BUL 1146

Understanding Growing Degree Days (GDD) to Predict Crop Growth and Pest Development in Idaho Cropping Systems

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Introduction

IN IDAHO, WEATHER CONDITIONS VARY CONSIDERABLY across years, elevations, and production systems (Figure 1). Because of this variability, crop growth and pest development are often influenced more by temperature than by calendar dates. The growth and development of plants, insects, and plant pathogens are strongly temperature-dependent (Yadav and Chang 2014). Within a favorable temperature range, biological processes such as germination, emergence, flowering, and insect development generally occur more rapidly, while cooler temperatures slow development. Extremely high temperatures can also reduce growth and cause stress.

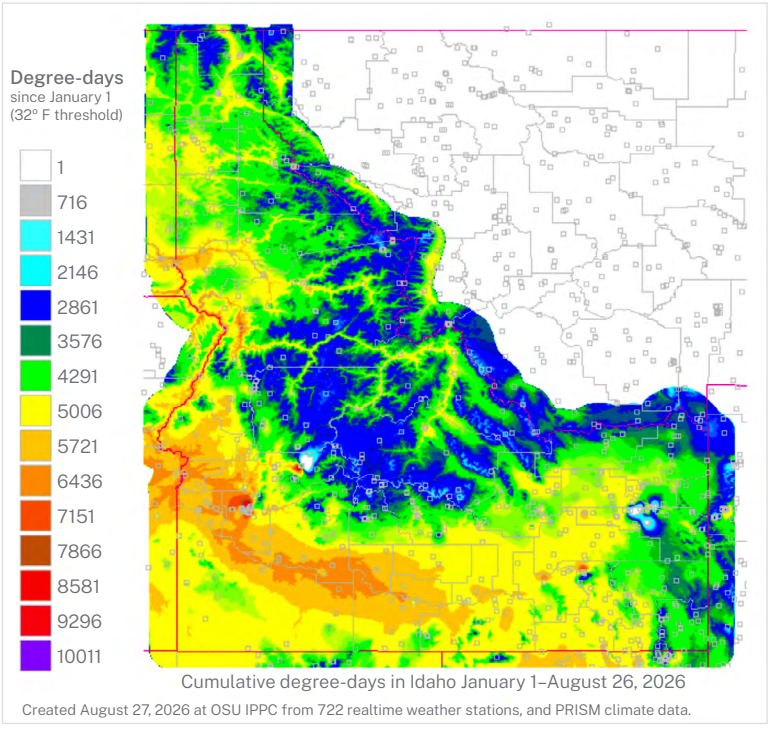


Figure 1. Weather conditions vary considerably across Idaho production regions, elevations, and microclimates. Weather station data are commonly used to calculate Growing Degree Days (GDD) and improve crop growth and pest development predictions. Source: Northwest Decision Support System (NWDSS), https://uspest.org/wea/gis/NW_32i.png.

What Are Growing Degree Days (GDD)?

Also called degree days, GDD is a measure of accumulated heat used to estimate the growth and development of plants and insects during a growing season. It is based on the principle that temperature is the primary factor that controls how fast or slow an organism develops. Generally, warmer temperatures increase biological activity and growth, while cooler temperatures slow development. Each crop and insect species has a minimum temperature threshold, called the **base temperature** (T_{base}), below which development slows significantly or stops. As temperatures rise above this threshold, heat accumulates over time and drives biological processes such as seed germination, root growth, flowering, crop maturity, insect egg hatch, larval feeding, pupation, and adult emergence. The total amount of accumulated heat required for an organism to move from one developmental stage to another is referred to as **physiological time**. Base temperatures vary among species, making the selection of the appropriate T_{base} essential for accurate GDD calculations. The base temperature represents the lower development threshold below which measurable growth or development is assumed to be minimal or absent. A GDD model for cool-season crops often uses lower base temperatures near 40°F, whereas models for many insect pests commonly use a base temperature around 50°F (Table 1). The appropriate T_{base} is, however, species-specific and should be selected according to the crop or pest being modeled.

