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Critters and Struggling Seeds/Seedlings – *(Christian Krupke and John Obermeyer) -*

- Many different "bugs" can be found with dead/dying seedlings.
- Most are attracted by, and feed on, decaying plant material.

Any seed in the ground has been punished with seemingly constant rains and cold soils. Corn that has emerged is yellow, sad-looking and waiting for the sunshine. There has already been much banter about replanting, or digging out the old rotary hoe from the back of the barn. Field inspections, and digging row skips, may reveal challenged seeds/seedlings. Many times, a range of soil organisms are found in association with these struggling plants and they are often implicated for poor stands. In reality, they are likely decomposers just doing their job…"clean up in aisle 3."

Millipedes are wireworm-like arthropods (like insects, they belong to the Phylum Arthropoda-means "jointed foot"), having two pairs of legs per body segment. Centipedes, which they are often confused with, are typically predators and have only one pair of legs per body segment. Millipedes have become more prevalent as no-till production becomes more widespread. They are often found in large numbers, but are rarely a pest. This is because they typically feed as scavengers, feeding on dead or decaying materials often associated with seedling blights. Several pest managers have reported numerous millipedes in and around corn kernels/sprouts that have been in the ground for two or more weeks. These kernels were probably fell victim to pathogens of some kind (bacteria/fungi), after sitting underwater and opportunistic millipedes were merely acting as the "clean-up crew" and hollowing out kernels that were in early stages of decay.

Millipede feeding on rotting corn seedling.

Juvenile ("baby") earthworms and potworms are closely-related, common animals found in soils. They are small, generally very pale in color, and often less than 1/4 inch long. These worms feed on damaged and decaying plant remains, not live tissue. Therefore they are closely associated with the decaying plant parts and surrounding soil and sometimes wrongly accused of damaging seedlings – in fact, they usually arrive after the seed is dead. Their mouthparts are incapable of causing damage to live tissue – they don't have "teeth" and instead are specialized to suck up partially-liquefied material. The point of all this is to reiterate that pest managers should keep an open mind when diagnosing field problems. As one submitter confessed, he was so convinced that it was an insect problem and therefore looked for anything moving when he couldn't find grubs or wireworms.

Many other critters, e.g., mites, symphylans, and springtails, have been observed on or around rotting seeds/seedlings. All are small, some fast moving, and certainly are unfamiliar to most. These animals never see the light of day and work beneath the soil. But they are not causing the poor emergence/growth, but taking advantage of weak and dying plants (including dead weeds and crop debris from previous years) in various stages of decay, as well as the hospitable environment supplied by atypically wet soils. In short, they're "good bugs" turning decaying plant material into soil.

Happy scouting!

Scavenger mite (greatly magnified) feeding on decayed plant material.

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Armyworm Pheromone Trap Report

County	Cooperator	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8	Wk 9	Wk 10	Wk 11	Wk 12
Dubois	SIPAC Ag Center	0	0	0	101	193	16	0	3				
Jennings	SEPAC Ag Center	0	1	1	56	57	9	4	32				
Knox	SWPAC Ag Center	0	13	26	42	189	57	2	10				
LaPorte	Pinney Ag Center	0	0	3	352	936	382	154	445				
Lawrence	Feldun Ag Center	4	108	216	246	650	348	112	31				
Randolph	Davis Ag Center	0	29	41	528	1232	300	72	10				
Tippecanoe	Meigs	0	2	15	107	730	243	98	95				
Whitley	NEPAC Ag Center	0	34	90	537	1689	1349	855	665				

Wk 1 = 3/16/17 - 3/22/17; Wk 2 = 3/23/17 - 3/29/17; Wk 3 - 3/30/17 - 4/5/17; Wk 4 - 4/7/18 - 4/12/17; Wk 5 - 4/13/17 - 4/19/17; Wk 6 - 4/ 20/17 - 4/26/17; Wk 7 = 4/27/17 - 5/3/17; Wk 8 = 5/4/17 - 5/10/17

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Black Cutworm Adult Pheromone Trap Report

County	Cooperator	BCW Trapped						
		Wk 1 3/23/17-3/29/17	Wk 2 3/30/17-4/5/17	Wk 3 4/5/17-4/12/17	Wk 4 4/13/17-4/19/17	Wk 5 4/20/17-4/26/17	Wk 6 4/27/17-5/3/17	Wk 7 5/4/17-5/10/17
Adams	Kaminsky/New Era Ag			13	35	61*	48*	30*
Adams	Roe/Mercer Landmark	11	17*	7	42	28*	35*	40*
Allen	Anderson/Syngenta Seed		0					
Allen	Gynn/Southwind Farms	2	1	0	15	21*	52*	50*
Allen	Kneubuhler/G&K Concepts - Trap 1		0	19*	36	60*	41*	
Allen	Kneubuhler/G&K Concepts - Trap 2		9	2		0	10	
Bartholomew	Bush/Pioneer Hybrids	1	13*	13	17	28*	36*	38*
Clay	Bower/Ceres Solutions - Clay City	0	0	7	4	2	4	0
Clay	Bower/Ceres Solutions - Bowling Green	0	0	0		1	1	0
Clay	Bower/Ceres Solutions - Brazil	0	0	0		0	0	0
Clinton	Emanuel/Boone Co. CES	8	9	6	10	5	8	14*
DeKalb	Hoffman/ATA Solutions	0	0	0	1	0	3	3
Dubois	Eck/Purdue CES	14	28*	41*	4	4	40*	16
Elkhart	Kauffman/Crop Tech Inc.	0	0	6	16	28*	36*	20*
Fayette	Schelle/Falmouth Farm Supply Inc.	5	33*	5		3	10	14

Fountain	Mroczkiewicz/Syngenta	7	18*	31*	93*	43*	44*	50*
Fulton	Jenkins/N. Central Coop - Talma	0	5	10	13	6	39*	5
Fulton	Ranstead/NCC Coop - Rochester	0	0	0	3	6	11	1
Gibson	Schmitz/Gibson Co. CES				0	0		
Hamilton	Campbell/Beck's Hybrids	14	13	18	55*	30*	45*	5
Hamilton	Truster/Reynolds Farm Equipment		1		1	2	4	0
Hendricks	Nicholson/Nicholson Consulting	0	3	4	11	17*	6	98*
Jasper	Overstreet/Jasper Purdue CES	2	5	0	5	10	12	20
Jasper	Ritter/Brodbeck Seeds	1	3	10	32	28*	10	7
Jay	Boyer/Davis PAC		3	14	19	19	43*	28*
Jay	Shrack/Ran-Del Agri Services	1	3	5	9	8	9	16
Jay	Temple/Jay County CES							
Jennings	Bauerle/SEPAC	0	0	0	0	0	0	5
Knox	Bower/Ceres Solutions - Freelandville	0	0	0	13*	4	3	0
Knox	Bower/Ceres Solutions - Vincennes	0	0	0		2	2	4
Kosciusko	Klotz/Etna Green	0	0	4	9	5	41*	21*
Lake	Kleine/Kleine Farms	4	16*	60*	83*	90*	62*	69*
Lake	Moyer/Dekalb Hybrids - Shelby	5	5	20*	27	6	5	7
Lake	Moyer/Dekalb Hybrids - Schneider	2	5	5	12	20	12	14
LaPorte	Rocke/Agri-Mgmt Solutions			4	41	9	38*	
Madison	Truster/Reynolds Farm Equipment		0		0	0	0	0
Marshall	Harrell/Harrell Ag Services		0	0	0	0	0	0
Marshall	Klotz/SR 10 & SR 331	0	0	0	8	9	20*	7
Marshall	Miller/North Central Coop	0	0	0	2	1	9	5
Miami	Early/Pioneer Hybrids	0	0	0	3	2	3	0
Newton	Moyer/Dekalb Hybrids - Lake Village	2	6	2	8	8	21	10
Porter	Leuck/PPAC	5	3	18	25	8	22	6
Pulaski	Capouch/M&R Ag Services	0	0	1	10	10	8	2
Pulaski	Leman/North Central Coop		0	10	21	30*	23	1
Putnam	Nicholson/Nicholson Consulting		2	6	2	8	2	4
Randolph	Boyer/DPAC		1	0	1	2	4	1
Rush	Schelle/Falmouth Farm Supply Inc.		6	10	1	3	17*	0
Shelby	Fisher/Shelby County Co-op	2	3	5	5	0	10	
Shelby	Simpson/Simpson Farms	7	49*	41*	67*	37	41*	27*
Starke	Capouch/M&R Ag Services	0	0	6	28	21*	22*	10
	Wickert/Wickert Consulting - California							

