

The Influence of Temperature on Cereal Crop Pests

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Temperature is a pivotal environmental factor governing the development, activity, and population dynamics of insect pests in agricultural ecosystems. Cereal crops, including sorghum, pearl millet, maize, and rice, are staple foods for a significant portion of the global population, but their yields are consistently threatened by a diverse array of insect pests. This review synthesizes existing knowledge on the optimal

Cereal crops form the backbone of global food security, providing essential carbohydrates and nutrients. However, their productivity is continually challenged by insect pests that cause significant yield

losses. Among the various environmental factors, temperature stands out as a critical determinant of insect life processes. As poikilothermic (cold-blooded) organisms, insects' metabolic rates,



temperature ranges for key pests affecting these major cereal crops, highlighting how temperature variations influence their life cycles, reproduction, and overall impact on crop production. Understanding these thermal requirements is crucial for developing effective and sustainable Integrated Pest Management (IPM) strategies in the face of changing climatic conditions.

development, reproduction, and survival are directly influenced by ambient temperatures. Variations in temperature, both within a season and across years, can significantly impact pest pressure, leading to outbreaks or suppressed populations. This review aims to compile and present the temperature ranges that are optimal for the development and activity of common pests of sorghum, pearl millet, maize, and rice, thereby

offering insights for improved pest management. Temperature is a critical abiotic factor that profoundly influences the biology and ecology of cereal crop pests, affecting their development, reproduction, survival, distribution, and the severity of their impact on crops. With ongoing climate change and rising global temperatures, these influences are becoming increasingly significant for food security.

1. Accelerated Development and Increased Generations

As insects are ectothermic (cold-blooded), their metabolic rates and developmental speeds are highly dependent on ambient temperature. Within their optimal temperature range, higher temperatures lead to faster development from egg to adult.

More Generations per Year: This accelerated development means that many pest species can complete more generations within a single growing season. More generations directly translate to higher pest populations and, consequently, more extensive crop damage. For example, a 2°C temperature increase could lead to one to five additional life cycles per season for some insects.

Earlier Emergence: Warmer spring temperatures can trigger earlier emergence of overwintering pests, potentially leading to a desynchronization with their natural enemies or a prolonged period of activity during the crop's vulnerable stages.

2. Geographical Range Expansion

Pole Ward and Altitudinal Shifts: Many insect species' geographic ranges are limited by temperature, particularly by minimum temperatures that affect overwintering survival. As global temperatures rise,

these species can expand their ranges towards higher latitudes (pole ward) and higher altitudes, colonizing areas previously too cold for them. This means that regions currently unaffected by certain pests may become vulnerable.

Introduction of Invasive Species: Warmer conditions can facilitate the establishment of invasive pest species that previously couldn't survive in a given climate. Increased global trade, coupled with rising temperatures, further exacerbates this risk.

3. Population Dynamics and Survival

Increased Overwintering Survival: Warmer winters reduce winterkill, leading to higher initial pest populations in the subsequent growing season.

Changes in Reproduction: Temperature directly impacts pest reproduction rates. While generally higher temperatures within an optimal range increase reproduction, excessively high temperatures can have detrimental effects, reducing longevity and reproduction. **Altered Feeding and Growth:** Increased temperatures can raise the metabolic rate of some insects, leading to higher food consumption and more intensive feeding on crops.

4. Impact on Host Plants and Plant-Pest Interactions

Plant Stress: High temperatures can stress cereal crops, weakening their natural defense systems and making them more susceptible to pest attacks.

Changes in Plant Physiology: Climate change can alter plant growth patterns, including the timing of leaf, stem, flower, or fruit formation. This can impact the insect's life cycle, potentially causing them to stay

longer on the host or produce more generations if conditions remain favorable.

Indirect Effects of Elevated CO₂: While temperature has direct effects, elevated CO₂ concentrations (another aspect of climate change) can indirectly influence pests by altering plant chemistry, physiology, and nutritional content.

5. Disruption of Natural Enemy-Pest Interactions:

Asynchrony: The development rates of pests and their natural enemies (predators and parasitoids) may respond differently to temperature changes. This can lead to a desynchronization, where the natural enemies are not present in sufficient numbers at the critical time to control the pest population effectively.

Differential Responses: Generalist and specialist natural enemies may respond differently to changing climatic conditions, potentially altering the balance of pest control.