Although some seeds may germinate below 50°F, many warm-season crops require sustained temperatures above this threshold for successful establishment and growth. Crop and insect development generally increase as temperatures rise above the base temperature until reaching an optimal range. However, excessively high temperatures can reduce biological activity. For many crops, growth slows significantly when temperatures exceed approximately 86°F because heat stress interferes with normal physiological processes. Similarly, insect development may become delayed or less efficient under extreme heat, since excessively high temperatures can negatively affect survival, feeding, reproduction, and overall development. Because biological development is more closely related to temperature than to calendar dates, GDD provides a more reliable method for predicting crop growth stages and pest activity under field conditions. By estimating daily heat accumulation above a crop- or pest-specific base temperature, GDD models help growers and agricultural professionals make better-informed management decisions related to planting, irrigation scheduling, crop scouting, pest monitoring, pesticide application timing, and harvest management.
The scientific basis for GDD originates from the close relationship between temperature and biological development, a concept first proposed by Réaumur in 1735. Since then, GDD has become one of the most widely used tools in agriculture and integrated pest management (IPM).

Table 1. Temperature effects on crop and insect development and their relationship to GDD.

Temperature	Crop Response	Insect Response	How GDD Uses This Information
Below T_{base}	Growth minimal or stopped	Development stops; inactive/dormant	No accumulation (0)
Near T_{base}	Slow emergence and growth	Slow development; delayed activity	Low accumulation
Optimal Range	Maximum growth; active development	Rapid development and reproduction	Rapid accumulation drives stages
Above Optimal	Stress; reduced growth efficiency	Less efficient development; possible mortality	GDD accumulates, but response is less predictable

Why GDD Improves Decision-Making

Growing degree days accumulate slowly in early spring, increase rapidly during warm periods, and level off later in the season. The cumulative heat drives both crop growth and pest development. Because temperature strongly influences biological activity, GDD provides a more accurate method than calendar dates for timing agricultural management decisions. Using GDD helps align planting, irrigation, harvest, scouting, and pest-management activities with actual field conditions. As a result, GDD-based thresholds are widely used in IPM programs to improve application timing and reduce unnecessary pesticide use. To apply GDD effectively, it is important to define a **biofix**, the biological starting point for heat accumulation, such as the first sustained insect trap capture. Using a biofix improves prediction accuracy by linking temperature accumulation to real pest activity in the field.

In Idaho cropping systems, GDD models are commonly used to support irrigation scheduling, fertility management, crop scouting, and pest monitoring (Table 2). For example, codling moth management in Idaho apple orchards relies on a 50°F base temperature and a biofix date determined from pheromone trap captures. Accumulated GDDs are then used to predict egg hatch and larval development, helping growers better time scouting and control measures.

Similarly, potato producers may use GDD to estimate crop development stages such as emergence and tuber initiation to guide irrigation and nutrient management decisions. Other Idaho examples include alfalfa weevil scouting in hay systems and potato psyllid monitoring in potatoes.

Since weather conditions vary considerably across Idaho regions and between years, crop growth stages and pest activity may occur earlier or later than expected. Growing degree days help producers make more informed and consistent management decisions by tracking biological development based on accumulated heat rather than fixed calendar dates.

How to Calculate and Apply GDD

The following steps outline how to calculate and apply GDD in practical field situations.

Step 1: Select Crop or Pest

Identify what you are tracking. First, identify what biological process you are monitoring. This could be crop growth, such as potato tuber development, or pest activity, such as potato psyllid, alfalfa weevil, or codling moth development. Growing degree days can be used to monitor both crop growth and pest development. Before calculating GDD, identify the crop or pest being tracked so the correct base temperature and developmental thresholds can be used for management decisions.

Table 2. GDD Guiding Crop Development and IPM Decisions.

Aspect	Crop Development	Pest Management
What GDD Predicts	Emergence, growth stages, flowering, maturity	Egg hatch, larval feeding, adult emergence, peak activity
Purpose	Guide planting, irrigation, and harvest decisions	Improve timing of scouting and IPM control
Applications in Idaho	Wheat/barley: jointing, heading; Potatoes: tuber initiation; Forages: cutting/grazing	Potato psyllid: egg hatch; Alfalfa weevil: larvae; Codling moth: egg hatch, larval stage
Example Use	Potatoes (T_{base} 45°F–50°F): tuber initiation ~300 GDD (irrigation timing)	Potato psyllid: ~160 GDD egg hatch; Alfalfa weevil: ~250 GDD (base 48°F), scout and assess damage
Decision	Based on crop growth stage	Based on pest stage and economic threshold
Management Strategy	Adjust field operations to heat accumulation	Target vulnerable pest stages for effective control

Step 2: Choose Base Temperature

Use the correct threshold (e.g., 48°F, 50°F). Base temperatures differ among crops and pests because biological development begins at different temperature thresholds (Figure 2). Select the base temperature needed for that crop or pest. Obtain recommended base temperatures from Extension publications, university pest models, and crop management guides or validated online tools.