Starke	Twnshp	1	1	3	4	11	37*	18*
Starke	Wickert/Wickert Consulting - Railroad Twnshp	0	0	0	0	9	17*	11
St. Joseph	Barry/Helena			1	3	15*	20*	7
Sullivan	Bower/Ceres Solutions - Farmersburg	0	1	2	14	18*	6	1
Sullivan	Bower/Ceres Solutions - Sullivan	6	21*	14*	16*	6	7	4
Tippecanoe	Bower/Ceres Solutions	0	0	0	7	3	12*	9
Tippecanoe	Westerfield/Monsanto Research Farm	0	0	13	11	16	8	18*
Tippecanoe	Nagel/Ceres Solutions	30	47*	44*	89	14	8	16
Tippecanoe	Obermeyer/Purdue Entomology	2	5	11	5	20*	9	11*
Tipton	Campbell/Beck's Hybrids	10	17	11	73*	33*	119*	8
Vermillion	Bower/Ceres Solutions		0	0		0	0	0
Wabash	Enyeart/North Central Coop				0			25
Whitley	Walker, Richards/NEPAC1 - Main	10	28*	37*	81*	87*	149*	90*
Whitley	Walker, Richards/NEPAC2 - Kyler	3	8	17*	36*	33*	79*	45*

* = Intensive Capture...this occurs when 9 or more moths are caught over a 2-night period

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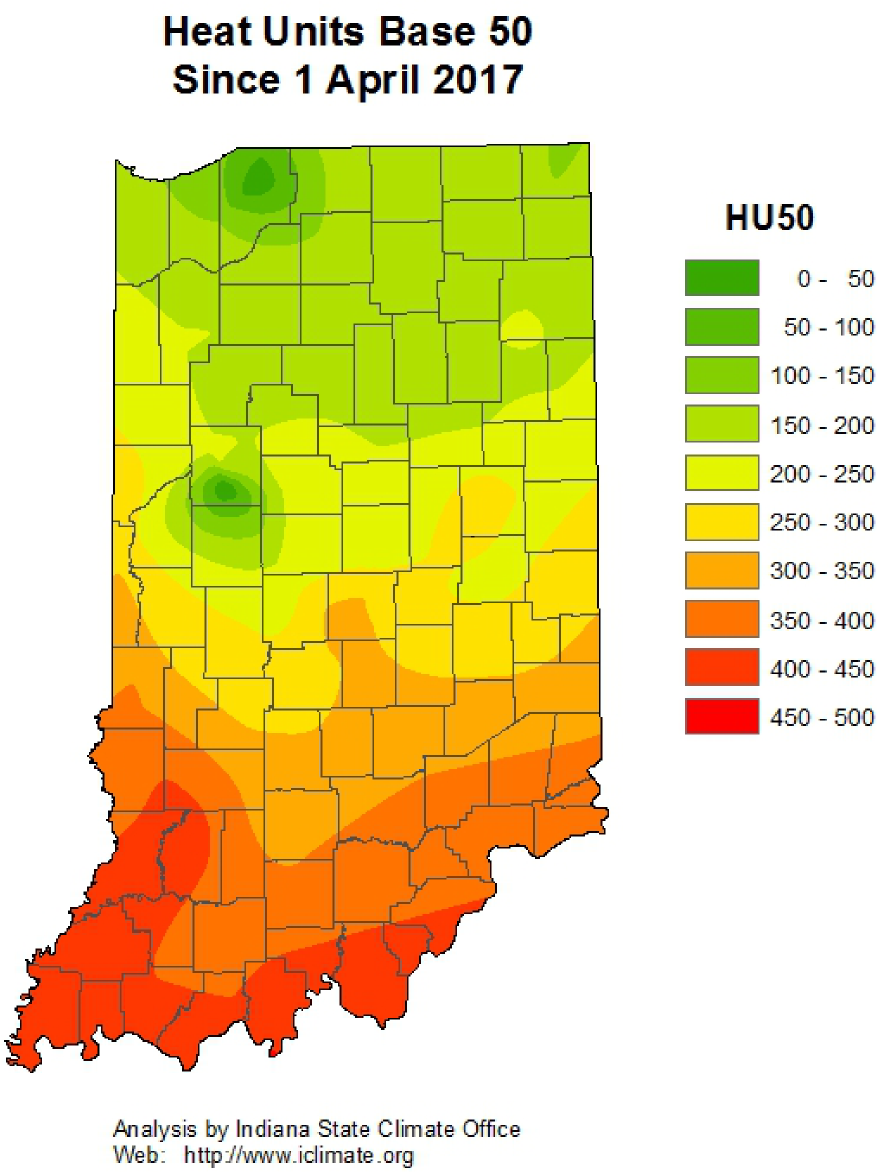
Black Cutworm Development Map


Heat Units Base 50
Since 1 April 2017
HU50
0 - 50
50 - 100
100 - 150
150 - 200
200 - 250
250 - 300
300 - 350
350 - 400
400 - 450
450 - 500
Analysis by Indiana State Climate Office
Web: http://www.iclimate.org

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When Will Soybeans Emerge? – *(Shaun Casteel and Ben Hall, Purdue Diagnostic Training Center Ph.D. Student) -*

Indiana has planted 19% of the soybeans as of May 8th, which is similar to the 5-year average of 17%. The majority of these soybeans were planted the week of April 24th and have not emerged. It is not uncommon for April and early May planted soybeans to sit in cool and wet soil for two and even three weeks. Many areas of Indiana and the Midwest have received excessive rain coupled with cooler temperatures. The question on many people's mind is how long does it take soybeans to emerge and more importantly, will they emerge in conditions like these.

Obviously, fields that are flooded and are excessively saturated with cold temperatures are the most likely to be replanted. The fields that are characterized as "cool and wet" over the past 2 to 3 weeks may still have hope. Over the past three years, we have been evaluating planting dates and planting operations for several management scenarios as well as documenting soybean phenology (development). The following information is really to help provide some guidelines to forecast soybean emergence. Heat unit accumulation is used in estimating the development of many crops (emergence to successive leaf development). However, field conditions can alter the precision/reliability of heat units needed for soybean emergence such as planting depth, residue cover (e.g., no till vs. conventional till), rainfall (and really, soil moisture), soil temperature, and soil crusting.

In our speed and seed rate trials, we were intensely monitoring emergence and seed spacing. Again, these can be used as guidelines. The wet spring of 2015 delayed the planting of that trial until May 24th near West Lafayette in no-till conditions. In 2016, we added the 12.5 mph and included 50 and 170 thousand seeds/acre to the seed rates. We were able to plant it April 19th south of Lafayette in conventionally tilled field. In Table 1, you will find the number of heat units (modified GDD formula with 50°F base) to reach 25%, 50%, 75%, and 90% emergence across the planting speeds and seed rates. For practical purposes, planting speed and seed rate had little variation in the time to emergence in these two trials. Although these were planted in 30-in rows, the seed spacing of 50 and 90 thousand seeds/ac would analogous to those of 15-in rows seeded at 100 and 180 thousand seed/ac (4.2 and 2.3 inches between seeds, respectively).

Table 1. Heat unit accumulation recorded for 25%, 50%, 75%, and 90% emergence of soybeans in 2015 and 2016. These values were averaged across seeding rates (50, 90, 130, 170 thousand seeds/acre) and planting speeds (5, 7.5, 10, 12.5 mph).

		Number of GDDs to Emergence:			
Planting Date	**Tillage**	**25%**	**50%**	**75%**	**90%**
May 24, 2015	No-Till	125	141	161	192
April 19, 2016	Conventional	131	141	168	200
Average		128	141	168	200

Based on the previous study, we would anticipate soybean emergence (greater than 50% or VE) with the accumulation of 140 to 160 GDDs. In our 2017 planting date trial (Figure 1), we planted soybeans on April 25th in a conventionally tilled field. Heat unit accumulation from April 25 to May 11 is only 132 GDDs with a few hypocotyls cracking the soil line. However, soil temperatures were near 50°F for five days and the rainfall has been high over the past 2.5 weeks. Saturated conditions will limit oxygen for plant respiration (i.e., burning energy for growth), and thus, extending the time (calendar days and thermal time) for emergence. Emergence is expected over the coming days with the accumulation of another 20 to 30 GDDs.