Temperature Thresholds

Insects, like plants, have cardinal temperatures:

Lower Developmental Threshold (T_{base})

The minimum temperature below which an insect cannot complete development. This helps predict when pests become active after overwintering. Optimal Temperature (Topt): The temperature range at which an insect develops most rapidly and thrives. Upper Developmental Threshold (Tupper) or Lethal Maximum Temperature (Tlmax): The highest temperature at which an insect can develop. Beyond

this point, high temperatures can slow growth, reduce numbers, and even lead to mortality. These thresholds are crucial for developing predictive models (e.g., using Growing Degree Days - GDD) to forecast pest emergence and population build-up, aiding in timely pest management strategies.

Major Cereal Crop Pests Affected by Temperature

Many common cereal crop pests are significantly influenced by temperature. Examples include: Aphids (e.g., Wheat Aphid): Their populations can increase rapidly with favorable temperatures, leading to significant sap-sucking damage. Stem Borers (e.g., Pink Stem Borer, European Corn Borer): Warmer conditions can lead to more generations and prolonged periods of boring activity within cereal stems. Leaf Folders (e.g., Rice Leaf Folder): Their developmental periods are reduced with increasing temperatures within their optimal range. Armyworms: Their development and outbreaks are often linked to specific temperature and moisture conditions.

Locusts: Warming trends can lead to range expansion and an increase in locust populations, potentially resulting in devastating plagues.

2. Temperature Requirements of Sorghum Crop Pests

Sorghum (*Sorghum bicolor* (L.) Moench) is a crucial cereal crop, particularly in arid and semi-arid regions. Its pests generally thrive in warm to hot climates, typically between 25°C and 35°C (77°F to 95°F).

Pest	Optimal Temperature Range	Notes
Sorghum Shoot Fly (<i>Atherigona soccata</i>)	25°C – 30°C	Eggs and larvae develop faster in this range; high humidity also favors population buildup.

Sorghum Midge (<i>Stenodiplosis sorghicola</i>)	27°C – 32°C	Activity peaks during warm, humid conditions during flowering.
Stem Borers (<i>Chilo partellus</i> , <i>Busseola fusca</i>)	25°C – 33°C	Larval development and adult activity increase with temperature.
Aphids (<i>Melanaphis sacchari</i>)	20°C – 30°C	Rapid population growth in warm, moderately humid conditions.
Shoot Bug (<i>Peregrinus maidis</i>)	28°C – 35°C	Favors dry and hot conditions; thrives in post-monsoon or dry spells.
Cutworms (<i>Agrotis spp.</i>)	15°C – 28°C	Prefer cooler temperatures; more active at night.
White Grubs	25°C – 30°C	Soil temperature plays a significant role in larval development.

General Guidelines for Sorghum Pests

- **Below 20°C:** Most pests show reduced activity and reproduction.
- **25°C – 35°C:** Ideal for most pest development, especially in tropical and subtropical climates.
- **Above 38°C:** Can suppress pest development or increase mortality in some species.

3. Temperature Requirements of Pearl Millet Crop Pests

Pearl millet (*Pennisetum glaucum*) is well-adapted to arid and semi-arid regions, and its associated pests are similarly adapted to warm to hot conditions, primarily within the 25°C to 35°C (77°F to 95°F) range.

Pest	Optimal Temperature Range	Notes
Shoot Fly (<i>Atherigona approximata</i>)	25°C – 30°C	More active during warm and humid conditions, especially at seedling stage.
Stem Borer (<i>Coniesta ignefusalis</i>)	25°C – 32°C	High temperatures speed up larval development.
Aphids (<i>Rhopalosiphum maidis</i>)	20°C – 30°C	Rapid multiplication in moderate warmth and moderate humidity.
White Grubs (<i>Holotrichia spp.</i>)	25°C – 30°C	Thrive in warm soils with moderate moisture.
Grasshoppers (<i>Hieroglyphus spp.</i>)	30°C – 38°C	Prefer hot, dry environments typical of millet-growing regions.
Earhead Worms (<i>Helicoverpa armigera</i>)	25°C – 33°C	Egg-laying and larval activity peak in this range.

General Temperature Impacts on Pearl Millet Pest Activity

- **<20°C:** Slowed pest metabolism and reproduction.

- **25–35°C:** Ideal for pest development; most pearl millet pests are highly active in this range.

- **>38°C:** Can reduce survival or egg viability for some pests, though others (e.g., grasshoppers) may still thrive.

