meters
Kilometers	x	0.6214	=	Miles
Kilometers	x	1,094	=	Yards
Liters	x	0.02838	=	Bushels
Liters	x	1,000	=	Cubic centimeters
Liters	x	0.0353	=	Cubic feet
Liters	x	61.02	=	Cubic inches
Liters	x	0.001	=	Cubic meters
Liters	x	0.2642	=	Gallons
Liters	x	1,000	=	Milliliters
Liters	x	2.113	=	Pints (liquid)
Liters	x	0.908	=	Quarts (dry)
Liters	x	1.057	=	Quarts (liquid)
Meters	x	100	=	Centimeters
Meters	x	3.281	=	Feet
Meters	x	39.37	=	Inches
Meters	x	0.001	=	Kilometers
Meters	x	1,000	=	Millimeters
Meters	x	1.094	=	Yards
Miles	x	5,280	=	Feet
Miles	x	1.6093	=	Kilometers
Miles	x	320	=	Rods
Miles	x	1,760	=	Yards
Miles/hour	x	88	=	Feet/minute
Miles/hour	x	1.467	=	Feet/second
Miles/hour	÷	60	=	Miles/minute
Miles/minute	x	88	=	Feet/second
Miles/minute	x	60	=	Miles/hour
Milligrams	x	0.001	=	Grams
Milligrams/kilogram	x	1	=	Parts/million
Milligrams/liter	x	1	=	Parts/million
Milliliters	x	0.1	=	Centimeters
Milliliters	x	0.0004228	=	Cups
Milliliters	÷	3,785	=	Gallons
Milliliters	x	0.001	=	Liters
Milliliters	x	0.034	=	Ounces (fluid)

MEASUREMENT UNIT CONVERSION (CONT.):

Milliliters	÷	473	=	Pints (liquid)
Milliliters	÷	946	=	Quarts
Milliliters	÷	15	=	Tablespoons
Milliliters	x	0.2	=	Teaspoons
Millimeters	x	0.1	=	Centimeters
Millimeters	x	0.001	=	Meters
Ounces	÷	32,000	=	Tons
Ounces (dry)	x	437.5	=	Grains
Ounces (dry)	x	28.3495	=	Grams
Ounces (dry)	x	0.0625	=	Pounds
Ounces (fluid)	x	29.573	=	Cubic centimeters
Ounces (fluid)	x	1.805	=	Cubic inches
Ounces (fluid)	x	0.125	=	Cups
Ounces (fluid)	x	0.0078125	=	Gallons
Ounces (fluid)	x	29.57	=	Milliliters
Ounces (fluid)	x	0.0625	=	Pints (liquid)
Ounces (fluid)	x	0.03125	=	Quarts (liquid)
Ounces (fluid)	x	2	=	Tablespoons
Ounces (fluid)	x	6	=	Teaspoons
Parts/million	x	0.0584	=	Grains/gallon
Parts/million	x	0.001	=	Grams/liter
Parts/million	x	1	=	Milligrams/kilogram
Parts/million	x	1	=	Milligrams/liter
Parts/million (nutrient)	x	2	=	Pounds/Acre (nutrient)
Percent	x	10,000	=	Parts/million
Pints	x	2	=	Cups
Pints (dry)	x	0.015625	=	Bushels
Pints (dry)	x	33.6003	=	Cubic inches
Pints (dry)	x	0.0625	=	Pecks
Pints (dry)	x	0.5	=	Quarts (dry)
Pints (liquid)	x	0.0167	=	Cubic feet
Pints (liquid)	x	28.875	=	Cubic inches
Pints (liquid)	÷	2,113	=	Cubic meters
Pints (liquid)	÷	1,616	=	Cubic yards
Pints (liquid)	x	2	=	Cups
Pints (liquid)	x	473	=	Milliliters
Pints (liquid)	x	32	=	Tablespoons
Pints (liquid)	x	0.125	=	Gallons
Pints (liquid)	x	0.4732	=	Liters
Pints (liquid)	x	16	=	Ounces (fluid)
Pints (liquid)	x	0.5	=	Quarts (liquid)

MEASUREMENT UNIT CONVERSION (CONT.):

