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## *Zygotogramma bicolorata*: A Biocontrol Hero to Emerging Sunflower Pests

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*Zygotogramma bicolorata*, commonly known as the Mexican beetle, was originally introduced as a biological control agent to manage the invasive weed *Parthenium hysterophorus* due to its high specificity and voracious feeding habits on the target plant. However, subsequent observations have indicated that this beetle exhibits a broader host range than initially anticipated, including the ability to feed on economically important crops such as sunflower (*Helianthus annuus*). This shift in host preference has raised significant concerns regarding the ecological safety and economic impact of the biocontrol agent, particularly when sunflower crops are cultivated in proximity to parthenium-infested areas. The literature documents that classical biological control programs utilizing *Z. bicolorata* were initiated in Australia during 1976 and subsequently in India by 1983, leading to the widespread establishment of this leaf-feeding beetle across tropical and subtropical regions. Despite the success of these programs in reducing *Parthenium* density, reports have emerged detailing the beetle's capacity to shift its feeding onto cultivated sunflower (*Helianthus annuus*), thereby transforming it from a beneficial agent into a potential agricultural pest. Studies have demonstrated that while *Z. bicolorata* effectively defoliates *Parthenium hysterophorus*, its feeding efficacy is influenced by population density and exposure time, with higher larval populations causing complete defoliation within 12 days under controlled conditions. This host shift phenomenon necessitates a critical examination of the biological parameters governing the beetle's adaptation to non-target hosts, particularly the developmental biology and feeding potential of *Z. bicolorata* on sunflower (*Helianthus annuus*) compared to its primary host. Research indicates that the beetle's nutritional physiology and ecological efficiency are modulated by abiotic factors such as temperature, which may influence its acceptance and performance on secondary hosts like sunflower.

### **Background: A Successful Biocontrol Agent for Parthenium**

*Parthenium*, often called Congress grass or carrot weed, is one of India's most troublesome invasive weeds. It causes:

- Severe reduction in crop yields
- Allergic reactions in humans and livestock
- Loss of biodiversity
- Rapid spread due to prolific seed production

To control this weed in an eco-friendly manner, *Zygotogramma bicolorata* was introduced in the 1980s. It became widely known as a natural, self-sustaining, and environmentally safe biocontrol agent.

### **How it controlled *Parthenium***

- Adult beetles and larvae feed on *Parthenium* leaves

- Continuous feeding results in defoliation
- Suppressed plant growth and reduced seed production
- Helped restore native vegetation

For decades, *Zygogramma* played a crucial role in managing *Parthenium* in India without major ecological side effects.

## Why is This Host Shift Happening?

### i) Decline in *Parthenium* Availability

In many managed landscapes, *Parthenium* density has reduced due to:

- Mechanical removal
- Biocontrol success
- Competitive native vegetation

This leads beetles to search for alternative hosts.

### ii) Physiological flexibility

Studies show that *Zygogramma* can survive on certain Asteraceae family crops, including sunflower, though they do not reproduce as efficiently on them.

### iii) High beetle population pressure

Favourable climatic conditions in some regions have resulted in a beetle population build-up

## Consequences for Sunflower Cultivation

### Short-term impacts

- Reduced leaf area
- Lower plant vigour
- Potential decline in seed yield

### Long-term concerns

- Possibility of *Zygogramma* establishing as a secondary or occasional pest
- Need to revise pest management strategies for sunflower-growing regions
- Monitoring required to avoid economic damage thresholds

## Management Strategies

### a) Conservation of *Parthenium* patches

Leaving small *Parthenium* stands along non-crop fields during peak beetle activity can reduce pressure on sunflower.

### b) Cultural practices

Timely sowing to avoid overlap with beetle population peaks

Awareness among farmers for early detection

### c) Mechanical removal

Hand-picking beetles in small fields can help.

### d) Biological insights

*Z. bicolorata* does not complete its life cycle effectively on sunflower, most infestations remain temporary and moderate.

### e) Judicious use of insecticides

Chemical control should be a last resort because:

*Zygogramma* is still valuable for long-term *Parthenium* suppression

Broad insecticide use may upset ecological balance

Instead, targeted, minimal, and need-based spraying of safer insecticides is recommended.

## Conclusion

*Zygogramma bicolorata* remains one of the most successful biological control agents against *Parthenium hysterophorus* in India. However, its emerging role as a minor or occasional pest of sunflower illustrates the complex ecological dynamics of biological control.

Recent field observations from parts of Karnataka, Andhra Pradesh, Telangana, and Maharashtra indicate that *Z. bicolorata* is now feeding on sunflower plants, causing noticeable foliar damage.

The demographic attributes of *Zygogramma bicolorata* reveal that its population growth is significantly modulated by host plant suitability and abiotic conditions, with intrinsic and finite rates of increase being highest when the beetle feeds on the inflorescences of *Parthenium hysterophorus* compared to leaves and stems. This heightened reproductive potential on the reproductive structures of the weed suggests that the beetle's life cycle is tightly synchronized with the phenology of *Parthenium*, yet laboratory studies have confirmed that *Z. bicolorata* can complete its entire development on sunflower foliage, albeit with extended larval durations and reduced survival rates compared to the primary host. Field evaluations have further demonstrated that the effectiveness of *Z. bicolorata* as a biocontrol agent is highly variable and dependent on environmental conditions, as significant defoliation of *Parthenium* was observed only during years with above-average summer rainfall, whereas subsequent years with below-average rainfall resulted in markedly lower feeding activity. Such variability underscores the critical influence of climatic factors on the beetle's efficacy and suggests that environmental stress may drive host shifts toward cultivated sunflower when the primary weed resource becomes desiccated or scarce. Specifically, thermal limits and resource availability act as key constraints on the occurrence and survival of arthropods, with investigations into the critical thermal maxima of adult *Z. bicolorata* revealing that increasing temperatures and exposure times significantly reduce heat survival. These thermal constraints may force populations to seek alternative hosts, such as sunflower, when thermal stress diminishes the quality or availability of *Parthenium hysterophorus*. Furthermore, empirical evidence from field releases indicates that the presence of *Z. bicolorata* significantly reduces the density, biomass, and reproductive output of *Parthenium* plants, with complete defoliation occurring within 60 to 80 days depending on the developmental stage released. However, the long-term ecological safety of this biocontrol strategy remains complex, as climate change may alter the dynamics between plant hosts and specialist natural enemies, potentially exacerbating the beetle's shift toward non-target crops like sunflower. The success of classical weed biocontrol programs is often contingent upon the specific traits of the insect herbivores and the target weeds, where factors such as feeding specificity and life history characteristics correlate with better establishment and control outcomes. Consequently, the potential for *Z. bicolorata* to become a pest of sunflower is likely exacerbated by climatic variability, as thermal stress and resource scarcity can drive host shifts from the target weed to non-target crops. Modeling approaches have further elucidated that climatic suitability, particularly average minimum temperatures between 24.2 and 26.2 °C and rainfall between 191.2 and 257.3 mm from July to October, creates optimal conditions for establishing *Z. bicolorata* populations. Field releases should therefore be accompanied by seasonal monitoring to confirm presence and activity of the beetles, especially after extreme thermal events, and if necessary, augmentative releases should be carried out to boost field populations. Global climate change is expected to disrupt biological control systems, necessitating the identification of natural enemies that can thrive under future climate scenarios to ensure agricultural sustainability.