The Nuance of Growing Degree Day Calculations

For ten years now, I've been talking and writing about using growing degree day (GDD) models to schedule plant growth regulator (PGR) applications. But GDD models have many other uses in turf management. For example, there are models to predict when to apply products for *Poa annua* seedhead control, GDD models to predict when to apply early season DMI fungicides for dollar spot control, and models for insect emergence and control.

There are subtle differences between the many different GDD models found in turf. It's important to understand these differences because they can be the difference between a model working great and being a massive failure.

What are growing degree days?

A growing degree day model is a way to track the accumulation of heat. Plants are "cold-blooded" like reptiles. Their biology, growth, and development is highly dependent on temperature. The classical example is corn development. Corn growth rate will increase as the average air temperature increases, up to 86°F. When the average air temperature is below 50°F, there is little new corn growth and development. By tracking the amount of heat accumulated (GDDs), farmers can estimate the corn's growth stage.

The daily GDD is calculated as the average air temperature minus a base temperature where metabolism is minimal. Those daily GDD values are then added together to get the cumulative GDD, which is correlated to plant growth, or insect/weed emergence, or even the amount of PGR remaining in a turfgrass plant.

$$Cummulative\ GDD = \sum_{Start\ Date}^{Current\ Date} \left(\frac{\text{High} + \text{Low Air Temp.}}{2}\right) - \text{Base Temp.}$$

Different Factors to Consider

While the calculation is fairly straight forward, there are big differences between GDD models. Users need to understand these subtle differences for the models to work correctly:

Temperature scale: Most GDD models use degrees Fahrenheit (°F), but PGR models in turf use degrees Celsius (°C). Using °F for PGRs will result in too frequent of PGR applications. This wastes money and leads to over-regulation.

Model Start Date: This depends on the model. For PGR modeling, the model starts the day the PGR is applied. It is reset to zero the next time the PGR is re-applied. For predictions of emergence (i.e. seedhead treatment/emergence, insect treatment) it is important to know the start date. Some models start on January 1st while other start on February 1st. This difference can have big impacts on the success rate of a GDD model.

Base Temperature: It is essential to use the correct base temperature and associated temperature unit (°F vs °C). For PGR models, the base temperature is 0°C for cool-season turf but 10°C for warm season turf. The base temperature is 32°F for *Poa annua* seedhead control with Proxy while the seedhead flush model uses a base of 22°F.

Action Thresholds: All GDD models are just numbers unless there is some level of interpretation included with the number. The action threshold is the GDD when something is likely to occur or something needs to be done. For example, the PGR Primo Maxx needs to be applied every 200 GDD (base 0°C) to sustain yield suppression on a creeping bentgrass putting green but 300 GDD when applied to a creeping bentgrass fairway. It's also important to know where action threshold was developed. The action thresholds may vary if a model is used outside of the region where it was developed. The PGR models have been verified across the country, but some models (i.e. seedhead control thresholds) may have a slightly different threshold in another region.

Tools to Help

There are great tools online to help use GDD models, and they are free. Michigan State University created a GDD tracker website to help predict pest emergence and schedule maintenance applications (http://gddtracker.net). Users can visualize the northward progression of GDDs for different pest on a large map of the US. You can also add your email and ZIP code and receive notifications about timings. Maps include Embark and Primo/Proxy Timers, seedhead flush, early season DMI fungicide applications, crabgrass germination and PRE application, Japanese beetle, bluegrass billbug, and BTA egg laying.

For PGR timings, our GreenKeeper website (www.greenkeeperapp.com) is programmed to track the GDD from the day the PGR is applied. It also projects when a PGR will need to be re-applied, based on weather forecasts. GreenKeeper will determine the ideal re-application interval (action threshold) based on the grass species, mowing height/area type, PGR, and application rate. This free site also tracks other applications as well.

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Table 1. GDD model details for various turf products and pests.

Pest/Product	Temperature Scale	Start Date	Base Temperature	Action Threshold or Range
Seedhead Control with Primo/Proxy	Fahrenheit	February 1st	32°F	200-500 GDD
Seedhead Control with Embark	Fahrenheit	February 1st	22°F	680-1050 GDD
Poa annua Seedhead Flush	Fahrenheit	February 1st	22°F	1050-2900 GDD
Spring Broadleaf Herbicide Timer	Fahrenheit	February 1st	50°F	110-150 – Ester 150-200 – Ester/Amine 200-600 – Amine
Plant Growth Regulator	Celsius	Day the PGRs was last applied	0°C – Cool-season 10°C – Warm-season	Ranges depending on species, mowing, PGR and rate.

Table 2. Examples of how the base temperature and temperature scale can affect the daily and accumulated GDDs. The cumulative GDDs in this example started on the first day. Different models have different start dates.

Temperature			Daily GDD					Cumulative GDD				
High (F)	Low (F)	Average (F)	Base 50F	Base 32F	Base 22F	Base 10C	Base 0C	Base 50F	Base 32F	Base 22F	Base 10C	Base 0C
95	70	82.5	32.5	50.5	60.5	18.1	28.1	33	51	61	18	28
88	62	75.0	25.0	43.0	53.0	13.9	23.9	58	94	114	32	52
72	55	63.5	13.5	31.5	41.5	7.5	17.5	71	125	155	39	69
67	63	65.0	15.0	33.0	43.0	8.3	18.3	86	158	198	48	88
49	32	40.5	0.0	8.5	18.5	0.0	4.7	86	167	217	48	93
32	20	26.0	0.0	0.0	4.0	0.0	0.0	86	167	221	48	93
25	10	17.5	0.0	0.0	0.0	0.0	0.0	86	167	221	48	93

* To convert from Fahrenheit to Celsius, subtract 32 the average air temperature and then divide by 1.8.