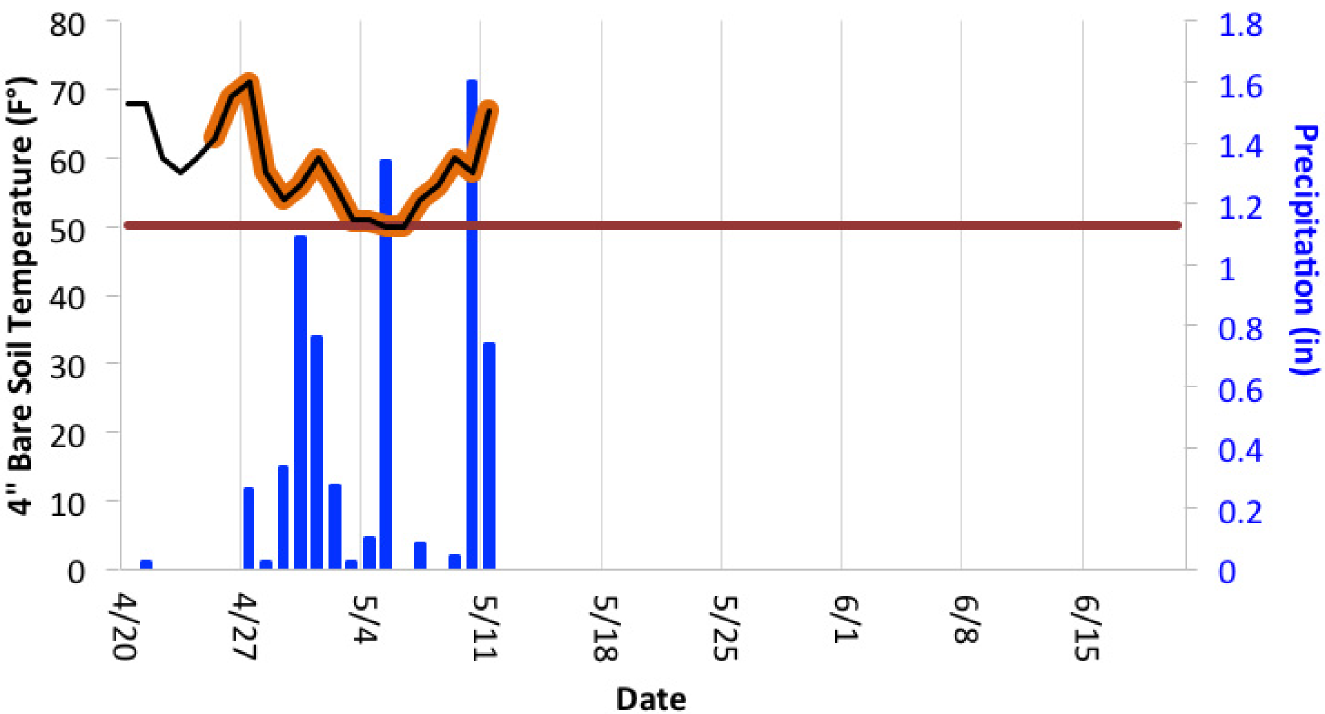

Figure 1. 2017 field conditions (average soil temperature at 4" depth of bare soil and precipitation) from April 20th near West Lafayette. The orange line represents the period that soybeans have been in the ground and the associated soil temperatures at the 4" depth of bare soil.

If your planted soybean fields are in the "cool and wet" situation and not emerged after 160 GDDs, you should determine the viability/progress of the seedlings in preparation for replanting decisions.

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Heat Unit Concepts Related to Corn Development – *(Bob Nielsen)* -

Growth and development of corn are strongly dependent on temperature. Corn develops faster when temperatures are warmer and more slowly when temperatures are cooler. For example, a string of warmer than normal days in late spring will encourage faster leaf development than normal. Another example is that a cooler than normal grain filling period will delay the calendar date of grain maturity.

The phrases "string of warmer than normal days" and "cooler than normal grain filling period" can be converted mathematically into measures of thermal time by calculating the daily accumulations of heat using temperature data. Commonly used terms for thermal time are Growing Degree Days (GDDs), Growing Degree Units (GDUs), or heat units (HUs).

Different methods exist for calculating heat units depending on a) the crop or biological organism of interest and b) the whim or personal preference of the researcher. The calculation method most commonly used throughout the U.S. for determining heat unit accumulation relative to corn phenology was first evaluated by Gilmore & Rogers (1958) and termed "Effective Degrees". Barger (1969) later proposed that the same method, which he termed "Modified Growing Degree Days", be adopted as the standard heat unit formula by the National Oceanic and Atmospheric Administration.

This method calculates daily accumulation of GDDs as the average daily temperature (^{o}F) minus 50. The "modification" refers to the limits imposed on the daily maximum and minimum temperatures allowed in the calculation. Daily maximums greater than 86 ^{o}F are set equal to 86 in the calculation of the daily average temperature. Similarly, daily minimums less than 50 ^{o}F are set equal to 50 in the calculation.

Example 1:

If the daily maximum temperature was 80^{o}F and the minimum was 55^{o}F, the GDD accumulation for the day would be ((80 + 55) / 2) - 50 or 17.5 GDDs.

Example 2 (Illustrating the limit on daily maximums):

If the daily maximum temperature was 90^{o}F and the minimum was 72^{o}F, the GDD accumulation for the day would be ((86 + 72) / 2) - 50 or 29 GDDs.

Example 3 (Illustrating the limit on daily minimums):

If the daily maximum temperature was 68^{o}F and the minimum was 41^{o}F, the GDD accumulation for the day would be ((68 + 50) / 2) - 50 or 9 GDDs.

In late April to early May, normal daily GDD accumulations for central Indiana are about 10 GDDs. By late July, the normal daily accumulation rises to about 23 GDDs. For a typical corn growing season in central Indiana, say from late April to late September, the total seasonal accumulation of GDDs is about 2800 GDDs.

The USDA-funded **Useful to Usable (U2U)** multi-state research and Extension project developed a GDD decision support tool that is now hosted by the Midwestern Regional Climate Center at http://mrcc.isws.illinois.edu/U2U/gdd/. The **GDD Tool** estimates county-level GDD accumulations and corn development dates based on current and historical GDD data plus user selected start dates, relative hybrid maturity ratings, and freeze temperature threshold values. The GDD and corn development predictions are displayed graphically and in tabular form, plus the GDD accumulation estimates can be downloaded in a Comma Separated Value (.csv) format for you to work with in your own spreadsheet program. The GDD Tool is currently available for the states of North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, Ohio, Kentucky, and Tennessee.

Figure 1 shows a screen capture from that calculator in which I selected "Tippecanoe Co., IN", a start date (aka planting date) of Apr 20, a relative hybrid maturity rating of 111 "days", and a freeze temperature threshold of 28^{O}F. The tool automatically adds estimated GDD values from planting to silking and black layer based on the "corn maturity days" you enter, but each is customizable if you know the GDD values specific to your hybrid. The tool displays estimates of actual cumulative GDD from planting to today's date, then estimates of cumulative GDD for the remainder of the season. Estimates of silking and black layer dates are displayed, as well as the early and late ranges of those estimates. When you are viewing the actual graph on the Web site, estimates of GDD accumulations at specific dates "pop up" when you hover your computer mouse over parts of the line graph.