A **biofix** is a biologically defined reference point that marks the initiation of heat-unit accumulation in GDD models. It represents a measurable biological event, such as the first sustained insect trap capture, flowering, or crop emergence, used to synchronize temperature accumulation with actual organism development under field conditions. Biofix establishment improves the precision of phenology-based forecasting and management decisions.

Step 3: Select a Start Date (Biofix)

Calendar date (e.g., January 1 or March 1) or a biological event/biofix date (e.g., first moth catch). Choose when GDD accumulation should begin. For crops, this may be a calendar date such as January 1, March 1, planting date, or crop emergence. For insect pests, the starting point is often a biofix, a biological event, such as the first sustained moth capture in a trap. A biofix helps connect GDD accumulation to actual pest activity in the field.

Step 4: Track Daily Temperatures

Use local weather stations, on-farm sensors, and online tools. Collect daily maximum and minimum temperatures from a local weather station, on-farm sensor, or online weather tool. Use the weather station closest to the field whenever possible because temperatures can vary by location, elevation, and microclimate. AgriMet Weather (US Bureau of Reclamation) and National Weather Service data provide daily maximum and minimum temperatures used for GDD calculations.

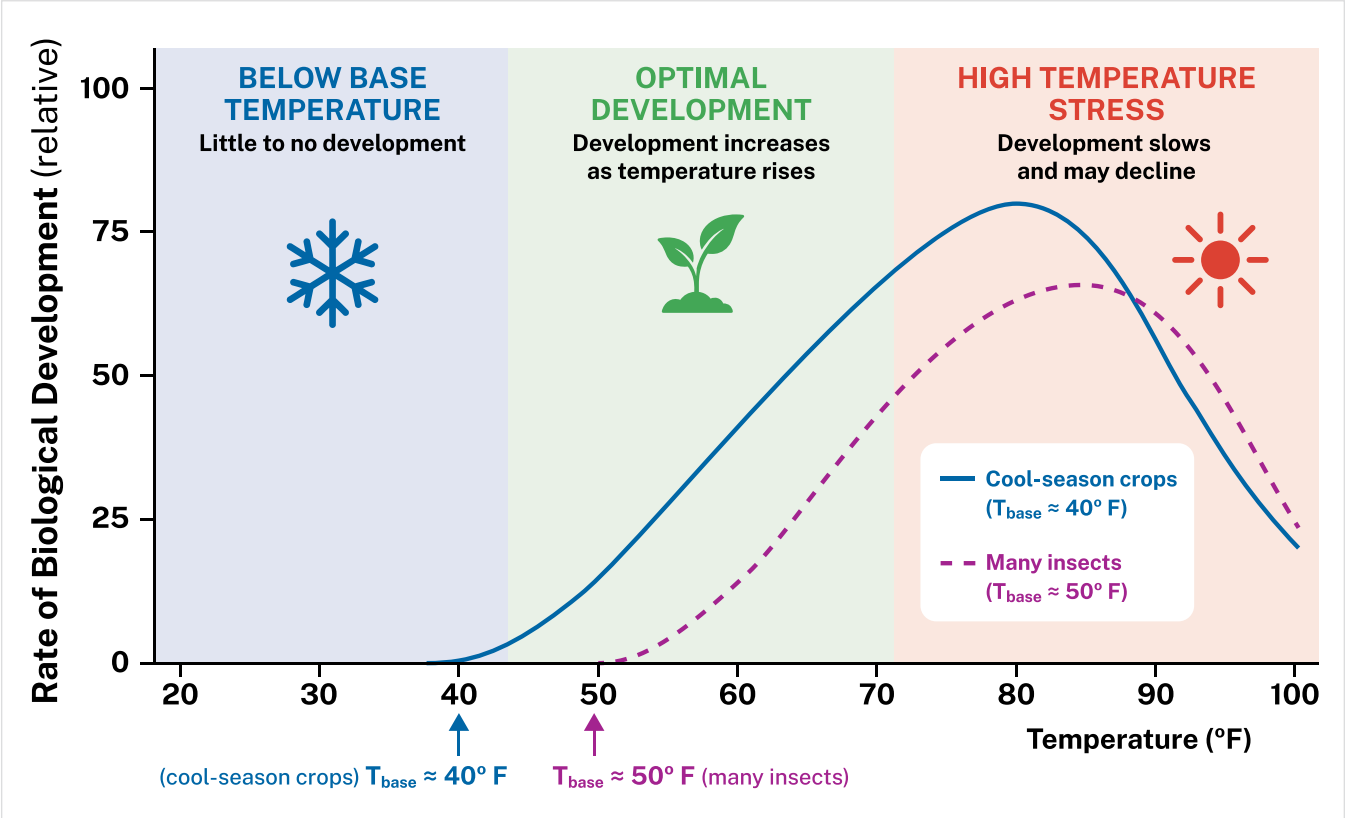


Figure 2. Relationship between temperature and biological development relative to base temperature (T_{base}). Biological development is minimal below the base temperature, increases as temperatures rise above the threshold, and may decline under excessively high temperatures due to heat stress. Base temperatures used in GDD calculations vary among crop and insect species.

To access temperature information:

1. Visit the AgriMet website: https://www.usbr.gov/pn/agrimet/.
2. Select the weather station closest to your field location.
3. Open the station's daily weather data page.
4. Record the daily maximum air temperature (T_{max}) and minimum air temperature (T_{min}).
5. Use these values to calculate daily GDD or enter them into a GDD calculator.

