



# WARMING AND DROUGHT AFFECT THE WAY FLOWERS ATTRACT AND REWARD THEIR POLLINATORS

Baby sage (*Salvia microphylla*) &  
Lucifer hummingbird (*Calothorax lucifer*)



Flowers have evolved over millions of years to lure pollinators with colorful petals, sweet or acrid scents, and sugary nectar. However, drought and warming are altering the signals and rewards that plants use to attract pollinators, threatening the production of fruits and seeds of nearly 90% of flowering plants. While visiting flowers, pollinators obtain food—like pollen and nectar—and sometimes oils, waxes, and other resources. Changes in flowers' nectar, pollen, and scent production could impact pollinator attraction, threatening plant reproduction, animal livelihoods, and even human food security.

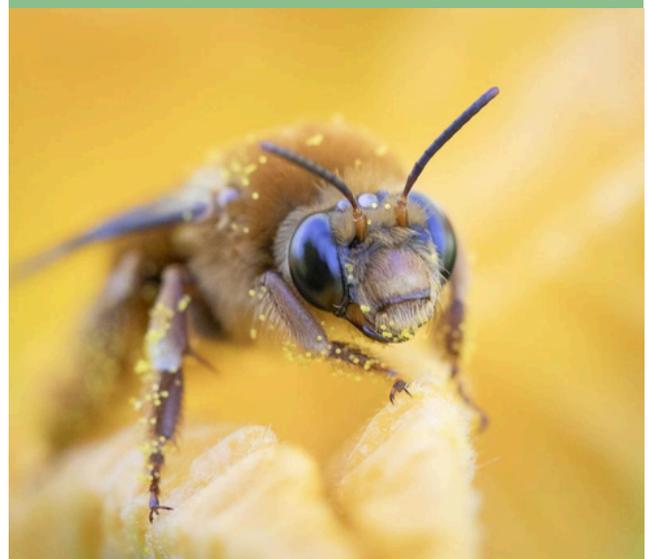
## Heat reduces pollen production and quality

In experiments with borage (*Borago officinalis*), warmer and drier conditions can reduce pollen production and lower the pollen's ability to fertilize flowers and make seeds. The nutritional value of pollen may also decline, especially its protein content. Because bees rely on protein-rich pollen to feed their larvae, poorer nutrition can weaken colonies and reduce pollination, leading to fewer fruits and seeds.

## Smaller flowers, less nectar, lower attraction

Studies conducted in the northern hemisphere show that warming temperatures and drought frequently lead to reduced flower size and nectar production. With fewer floral rewards available, pollinators such as bees, butterflies, and birds obtain less energy from each visit and must forage longer or visit different flowers to meet their needs. In one greenhouse study in California, native wildflowers exposed to warmer conditions (+4 °C) produced fewer and smaller blossoms with less nectar. As a result, female mason bees (*Osmia lignaria*, a solitary native species) reduced their foraging activity, and plants set fewer seeds. This example highlights how climate warming can simultaneously diminish floral resources and pollinator activity, ultimately reducing plant reproduction.

Squash flower (*Cucurbita* sp.) &  
Fulvous squash bee (*Xenoglossa fulva*)



## Floral scents out of tune

Rising global temperatures are changing the way many flowers smell. A global review of published studies found that more than 60 % of plant species examined emitted stronger or chemically modified floral scents under warmer conditions, while only a few showed declines. Experiments with Mediterranean plants, for example, revealed that a 5 °C increase in temperature can intensify scent release up to ninefold and alter its chemical composition. These shifts in scent intensity and chemical blends may alter how pollinators perceive and recognize flowers, potentially reducing their fidelity to specific plants and leading to fewer visits and lower fruit and seed production. More research is needed to determine which scent changes are most disruptive and how to safeguard specialized plant–pollinator relationships in a changing climate.

*Priva aspera* (Verbena family) & common sootywing (*Pholisora catullus*)



### Reference

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## Pollinator behavioral shifts under warming

Rising temperatures can directly affect pollinators, not just the flowers they visit. Experiments with the common eastern bumblebee (*Bombus impatiens*) showed that simulated heatwaves cut foraging time in half, even when nectar was available. When flowers were exposed to high temperatures, the plants produced about 70 % less nectar, further shortening bee visits. These direct and indirect effects—heat stress on bees and lower floral rewards—independently reduced pollinator activity. During heatwaves, bees may abandon flowers sooner or avoid foraging altogether, leaving colonies with fewer resources and plants with limited opportunities to reproduce. Understanding how heat independently influences pollinators and flowers will be essential to predict the resilience of pollination under future climate.

## Evidence is still limited to temperate regions

Most studies of climate change effects on floral attractants and rewards have focused on temperate and alpine regions. There is still a major knowledge gap in tropical and subtropical ecosystems, where floral diversity is exceptionally high and many plant–pollinator interactions are specialized. These regions are also home to a large proportion of the world's crops that depend on pollinators – from coffee and cacao to tropical fruits and spices. Expanding research in these ecosystems is crucial to understanding and protecting these vulnerable yet invaluable plant–pollinator interactions that sustain biodiversity and human food security.

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