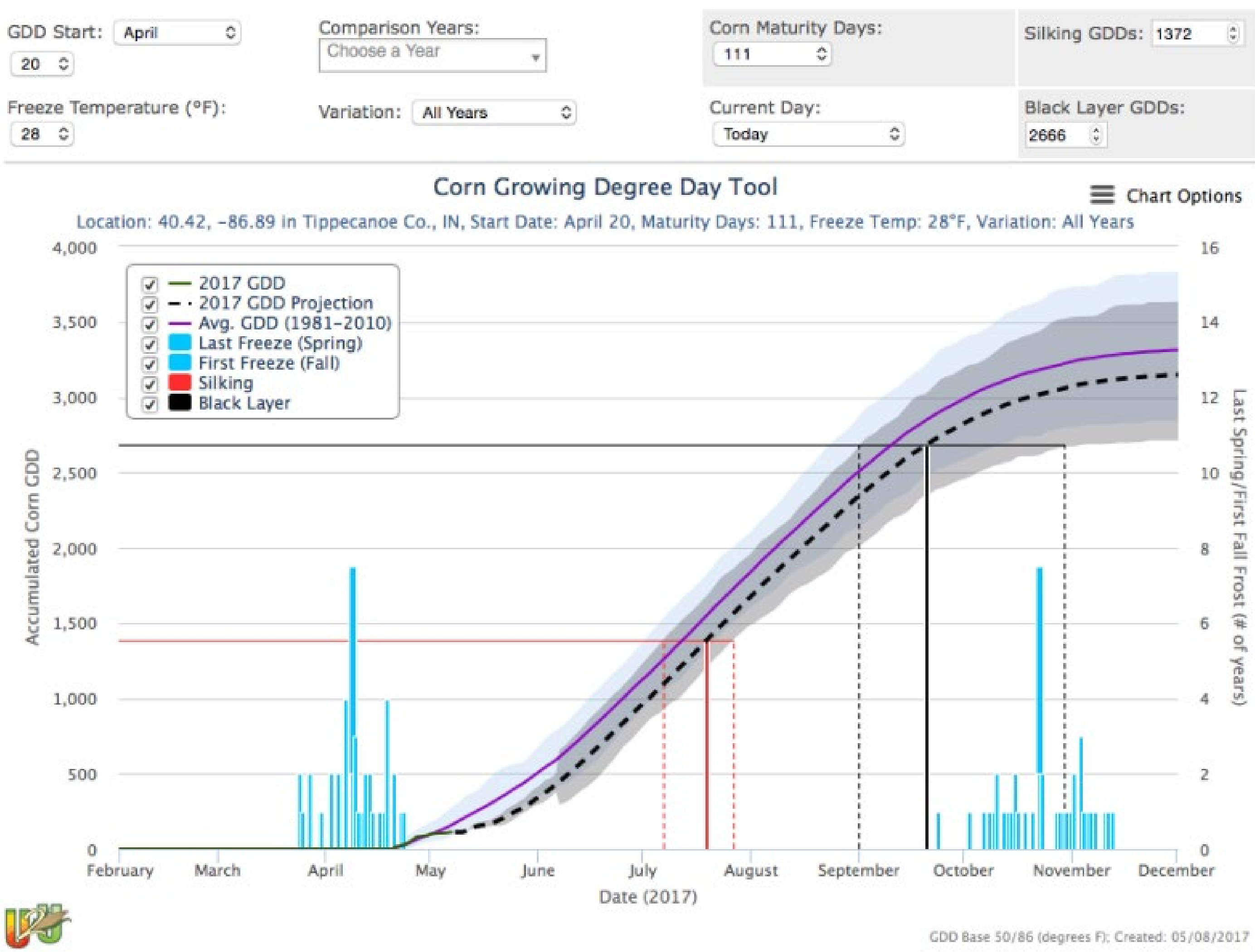

Fig. 1. Screen capture of U2U GDD Tool graphical display of historical and estimated future GDD accumulations and predicted corn development stages for a 111-day hybrid

planted Apr 20 in Tippecanoe County, IN.

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Corn Replant Considerations 2017 – *(Bob Nielsen)* -

The recent spate of rainy weather and chilly temperatures does not bode well for some corn fields planted prior to the onset of the nasty weather. Problems with germination, emergence, or survival of emerged seedlings are likely to occur in fields that received truly excessive rainfall and / or are poorly drained and susceptible to ponding or soil saturation for days on end (**Thomison, 2017**). Some fields are damaged or destroyed by outright flooding of creeks and rivers. Some of the damage will be caused by the smothering effects of surface residues drifted about by ponding or flooding of fields. Significant surface soil crusting will likely develop in some conventionally-tilled fields and restrict emergence of the corn plants. There may well be some imbibitional chilling injury to seed in fields planted just ahead of the cold, wet spell. Other fields planted a bit earlier may exhibit corkscrewed elongation of mesocotyls and underground leafing out in response to cold temperature shock during emergence (**Nielsen, 2015**). The potential for frost damage to emerged crops was real in parts of Indiana in recent days (**Nielsen, 2017a**). Seedling blight may yet develop in earlier planted fields once fungicidal seed treatments break down 14 to 21 days after planting (**Jackson-Ziems, 2017**).

In short, there is a significant risk for a "boat load" of **crappy-looking fields of corn** within the 45% of the statewide acreage planted through the end of April (**USDA-NASS, 2017**).

Assessing Surviving Populations & Effect on Yield

As soils slowly dry and weather slowly turns warm, some growers will face the difficult decision whether to replant damaged fields. Replant decisions are always based on a combination of known facts, uncertain outcomes, and emotions. The important facts to ascertain include the extent and severity of the stand loss throughout a field, plus an initial assessment of the health of the surviving plants.

As questionable fields dry to the point where they can be easily scouted, stand counts should be made throughout the field to estimate surviving populations of healthy plants. If you are uncertain about the health of surviving plants on your first visit to the field, give it a few days of sunshine and warmth, then evaluate stands again.

Our recent research on corn yield response to plant population allows us to predict with some confidence the yield response of corn to low populations (**Nielsen et al., 2017**). The good news is that modern hybrids are fairly tolerant to populations in general. What this means is that not only will they tolerate high plant populations without dramatic decreases in yield, but will also tolerate low plant populations without dramatic yield decreases. Because the yield response to plant population is fairly flat, the economically optimum plant population (EOPP) at harvest is already lower than you probably thought. Based on $3.50 market price for corn and $240 seed corn, the EOPP for much of Indiana is about 26,250 plants per acre at harvest. Final stands as low as 24,500 to as high as 28,000 plants per acre at harvest translate to marginal dollar returns to seed only $1 per acre lower than the EOPP of 26,250 plants per acre.

The results of our research with plant populations in corn are most accurate within a range of about 23,500 to about 39,500 plants per acre at harvest because that has been the most common range of populations evaluated in our field trials around the state. Extrapolating the results to populations beyond those is a bit risky, but we speculate that final populations as low as 20,000 plants per acre at harvest may result in marginal returns to seed only about $12 per acre lower than that at the EOPP. That at least gives you an estimate to work with if you are considering replanting and your estimates of surviving populations are no lower than 20,000 plants per acre.

Yield Potential of Replanted Field

One of the many uncertainties involved with making an economic replant decision revolves around the difficulty in predicting yields of an untouched, but damaged, original field of corn versus that of a field replanted at some date in the future. While it is tempting to follow a rule of thumb for late plantings along the lines of "2 bushel decrease per day of delayed planting beyond May 10", that may not turn out to be an accurate estimate. The reason is that planting date itself is not an accurate predictor of absolute number of bushels per acre. Planting date is only one of about a gazillion factors that influence yield (**Nielsen, 2017c**). The simplest way to approach estimating yield differences of replanted versus original stands may simply be to base it on differences in population, as previously discussed.

Seeding Rates for Replanting or Late Planting in General

The target EOPP for fields replanted in mid- to late May is essentially unchanged from that targeted with late April plantings. The difference is that the success rate for germination / emergence with later planting is typically greater than early plantings because of typically warmer soils in late plantings. Instead of using seeding rates 5 to 10% higher than the targeted EOPP, late planting of corn can probably be done using seeding rates much closer to the targeted final population.

Hybrid Maturities for Replanting or Late Planting in General

Replanting a damaged field of corn in mid- to late May might require the use of a shorter-season corn hybrid than the one originally planted in the field. Consult my article about hybrid maturities for delayed planting (**Nielsen, 2017b**) and start checking with your seed dealer about availability of earlier maturity hybrids that also have good disease resistance characteristics. The latter is important because late-planted corn, relative to earlier-planted corn, is vulnerable to infection at relatively younger growth stages by foliar diseases (e.g., gray leaf spot, northern corn leaf blight) that typically begin to develop in late June - early July.

"Patch In" vs. "Destroy & Replant"

One of the difficult decisions to make when considering replanting is whether to kill the original stand of corn or replant right through it. My limited experience evaluating "patching in" versus "destroy and replant" suggests that "patching in" without killing the original stand should not be done unless surviving stands are roughly 25% or less of the original population. The risk with "patching in" surviving stands with populations higher than that is the original survivors will provide too much competition for the newly emerging replant population. There is also the tendency to "patch in" at the same original seeding rate, assuming that the planter will destroy quite a bit of the original stand, and then ending up with a final stand that is 1.5 times or more what you intended because a lot of the original stand survived.

Choosing to kill the original stand of corn before replanting turns out to be a headache because of the preponderance of herbicide-tolerant traits in modern hybrids (e.g., tolerance to glyphosate, glufosinate). Fewer herbicide options exist to terminate fields of damaged corn planted to such hybrids. My colleagues in Weed Science recently published an article that addresses the challenges of killing an existing stand of corn prior to replanting (**Ikley et al., 2017**).

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Assessing Frost/Cold Temperature Injury to Young – *(Bob Nielsen)* -

The risk of damaging spring frost events is one of the downsides to planting corn earlier than normal, but is one growers often accept when early spring field conditions are otherwise suitable for planting. However, the threat of low temperatures in late May or early June also raises the specter of frost or low temperature damage to young corn plants, regardless of planting date. Early morning temperatures in the 30s^{o}(F) coupled with clear calm conditions overnight certainly are favorable for frost formation on exposed surfaces, including leaves of young corn plants. In other words, temperatures do not need to drop to 32^{o}F or cooler in order for frost to form.

When significant frost develops on young corn plants, it is tempting to jump to the logical conclusion that significant plant mortality will soon follow. However, frost by itself is not a guaranteed "kiss of death" for young corn plants. What is more important is whether the temperature that accompanied the frost event was lethal or not. Most agronomists agree that "lethally cold" temperatures for young corn are those that dip to 28^{o}F or lower for 1 to 2 hours.

The effect of frost on young corn when it is accompanied by temperatures no lower than about 30^{o}F is primarily damage and death of the exposed above ground leaf tissue. As long as the **growing point of the young plant** (aka the apical meristem) is still protected below the soil surface, the injured plant usually recovers from the effects of the superficial leaf damage.

Within 3 to 5 days of the frost event (more quickly with warm temperatures, more slowly if cool), elongation of the undamaged leaf tissue in the whorl will become evident. As long as the recovery is vigorous, subsequent stand establishment should be not be affected.

