What are growing degree days and how are they useful for rice growers in the northeastern USA

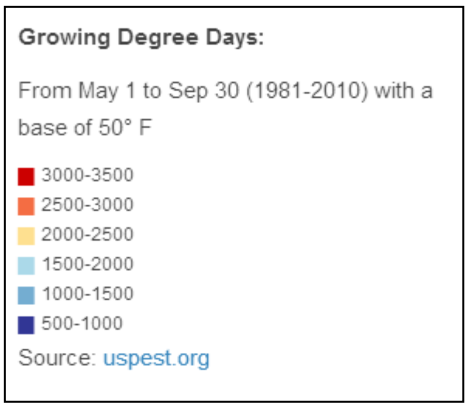
What are growing degree days, and how are they calculated?

Growing degree days (GDD), sometimes also called thermal days, are a unit of measure describing the amount of **accumulated heat** through the growing season. Temperature data from 1981 to 2010 was used to construct an interactive growing degree day map of the northeastern USA. Specifically, the calculation is done by adding the maximum and minimum temperature for a given day, dividing by two to obtain an average, and subtracting 50 °F (a common base point for GDD calculations.) Daily results were added from May 1 through September 30 (an approximate standard growing season for rice in the Northeast) for each year that data was available. In the final step to generate the map, data was averaged across the years.

GDD accumulated per day = [(Max. + Min. Temperature)/2] - 50 °F. Sum over the growing season.

How do I read the growing degree day (GDD) map?

All locations reporting temperature data between 1981 and 2010 are marked with a colored circle based on the GDD range in which they fall. For the locations on the current map, average GDD values ranged from 500 to 3500 degrees above 50 °F per growing season. Each 500-degree increment is marked with a different color, with the colors in a gradient from highest increment (3000 - 3500 = most degrees above 50 °F, marked in red) to lowest (500 - 1000 = least degrees above 50 °F, marked in blue).



If your exact location does not appear, moving east/west along the map to the closest reporting location (cross-check altitudes to be sure no major changes) will give you the most reasonable estimate, for average temperatures tend to change more quickly with elevation and latitude than with longitude.

How is the GDD map useful to me?

Growing degree days is a standard measure that is used for many crops to determine the degree of adaptation to a particular region, or whether a variety is likely to mature in a particular geographical zone. Because there is currently very little information about which varieties can mature in the Northeast's cold climate, comparing growing degree days with other temperate rice growing regions, including northern Japan and California, can be helpful. Once you have looked up the GDD value for your area, you can check the map and other existing resources from those regions to get a better idea of what varieties may work well in your fields. In general, it seems that growing degree days above ~1500 may allow many of the early varieties from Hokkaido to mature. Growing degree days above ~2500 may allow later-maturing varieties from Hokkaido and early-maturing varieties from California to mature and produce grain in the northeastern USA.

Growing Degree Days (GDD) and Maturing Rice Varieties

Location		Average GDD	Year(s)	Planting	Some Maturing Varieties
Akaogi Farm		1906	2009	transplant	Hayayuki (early), Kitaake (early), Yukihikari (mid-early), Matsumae (late), Akitakomachi (very late)
Hokkaido, Japan	Kitami	1681	1981-2010	transplant	Hayayuki, Kitaake
	Hippu	1830	1981-2010	transplant	Yukihikari
	Hokuto	1918	1981-2010	transplant	Matsumae
Honshu, Japan	Yuuwa	2649	2003-2010	transplant	Akitakomachi
	Nagaoka	3220	1981-2010	transplant	Koshihikari
Rio Vista, California (coldest rice growing region in CA)		2961	2008-2012	direct seed	Akitakomachi, Koshihikari, Calrose, other medium grain varieties
Colusa, California (northern CA)		3605	2008-2012	direct seed	Akitakomachi, Koshihikari, Calrose, other medium grain varieties

Akaogi Farm data collected through use of an on-site weather station. Data for Japan obtained from the Japan Meteorological Agency (http://www.data.jma.go.jp/obd/stats/etrn/index.php). Growing degree day data for California obtained from http://www.weather.com/outdoors/agriculture/growing-degree-days/.