Step 5: Calculate GDD Using the Formula or Online Tools

Calculate a daily degree day value by averaging the day's maximum and minimum temperatures and subtracting the base temperature of the crop or pest being tracked. Each day contributes a small amount of heat called a degree day. Calculate GDD by adding these daily heat units over time to estimate accumulated heat throughout the growing season. Use the GDD formula or an online calculator to estimate daily GDD values. Add each day's GDD to the previous total to calculate the cumulative GDD for the season.

Formula:

$$GDD = \frac{T_{max} + T_{min}}{2} - T_{base}$$

Where:

- T_{max} = daily maximum temperature
- T_{min} = daily minimum temperature
- T_{base} = crop- or pest-specific threshold

If the average daily temperature is below the base temperature (T_{base}), GDD accumulation for that day is recorded as zero (not negative). To prevent overestimating growth, maximum temperatures are capped at 86°F and minimums are raised to 50°F if they fall below. Many pest models use a 50°F base temperature since heat accumulation occurs only when the average daily temperature exceeds 50°F (10°C). Temperatures below this threshold do not contribute to development.

For a day if observed T_{max} = 95°F; T_{min} = 45°F; T_{base} = 50°F

T_{max} is capped at 86°F (since 95°F > 86°F)

T_{min} is raised to 50°F (since 45°F < 50°F)

Adjusted values: T_{max} = 86°F; T_{min} = 50°F

Average temperature = (86°F + 50°F) ÷ 2 = 68°F

GDD for that day = 68 - 50 = 18

Add daily GDD to get cumulative GDD for the season (Table 3).

This method is commonly used in pest models (e.g., codling moth), where extreme temperatures do not accelerate development beyond biological limits. Organizations like the Northwest Decision Support System, US Pest.org (https://uspest.org), and the USA National Phenology Network provide online tools to track local GDD accumulations. Idaho-specific tools, such as the PNW Pest Alert Network's Growing Degree Days Calculator, https://pnwpestalert.net/gdd/, can simplify GDD calculations by automatically processing local weather data and cumulative heat-unit accumulation for crop and pest monitoring.

Table 3. Example of daily and cumulative GDD calculation with temperature adjustments (base 50°F).