Plant appearance following damage by lethal cold temperatures (28^{o}F or lower for a couple hours) may initially be similar to that due to "simple" frost damage. The difference is that there will be no subsequent elongation or "recovery" of leaf tissue from the whorl like you would see in the days following "simple" frost damage to leaves. Inspection of the growing point area (by slicing down middle of stem, through the crown of the young plant) will eventually reveal discolored, soft or mushy tissue as a consequence of the lethal temperatures.

The bottom line for diagnosing the severity of frost or low temperature injury to corn is that you generally need to wait three to five days after the weather event before you can accurately assess the extent of damage or recovery. Injury to the crop can look very serious the day after the event or even two days after the event, but recovery is likely if there is no injury to the growing points of the affected plants.

Frost Crystals on a Corn Leaf at Sunup.

Subsequent evidence of frost injury to corn; 7 hours after frost event.
Image 2 of 4

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Leaf Injury Due to Frost (7 hrs after frost melted).

Leaf Injury Due to Frost (12 hrs after frost event).

Leaf Injury Due to Frost (60 hrs after frost event).

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Hybrid Maturities for Delayed Planting – *(Bob Nielsen)* -

Delayed planting seasons create a lot of frustrations for everyone involved with planting crops. One of the agronomic questions that comes up when planting is seriously delayed is whether farmers should consider switching from their normal full-season maturity hybrids to shorter-maturity hybrids. The question is based, of course, on the perceived risk of the crop not reaching physiological maturity before a killing fall freeze and the yield losses that could result. A related, and economic, concern with delayed planting of normal full-maturity hybrids is the risk of high grain moisture contents at harvest and the resulting costs incurred by artificial drying of the grain or price discounts by buyers.

Corn development (think growth stage progress) is very dependent on temperature (warm = fast, cool = slow). The accumulation of heat on a daily basis can be quantified on the basis of calculated Growing Degree Days or GDDs. Hybrids can be characterized by how many GDDs they require from planting to physiological maturity (kernel black layer). Conceptually, therefore, one should be able to estimate the GDDs remaining from a delayed planting date to the end of the season using long-term climate data and then choose hybrids with GDD ratings that should mature no later than the date you chose to define "the end of the season".

FYI: The GDD concept and calculation are described in a related article (Nielsen, 2017a). Interpretation of corn hybrid maturity ratings is also discussed in a related article (Nielsen, 2012).

One "wrinkle" in this concept is that it appears that **hybrids mature in fewer GDDs than expected when planted "late".** Relative to a May 1 planting date, hybrids planted later mature approximately 6.8 fewer GDDs for every day of delay beyond May 1 (Nielsen et al., 2002). For example, a hybrid rated at 2700 GDDs from planting to physiological maturity and planted on May 31 will reach physiological maturity in less than 2500 GDDs after planting (e.g., 2700 - (30 days x 6.8)). That response of hybrid development relative to delayed planting means that normal full-maturity hybrids can be safely planted later than one would think and, consequently, means that growers can avoid switching to earlier maturity hybrids until planting dates later than one would think.

Estimating GDDs Between Two Dates at a Specific Location

The challenge in taking advantage of this relationship between hybrid GDD ratings and delayed planting lies with the estimation of available GDDs with delayed plantings for specific locations. Historical data for daily GDD accumulations exist for a limited number of weather reporting stations around the state, but accessing such data can be difficult. Currently, the Indiana State Climate Office (iClimate.org) does not offer an easy calculator for estimating the number of historical GDDs between two dates at a specific location.

The USDA-funded **Useful to Usable (U2U)** multi-state research and Extension project developed a GDD decision support tool that is now hosted by the Midwestern Regional

Climate Center at http://mrcc.isws.illinois.edu/U2U/gdd/. The **GDD Tool** estimates county-level GDD accumulations and corn development dates based on current and historical GDD data plus user selected start dates, relative hybrid maturity ratings, and freeze temperature threshold values. The GDD and corn development predictions are displayed graphically and in tabular form, plus the GDD accumulation estimates can be downloaded in a Comma Separated Value (.csv) format for you to work with in your own spreadsheet program. The GDD Tool is currently available for the states of North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, Ohio, Kentucky, and Tennessee.

Figure 1 shows a screen capture from that calculator in which I selected "Tippecanoe Co., IN", a start date (aka planting date) of May 31, a relative hybrid maturity rating of 112 "days", and a freeze temperature threshold of 28F. The graph illustrates estimates of silking and black layer dates for the 112-day hybrid planted on May 31, as well as the range of the estimates. When you are viewing the actual graph on the Web site, estimates of GDD accumulations at specific dates "pop up" when you hover your computer mouse over parts of the line graph.

WORD OF CAUTION: The U2U GDD Tool does not currently account for the "wrinkle" discussed earlier in this article wherein corn hybrids typically mature in fewer GDDs than expected when planted "late" (Nielsen et al., 2002). In other words, the GDD Tool assumes the same GDDs to silking and black layer for a given hybrid maturity whether planted April 20 or May 31. Consequently, you can be led astray by the Tool if you do not modify the "Black Layer GDDs" value in the Tool's input area. For example, the screen capture displayed in Fig. 1 for a 112-day hybrid with a GDD rating of 2691 planted in Tippecanoe Co. on May 31 indicates the hybrid would mature on about October 23 when the estimated GDD accumulation exceeded 2691. If, however, you manually change the expected "Black Layer GDD" value from 2691 to 2481 GDDs (30 days after May 1 x 6.8 fewer GDDs per day delay), the GDD Tool estimates the hybrid would safely mature on about September 30, well ahead of the usual fall freeze date (Fig. 2).

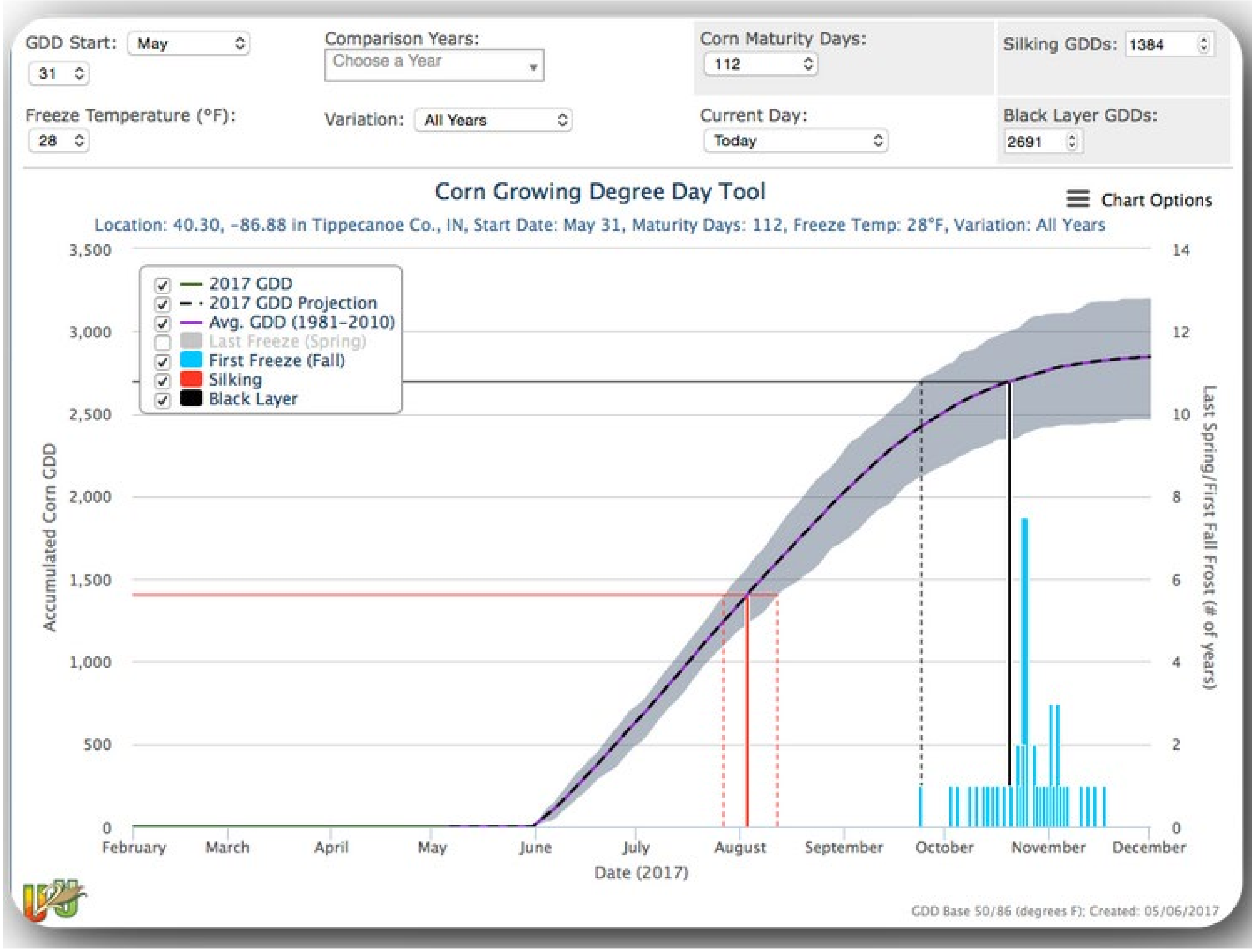

Fig. 1. Screen capture of U2U GD Tool graphical display of historical and estimated future GDD accumulations and predicted corn development stages for a 112-day hybrid planted May 31 in Tippecanoe County, IN.