4. Temperature Requirements of Maize Crop Pests

Maize (*Zea mays*) is a globally significant cereal, and its pests exhibit varying temperature preferences, generally favoring warm conditions for optimal development.

Pest	Optimal Temperature Range	Notes
Fall Armyworm (<i>Spodoptera frugiperda</i>)	28°C – 30°C	High temperatures accelerate development; thrives in warm climates.
Stem Borer (<i>Chilo partellus</i> , <i>Busseola fusca</i>)	25°C – 33°C	Warmer temperatures favor multiple generations per season.
Corn Earworm (<i>Helicoverpa armigera</i>)	27°C – 32°C	Prefers warm, dry conditions; attacks ears and kernels.
Maize Aphid (<i>Rhopalosiphum maidis</i>)	20°C – 30°C	Rapid population increase in moderate warmth and humidity.
Rootworm (<i>Diabrotica</i> spp.)	25°C – 30°C	Soil temperature affects larval emergence and development.
Cutworms (<i>Agrotis</i> spp.)	15°C – 28°C	Prefer cooler nights and moist soil; early-season pest.
White Grubs (<i>Holotrichia</i> spp.)	25°C – 30°C	Soil temperature and moisture influence larval growth.
Stalk Borer (<i>Papaipema nebris</i>)	22°C – 28°C	Moderate temperature and humidity favor larval development.

Temperature Impact Summary for Maize Pests

- **<20°C:** Most pests develop slowly; some may become inactive.
- **25°C – 35°C:** Ideal range for most maize pests; favors high reproductive and feeding rates.
- **>35°C:** Can be stressful to certain pests but may benefit heat-tolerant ones like *Spodoptera frugiperda*.

5. Temperature Requirements of Rice Crop Pests

Rice (*Oryza sativa*) is a staple crop for a large part of the world, particularly in Asian countries. Rice pests are largely adapted to warm, humid, and often tropical or subtropical climates.

Pest	Optimal Temperature Range	Notes
Brown Plant hopper (<i>Nilaparvata lugens</i>)	27°C – 30°C	High humidity and warm temperatures promote rapid reproduction.
White-Backed Planthopper (<i>Sogatella furcifera</i>)	25°C – 30°C	Similar to brown planthopper; prefers moist, warm climates.
Rice Stem Borer (<i>Scirpophaga incertulas</i> , etc.)	25°C – 33°C	Larval development and pupation accelerate in warm temperatures.

Rice Leaf Folder (<i>Cnaphalocrocis medinalis</i>)	27°C – 32°C	Most damaging during high humidity and moderate to high temperatures.
Gall Midge (<i>Orseolia oryzae</i>)	25°C – 30°C	Outbreaks common during high humidity and cloudy weather.
Rice Hispa (<i>Dicladispa armigera</i>)	28°C – 35°C	Population builds up in warm, dry conditions.
Rice Water Weevil (<i>Lissorhoptrus oryzophilus</i>)	20°C – 30°C	Prefers slightly cooler temperatures, but can adapt to warmer ones.
Armyworms (<i>Mythimna separata</i>)	24°C – 30°C	Thrive in warm, moist climates; major outbreaks after rains.

Temperature Impacts on Rice Pests

- **Below 20°C:** Slows down pest development significantly; some may enter dormancy or die.
- **25°C – 35°C:** Ideal for the growth, reproduction, and spread of most rice pests.
- **Above 35°C:** Can reduce survival or fertility of some pests, but others like Rice Hispa may still thrive.

6. Conclusion and Future Implications

The information presented highlights the strong dependency of cereal crop pests on specific temperature ranges for their optimal development and activity. While most cereal pests generally thrive in warm to hot conditions (25°C to 35°C), there are species-specific variations and tolerances to temperature extremes. Understanding these thermal thresholds is fundamental for predicting pest

outbreaks, assessing the risk of new invasive species under changing climates, and developing climate-resilient pest management strategies.

As global temperatures continue to rise, it is anticipated that pest geographic ranges may expand, overwintering survival may increase, and the number of generations per season could intensify. This necessitates ongoing research into the precise thermal biology of cereal pests, including their physiological responses to fluctuating temperatures, heat stress, and the interaction of temperature with other environmental factors like humidity and rainfall. Integrating this knowledge into predictive models and early warning systems can significantly enhance the effectiveness of IPM programs, contributing to food security in a changing world.

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