So far, over 80 different rice varieties have been evaluated for adaptation on the Akaogi Farm in southeastern Vermont, and varieties from Hokkaido are the top performers. For more information about the varieties trialed at Akaogi Farm in 2008 and 2009 please refer to the Northeast SARE grant reports (http://www.ricenortheasternus.org/grant/).

By spring 2015, we aim to have a fuller survey (and map similar to this one) documenting how well a few common varieties perform at various other sites. In the meantime, and even once those data are available, growing degree days provide a way to 1) learn from the past field seasons of farmers working in similar microclimates (hopefully saving time, money, and effort) and 2) contribute new varietal diversity to the Northeast rice community--and possibly find a new favorite variety along the way!

Why not use hardiness zones or heading dates?

Hardiness zones, constructed based on annual minimum temperatures, are helpful for many crops, particularly perennial crops that have to endure cold winter temperatures. In the case of rice in the Northeast, however, minimum winter temperatures do not appear to be the deciding factor in determining a variety's ability to mature. Given the short growing season and cool temperatures that characterize the northeastern region of the US, compared to much of the rest of the rice-growing world, the amount of heat and sunlight accumulated over the growing season has been observed to be a better predictor of varietal adaptation than hardiness zones.

[More detail if desired: Accumulated heat and light over the growing season are very important in determining both the maturity and **final yield** of a variety**,** for they both dramatically impact the plant's photosynthetic machinery. If it is too cold for the machinery to operate at maximum capacity, incoming solar energy will be dissipated by the plant as heat (to prevent damage from excess sunlight) rather than being used for biomass (green leaf and stem tissue) production. Similarly, if incoming sunlight is lower than what the plant can optimally use, photosynthetic activity won't be maximized and plant growth will be stunted and delayed. These and other aspects of a plant’s response to temperature and light add up over the growing season-- one reason why GDD is a useful way to think about things--and over the course of an entire growing season, become key determinants of whether a plant achieves its full yield potential.

In the case of the northeastern USA, the amount of accumulated sunlight is not as important as the GDD in determining a rice plant's **flowering or maturation time**. Why not? The varieties being grown in this region are temperate in origin, meaning they mature quickly during the long days of summer, and are part of the *Japonica* varietal group. Unlike many tropical rice varieties, *temperate japonica* varieties are not sensitive to photoperiod (day length) in their flowering time--a good thing since photoperiod sensitive varieties of rice will not mature until the daylength is less than 12 hrs (rice is considered a “short day” species). Thus, photoperiod insensitivity is a favorable trait in temperate regions where daylength in summer is >12 hours and the growing season is short. One way to reason it out: when a variety that is photoperiod-sensitive, meaning flowering is delayed until Sept. 15 in the northern hemisphere or March 15 in the southern hemisphere, when the daylength drops below 12 hrs, is planted in a temperate location, it risks cold temperatures coming through before it is fully developed.]

Heading dates of specific varieties may prove to be useful, and this data will be collected from farmers in the Northeast this year. However, heading dates are not as easily generalizable across regions as growing degree days, and given that no historical data are yet available, a few years of data on a range of different varieties will be needed to get enough points and years on the map--especially with the growing seasons varying as much in weather patterns as they have been.

Summary

We recommend using GDD, a measure of accumulated heat over the growing season, as a guiding metric when deciding which varieties to plant in a given geographical region. In review, the GDD metric accomplishes the following:

1) Summarizes accumulated temperatures (heat) throughout the entire crop growing season in a single number. Hardiness zones are based on minimum annual temperatures, which more than likely (hopefully) fall outside of the rice growing season.

2) Connects us with the global rice community and its established resources, especially useful for helping to identify suitable varieties for the northeastern USA.

3) Successfully predicted that modern Hokkaido varieties would perform best on the Akaogi Farm, likely because it incorporates aspects of rice maturation that are especially important in cold climates and are difficult to discern.

4) Appears to be a reliable measure for the climatic factors most important to rice varieties' viability and productivity in the northeastern USA.

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