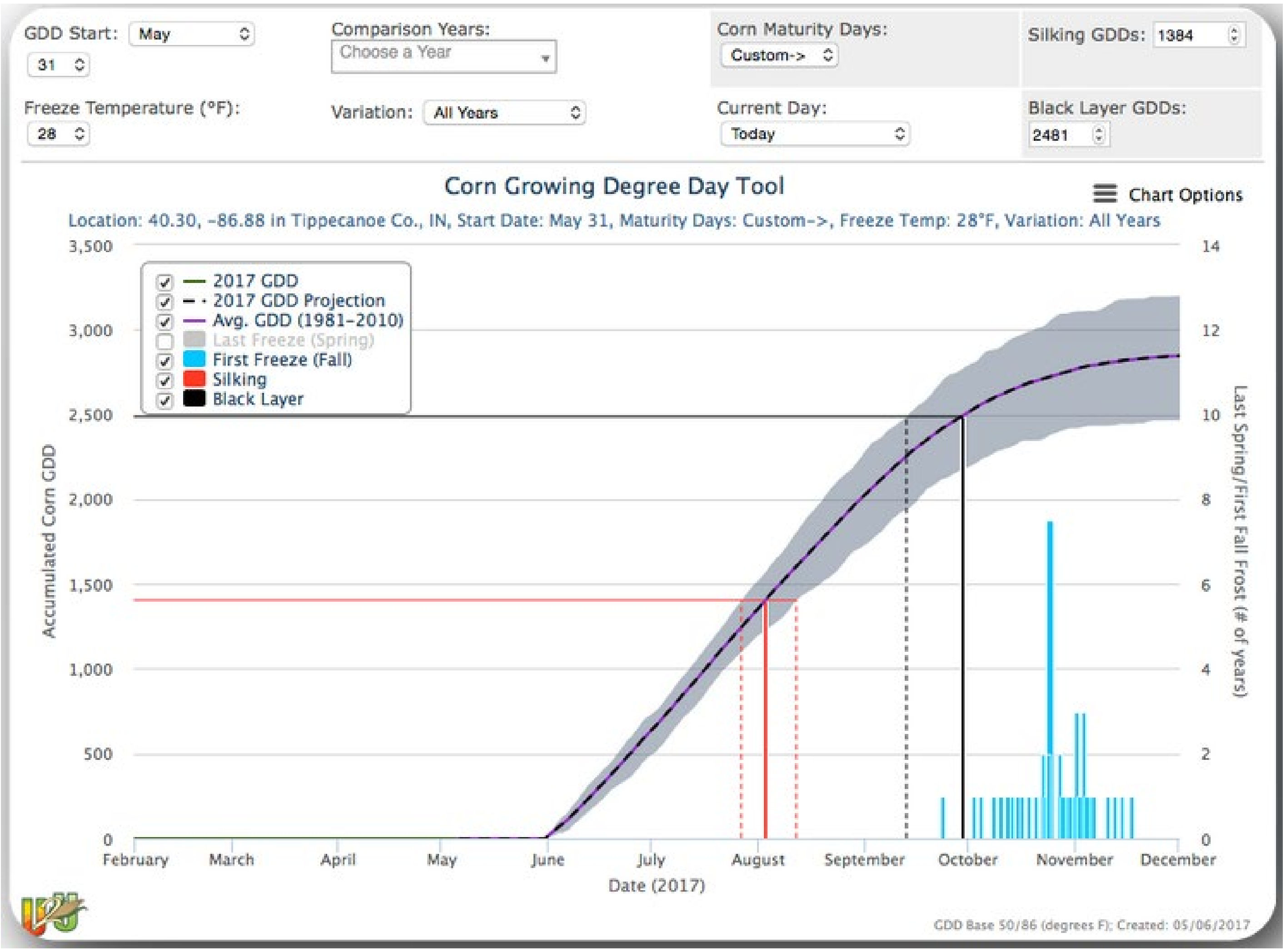

Fig. 2. Screen capture of U2U GDD Tool graphical display of historical and estimated future GDD accumulations and predicted corn development stages for a 112-day hybrid planted May 31 in Tippecanoe County, IN, BUT WITH ITS GDD MATURITY REQUIREMENTS ADJUSTED FOR LATE PLANTING.

Choice of "End of Season" Date

The choice of a date to represent the "end of the season" (abbreviated EOS) can be straight-forward or one of those "eyes of the beholder" decisions. If the main concern is to identify a "safe" hybrid maturity that will reach physiological maturity before a typical fall freeze date, then the spatial maps illustrated in the accompanying figures can be used to choose that date. Figure 3 depicts the historical average dates of the first 32^{o}F temperature in the fall throughout Indiana, while Figure 4 depicts the historical average dates of the first 28^{o}F temperature in the fall throughout Indiana.

TIP: Temperatures of 32^{o}F or slightly higher typically result in leaf injury or death due to frost damage, but the corn plant technically will survive and be able to at least continue remobilizing stored carbohydrates from the stalk tissues to immature grain. A temperature of 28^{o}F for several hours is considered to be lethal for corn plants.

Some growers may opt to select an "end of season" date earlier than the historical first fall freeze date to ensure that physiological maturity will occur earlier during a time period that may yet be conducive for grain drydown in the field and thus minimize their expenses of drying the grain artificially.

Hybrid Maturity Ratings for Delayed Planting

With an estimate of available growing season GDDs in hand, one can then identify approximate relative hybrid maturities that would be suitable for delayed planting (Tables 1 and 2).

Table 1 can be used to identify "safe" hybrid maturities in terms of of their GDD ratings, though it is important to recognize that the hybrid GDD ratings in this table are for accumulated GDDs from planting to physiological maturity. Recognize that some seed companies assign GDD ratings beginning at emergence, not planting. If your seed company is one of these, then add 115 GDDs to the hybrid GDD ratings and you will be in the proverbial "ball park" using this table.

EXAMPLE: Using the U2U GDD Tool, you determine that for Blackford County, Indiana, approximately 2462 GDDs will accumulate between a delayed planting date of May 20 and a selected EOS of Sep 21. Using Table 1, the approximate "safe" hybrid GDD rating that most closely matches the combination of 2462 (the 2450 value in column 1) and a May 20 planting date (column 4) is 2579. What this means is that, for the planting date and EOS date you selected, you could safely plant a hybrid with a GDD rating of 2579 from planting to physiological maturity.

Some folks are more comfortable with the relative "days to maturity" ratings for corn hybrids (Nielsen, 2012). Table 2 expresses the GDD values of Table 1 in terms of CRM ratings as defined by DuPont Pioneer. Recognize that I am not by any stretch of your imagination promoting Pioneer hybrids. I simply know that Pioneer assigns GDD ratings to their hybrids based on GDD accumulations between planting and physiological maturity. The mathematical relationship between their GDD ratings and their CRM ratings is pretty good and, thus, can be used to calculate approximate CRM ratings from known GDD ratings. If you are not comfortable using Pioneer's CRM ratings, then use the GDD ratings in Table 1.

EXAMPLE: Using the U2U GDD Tool, you determine that for Blackford County, Indiana, approximately 2462 GDDs will accumulate between a delayed planting date of May 20 and a selected EOS of Sep 21. Using Table 2 instead, the approximate "safe" hybrid Pioneer CRM rating that most closely matches the combination of 2462 (the 2450 value in column 1) and a May 20 planting date (column 4) is 107. What this means is that, for the planting date and EOS date you selected, you could safely plant a hybrid with a Pioneer CRM rating of about 107.

PLEASE NOTE: Please understand that ratings for relative hybrid maturity (i.e., CRM, RM, "days to maturity", etc.) are notoriously inconsistent one seed company to another. Consequently, relationships between hybrid GDD ratings and their relative maturity ratings will vary one seed company to another. I believe the relationships listed in Table 2 are valid for Pioneer's lineup of hybrids, but cannot make the same claim for any other seed company's lineup of hybrids. Consult your seed dealer!

Caveats (e.g., disclaimers)

Recognize that actual GDDs deviate year to year from the historical "norm" because of natural variability in growing season temperatures. Also recognize that hybrids undoubtedly vary in their GDD response to delayed planting. Also recognize that hybrid GDD response to delayed planting in other parts of the country may differ from what we have documented in the eastern Corn Belt.