Pounds	x	7,000	=	Grains
Pounds	x	453.5924	=	Grams
Pounds	x	0.01	=	Hundredweight (cwt.)
Pounds	x	16	=	Ounces
Pounds	x	0.0005	=	Short tons
Pounds	x	0.45359	=	Kilograms
Pounds of water	x	0.01602	=	Cubic feet
Pounds of water	x	27.68	=	Cubic inches
Pounds of water	x	0.1198	=	Gallons
Pounds/A	x	1.12	=	Kilograms/hectare
Pounds/A (nutrient)	x	0.5	=	Parts/million (nutrient)
Quarts	x	4	=	Cups
Quarts (dry)	x	0.03125	=	Bushels
Quarts (dry)	x	0.038895	=	Cubic feet
Quarts (dry)	x	67.20	=	Cubic inches
Quarts (dry)	x	1.101	=	Liters
Quarts (dry)	x	0.125	=	Pecks
Quarts (dry)	x	2	=	Pints (dry)
Quarts (liquid)	x	0.03342	=	Cubic feet
Quarts (liquid)	x	57.75	=	Cubic inches
Quarts (liquid)	÷	1,057	=	Cubic meters
Quarts (liquid)	x	0.001238	=	Cubic yards
Quarts (liquid)	x	0.25	=	Gallons
Quarts (liquid)	x	0.9463	=	Liters
Quarts (liquid)	x	946	=	Milliliters
Quarts (liquid)	x	32	=	Ounces (fluid)
Quarts (liquid)	x	2	=	Pints (liquid)
Short tons	x	907	=	Kilograms
Short tons	x	0.9072	=	Metric tons
Square feet	x	0.000022965	=	Acres
Square feet	x	144	=	Square inches
Square feet	÷	27,878,400	=	Square miles
Square feet	x	0.11111	=	Square yards
Square inches	x	0.00694	=	Square feet
Square inches	÷	1,296	=	Square yards
Square meters	x	0.0001	=	Hectares
Square miles	x	640	=	Acres
Square miles	x	27,878,400	=	Square feet
Square miles	x	3,097,600	=	Square yards
Square yards	x	0.0002066	=	Acres
Square yards	x	9	=	Square feet

MEASUREMENT UNIT CONVERSION (CONT.):

Square yards	x	1,296	=	Square inches
Square yards	÷	3,097,600	=	Square miles
Tablespoons	x	0.0625	=	Cups
Tablespoons	x	15	=	Milliliters
Tablespoons	x	0.5	=	Ounces (fluid)
Tablespoons	x	0.03125	=	Pints (liquid)
Tablespoons	x	3	=	Teaspoons
Tons	x	907.1849	=	Kilograms
Tons	x	32,000	=	Ounces
Tons (long)	x	2,240	=	Pounds
Tons (metric)	x	39.3683	=	Bushels (corn)
Tons (metric)	x	36.7437	=	Bushels (soy)
Tons (metric)	x	2,204.62	=	Pounds
Tons (metric)	x	1.1023	=	Short Tons
Tons (short)	x	2,000	=	Pounds
Yards	x	3	=	Feet
Yards	x	36	=	Inches
Yards	÷	1,094	=	Kilometers
Yards	x	0.9144	=	Meters
Yards	x	0.000568	=	Miles

SOME COMMON UNITS OF IRRIGATION WATER MEASUREMENT:

Volume:

1 acre-inch (ac in.): volume of water required to cover an **acre** 1 inch deep = **27,154.29 gallons** = 3,630 cubic feet

1 acre-foot (ac ft.) = 325,851 gallons = 43,560 cubic feet

1 cubic foot = 7.48 gallons = 62.4 pounds

100 cubic meters = 100,000 liters = **26,417.2 gallons**

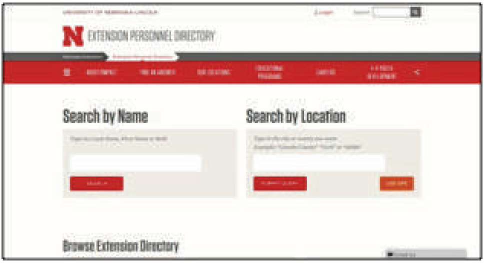
Flow Rate:

1 ac-in./hour = 452.57 gallons/minute = ~ **1 cubic foot/sec**

For a user-friendly conversion of any given measurement unit into another measurement unit, a handy application that you can freely download and install on your office computer is the convert.exe app available at this website: http://joshmadison.com/convert-for-windows/.