Day	T_{max} (°F)	T_{min} (°F)	Adjusted T_{max}	Adjusted T_{min}	Avg Temp $\frac{T_{max} + T_{min}}{2}$	Daily GDD Avg Temp - T_{base}	Cumulative GDD
Day 1	95	45	86	50	(86+50)/2 = 68	18	18
Day 2	80	52	80	52	(80+52)/2 = 66	16	34
Day 3	70	40	70	50	(70+50)/2 = 60	10	44
Day 4	60	48	60	50	(60+50)/2 = 55	5	49
Day 5	55	42	55	50	(55+50)/2 = 52.5	2.5	51.5

Step-By-Step: Using the PNW Pest Alert Network GDD Calculator (Figure 3)

1. Go to the PNW Pest Alert Network Growing Degree Days Calculator: https://pnwpestalert.net/gdd.
2. Select the location closest to your field or monitoring site.
3. Select the pest you want to track.
4. Check the start date: For pests with an active biofix, the start date may be locked to the biofix date for that location and pest.
5. Click calculate.

The GDD value tells you when to look and scout; it does not automatically mean you need to spray.

Step 6: Interpret GDD Thresholds and Take Action

Once cumulative GDD reaches a key threshold, use that information to guide field observations (Figure 4). For example, if a pest model indicates activity near 250 GDD, begin scouting to confirm pest presence, crop injury, or pest life stage. For potatoes, tuber initiation may occur around 300 GDD, which can help guide irrigation and nutrient management. Use field observations and economic thresholds to decide if action is needed. Growing degree days indicate when to look, not automatically when to spray.

The GDD value also provides a practical and science-based approach for improving crop management and pest monitoring decisions in Idaho agriculture. When combined with field scouting, economic thresholds, and local Extension recommendations, GDD tools help producers improve timing, efficiency, and sustainability across diverse cropping systems.

Summary

Using GDD provides a more effective guide for scouting and timing management practices than relying only on general calendar estimates, such as insect pests usually arriving in late June or early July. The models help align management decisions with actual field conditions and biological activity. When combined with field scouting and economic thresholds, GDD improves the timing and effectiveness of pest management while supporting an integrated approach that balances chemical, cultural, and mechanical methods of control and plant care.

Limitations: Although GDD is a powerful tool, it does not account for factors such as soil moisture, nutrients, photoperiod, or plant stress.