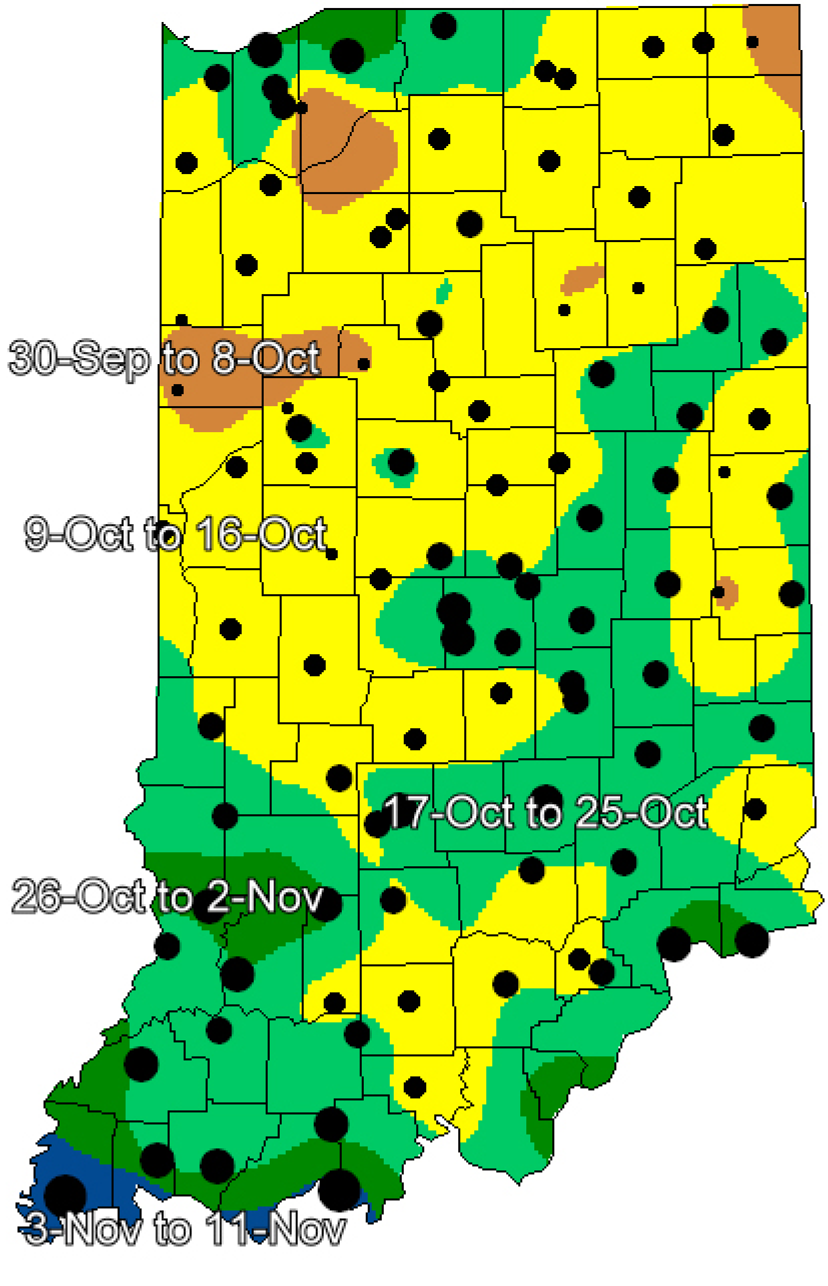

Fig. 3. Average first fall dates of 32°F temperatures throughout Indiana. Interpolated data derived from spatial analysis of 1981-2010 normal data from Indiana and surrounding states. Brown: 30-Sep to 8-Oct, yellow: 9-Oct to 16-Oct; light green: 17-Oct to 25-Oct; dark green: 26-Oct to 2-Nov; blue: 3-Nov to 11-Nov. Spatial data source: National Climatic Data Center 1981-2010 US Normals Data.

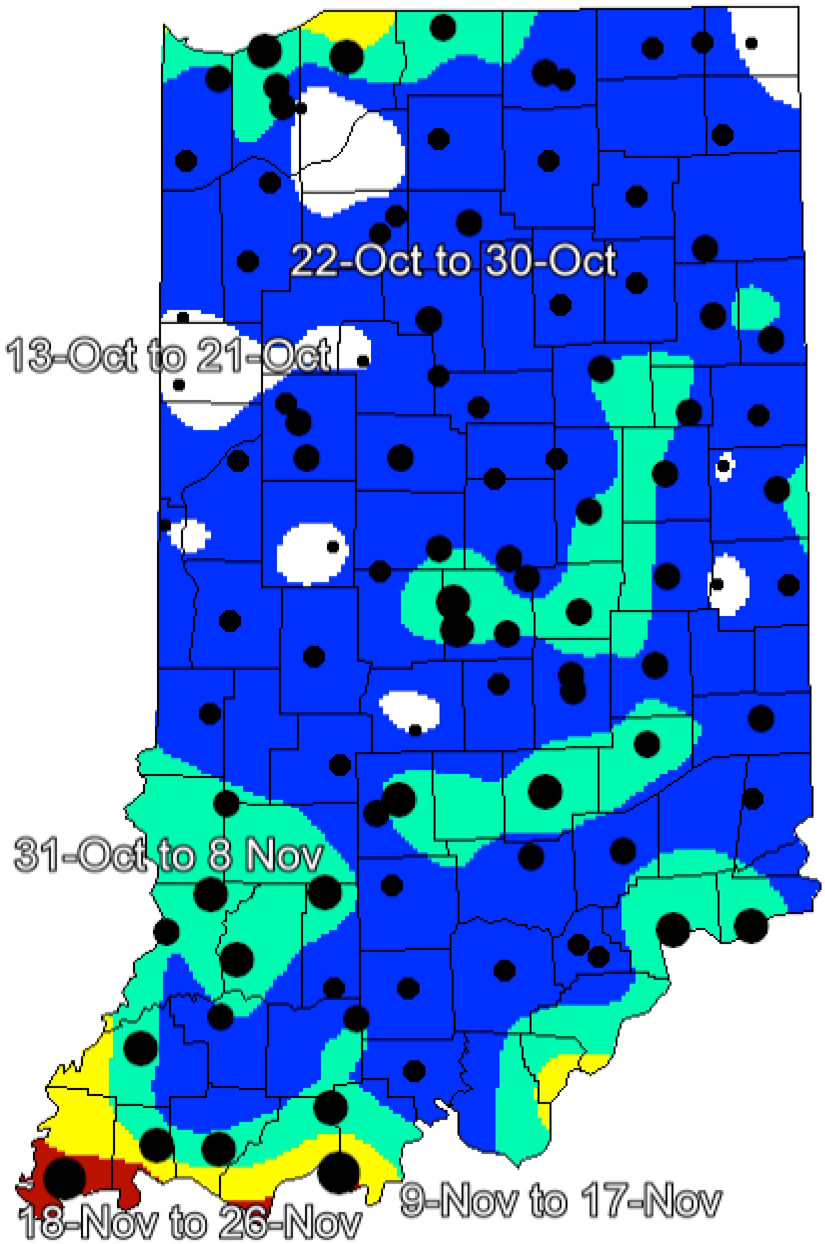

Fig. 4. Average first fall dates of 28°F temperatures throughout Indiana. Interpolated data derived from spatial analysis of 1981-2010 normal data from Indiana and surrounding states. White: 13-Oct to 21-Oct; Blue: 22-Oct to 30-Oct; Green: 31-Oct to 8-Nov; Yellow: 9-Nov to 17-Nov; Red: 18-Nov to 26-Nov. Spatial data source: National Climatic Data Center 1981-2010 US Normals Data.

Table 1. Approximate equivalent hybrid GDD requirements for delayed planting relative to estimated actual GDDs available from delayed planting date to the end of the season (EOS).

Plant Date	1-May	10-May	20-May	30-May	10-June
Est. Avail. GDD From Planting to EOS	Approx. equivalent hybrid GDD; adjusted for delayed planting				

2000	2000	2061	2129	2197	2272
2050	2050	2111	2179	2247	2322
2100	2100	2161	2229	2297	2372
2150	2150	2211	2279	2347	2422
2200	2200	2261	2329	2397	2472
2250	2250	2311	2379	2447	2522
2300	2300	2361	2429	2497	2572
2350	2350	2411	2479	2547	2622
2400	2400	2461	2529	2597	2672
2450	2450	2511	2579	2647	2722
2500	2500	2561	2629	2697	2772
2550	2550	2611	2679	2747	2822
2600	2600	2661	2729	2797	2872
2650	2650	2711	277	2847	2922
2700	2700	2761	2829	2897	2972
2750	2750	2811	2879	2947	3022
2800	2800	2861	2929	2997	3072
End of Season (EOS) defined by user, but may be based on expected first fall 32^{o}F temperature. Equivalent hybrid GDDs = Available GDDs adjusted for hybrid GDD response to planting delays beyond May 1 (Nielsen, et.al., 2002)					

Table 2. Approximate maximum "safe" hybrid CRM for delayed planting relative to estimated actual GDDs available from delayed planting date to the end of the season (EOS).