UNL-IANR EXTENSION SPECIALIST DIRECTORY:

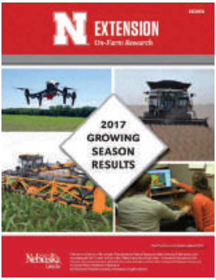
To search for a Nebraska Specialist who can help you diagnose a soybean/corn symptom, go to this **Extension Personnel Directory**: http://epd.unl.edu/.



Note that you also can submit an insect specimen and/or a diseased or injured plant tissue sample to the **Nebraska Diagnostic Clinic** – see guide page 7 for more details.

Are you interested in results obtained in Nebraska producer on-farm field trials? Want to conduct a trial on your farm?

See https://cropwatch.unl.edu/on-farm-research. Here you can view last year's on-farm trial data, results, and conclusions. Producers who want to test the agronomic/economic value of a management practice of their interest on their farm can join the On-Farm Research Network, which will entitle them to assistance and advice from a UNL Extension Specialist, who will design a suitable, scientifically valid field trial for the producer, and who will also statistically analyze the data that the producer collects and provides to the specialist.



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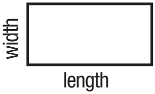
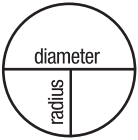
REFERENCE INFORMATION

GUIDE FOR CALCULATING AREA OR VOLUME:

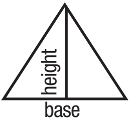


Area of rectangle or square = length x width

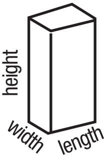


Area of a circle = 3.1416 x radius squared; or 0.7854 x diameter squared

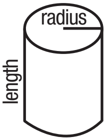
Circumference of a circle = 3.1416 x diameter; or 6.2832 x radius



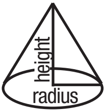
Area of a triangle = base x height ÷ 2



Volume of rectangular box or cube = length x width x height



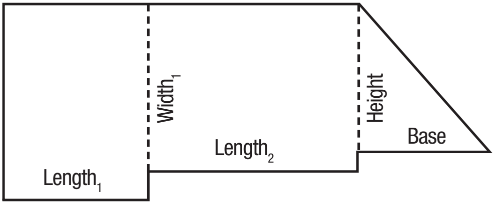
Volume of a cylinder = 3.1416 x radius squared x length



Volume of cone = 1.0472 x radius squared x height

GUIDE FOR CALCULATING AREA OR VOLUME (CONT.):

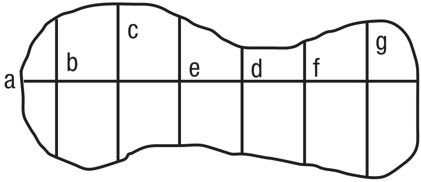
Reduce irregularly shaped areas to a combination of rectangles, circles, and triangles. Calculate the area of each and add them together to get the total area.



Example: If B = 25’, L1 = 30’, W1 = 42’, L2 = 33’, W2 = 31’, then the equation is:

Area = (B x H ÷ 2) + (L1 x W1) + (L2 x W2)
= (25 x 25 ÷ 2) + (30 x 42) + (31 x 33)
= 259.5 sq. ft.

Another way is to draw a line down the middle of the property for length. Measure from side to side at several points along this line. Use the average of these values as the width. Calculate the area as a rectangle.



Example: If a = 45’, b = 19’, c = 22’, d = 15’, e = 17’, f = 21’, g = 22’, then the equation is:

Area = (a) x (b + c + d + e + f + g) + 6
= (45) x (19 + 22 + 15 + 17 + 21 + 22) + 6
= 870 sq. ft.

NOTES:

1 cm 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Technical editing for this guide was led by Dr. James E. Specht and Dr. Thomas Hoegemeyer, University of Nebraska-Lincoln. The Nebraska Soybean Board, United Soybean Board and the Nebraska Corn Board neither recommend nor discourage the implementation of any advice contained herein and are not liable for the use or misuse of the information provided.