Further Reading

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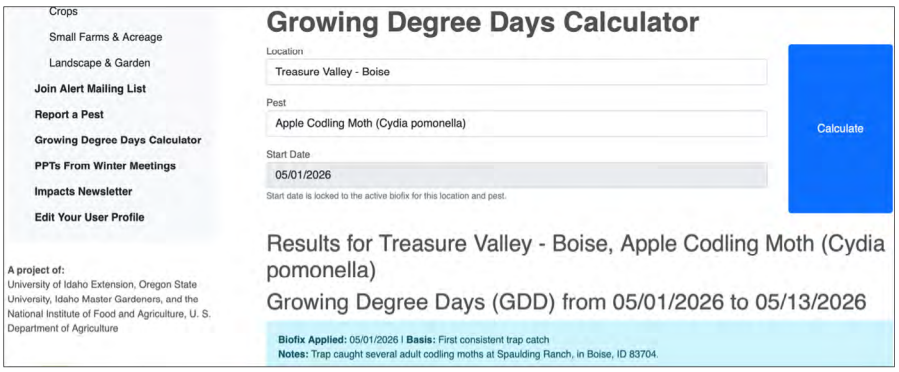
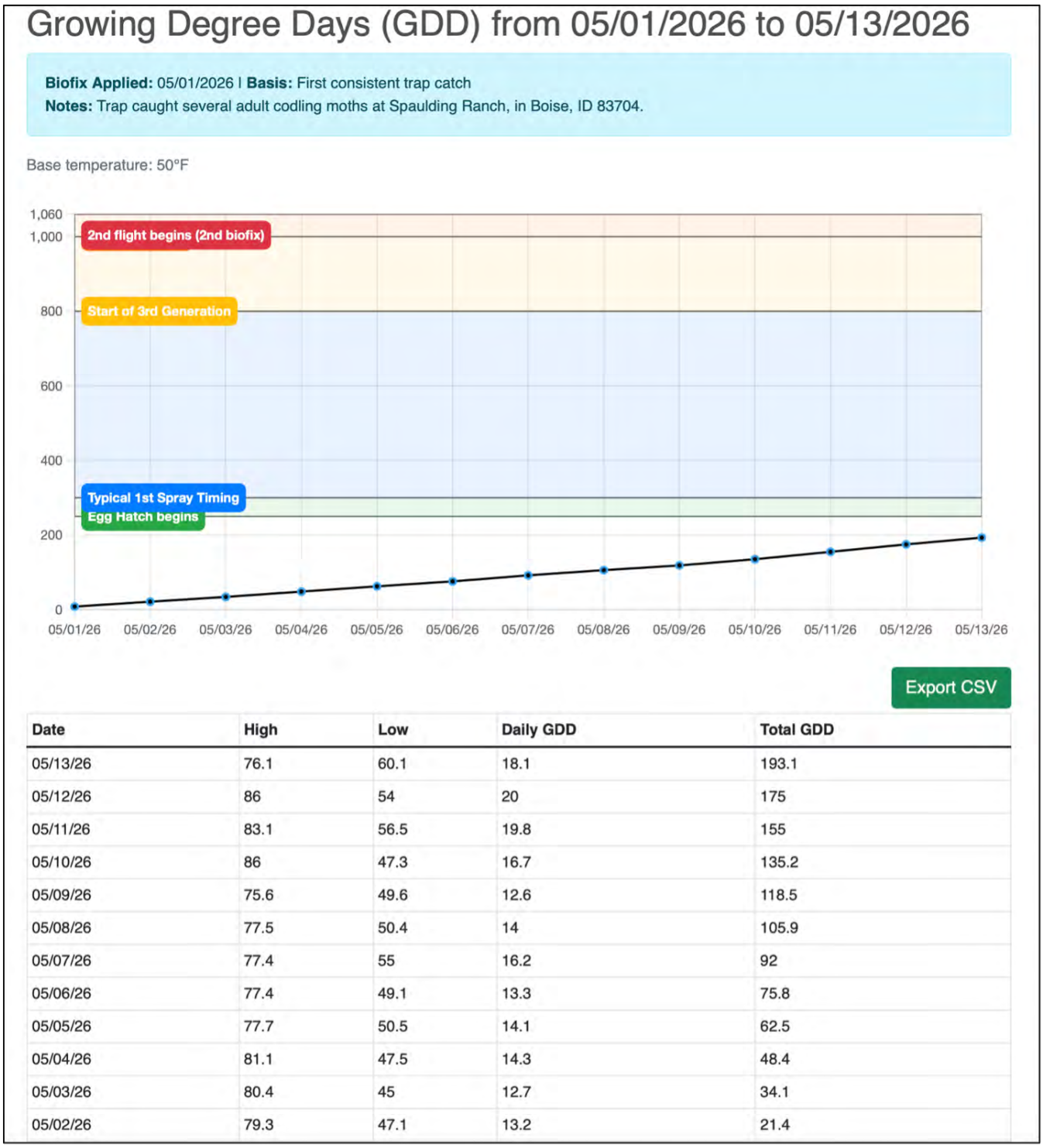


Figure 3. Screenshot of the https://pnwpestalert.net/gdd/ for codling moth (*Cydia pomonella*) when Treasure Valley–Boise, Idaho, was selected.



Date	High	Low	Daily GDD	Total GDD
05/13/26	76.1	60.1	18.1	193.1
05/12/26	86	54	20	175
05/11/26	83.1	56.5	19.8	155
05/10/26	86	47.3	16.7	135.2
05/09/26	75.6	49.6	12.6	118.5
05/08/26	77.5	50.4	14	105.9
05/07/26	77.4	55	16.2	92
05/06/26	77.4	49.1	13.3	75.8
05/05/26	77.7	50.5	14.1	62.5
05/04/26	81.1	47.5	14.3	48.4
05/03/26	80.4	45	12.7	34.1
05/02/26	79.3	47.1	13.2	21.4

Figure 4. Example output from the https://pnwpestalert.net/gdd/, showing cumulative GDD for codling moth development in Treasure Valley–Boise, Idaho. The graph displays cumulative GDD accumulation relative to codling moth phenology thresholds, including egg hatch, typical first spray timing, second flight initiation, and third-generation development. Daily temperature data and cumulative GDD values summarized below the graph support pest monitoring and IPM decisions..

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