Plant Date	1-May	10-May	20-May	30-May	10-June
Est. Avail. GDD From Planting to EOS	Approx. hybrid CRM based on Plant date & approx. available GDDs				
2000	82	85	88	91	94
2050	84	87	90	93	96
2100	87	89	92	95	98
2150	89	91	94	97	101
2200	91	94	97	100	103
2250	93	97	99	102	105
2300	95	98	8101	104	107
2350	97	100	103	106	109
2400	100	102	105	108	111
2450	102	104	107	110	114
2500	104	107	110	113	116

2550	106	109	112	115	118
2600	108	111	114	117	120
2650	111	113	116	119	122
2700	113	115	118	121	125
2750	115	118	120	123	127
2800	117	120	123	126	129
End of Season (EOS) defined by user, but may be based on expected first fall 32^{o}F temperature. Hybrid CRMs as defined by DuPont Pioneer and calculated on the basis of the relationship between GDDs from plantimg to physiological maturity and hybrid CRMs of 73 hybrids listed in DuPont Pioneer's 2012 hybrid characteristics table.					

Related reading

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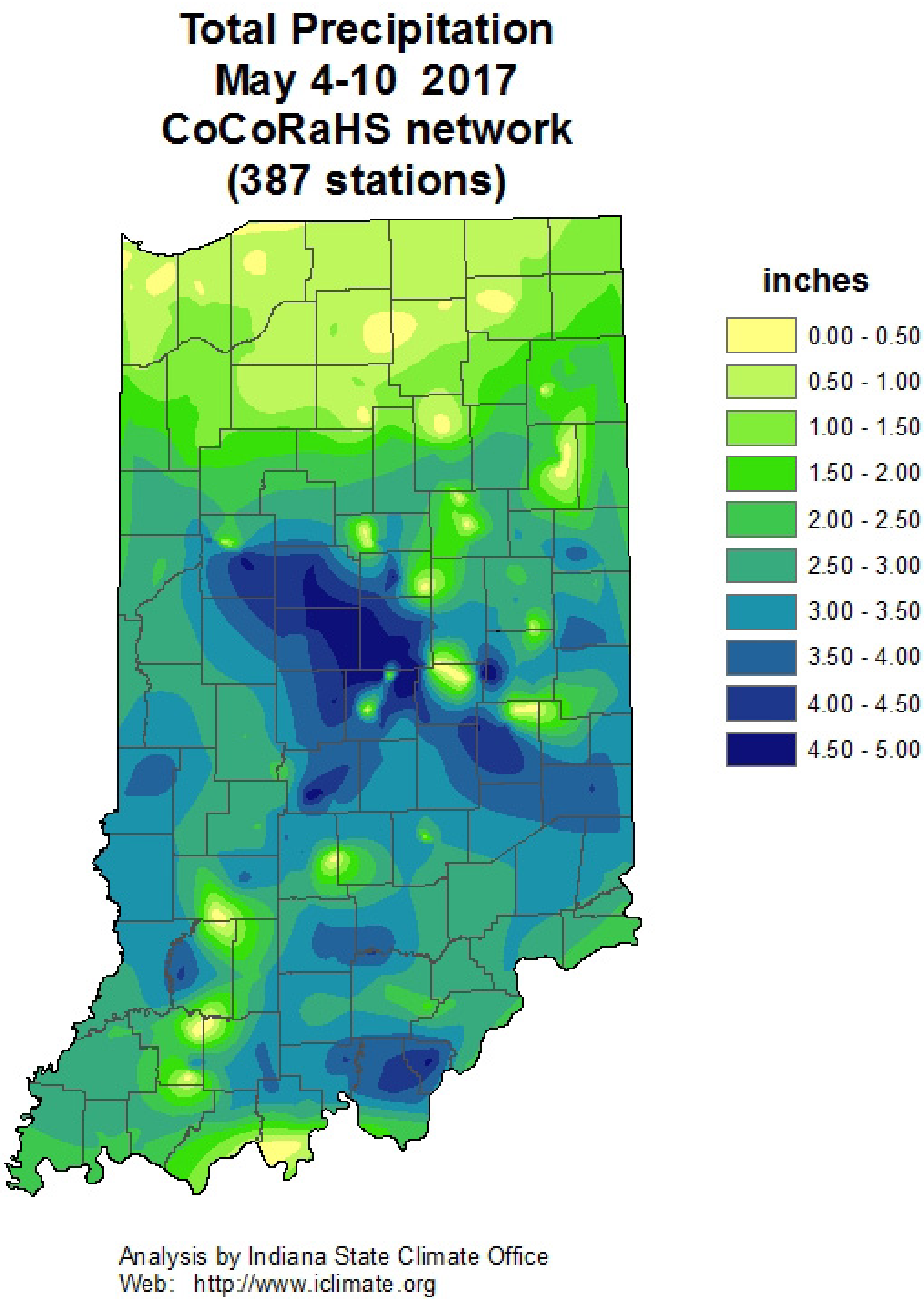
Precipitation



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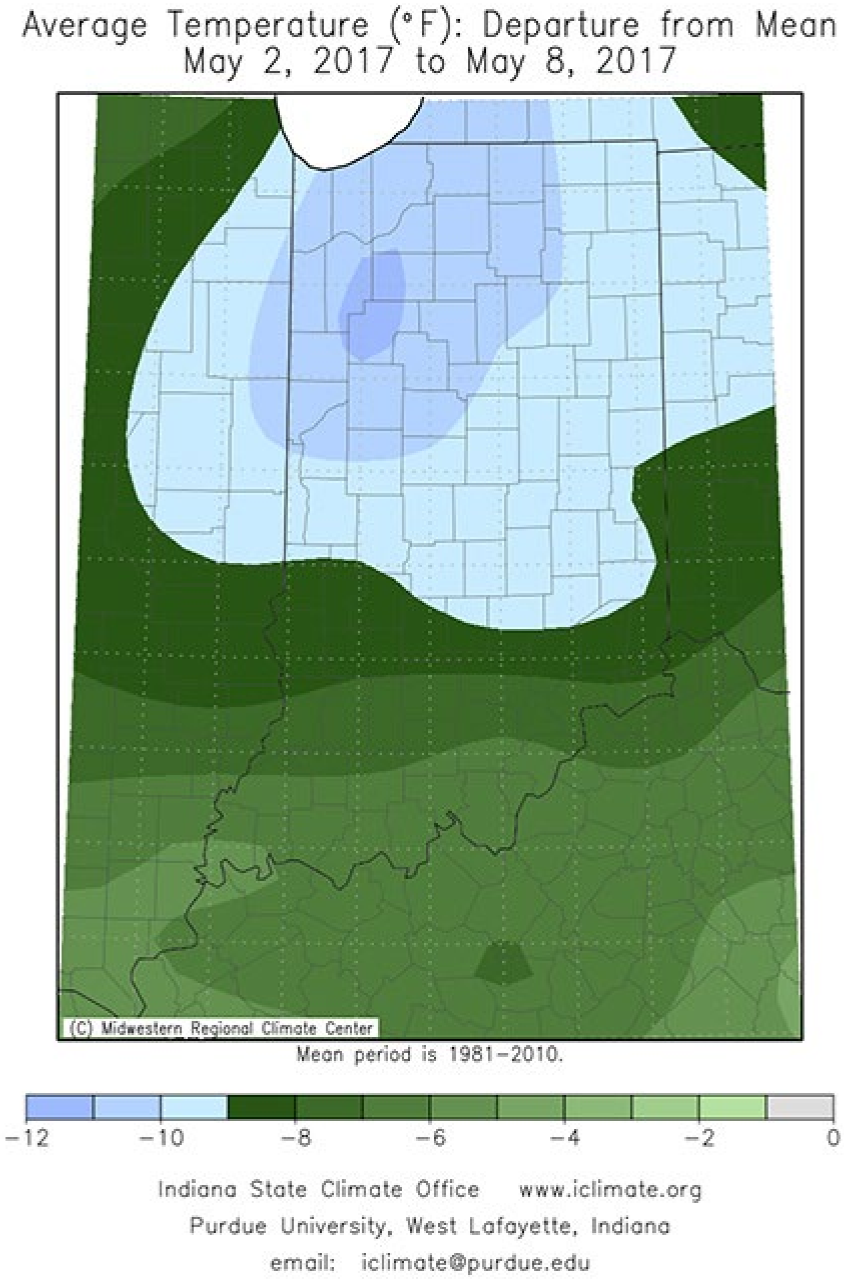
Average Temperature (°F): Departure from Mean
May 2, 2017 to May 8, 2017
(C) Midwestern Regional Climate Center
Mean period is 1981-2010.
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-6
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-2
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Indiana State Climate Office www.iclimate.org
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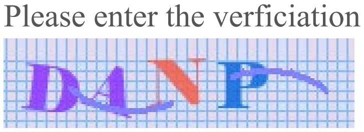

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