

crops over time (Kranthi and Stone, 2020). Therefore, it is essential to focus on developing new Bt traits and improving existing ones to delay resistance. This includes increasing the prevalence of refuges and using integrated pest management strategies (Gassmann and Reisig, 2022). Additionally, research should explore the socio-economic impacts of Bt crops on farmers and communities to ensure that the benefits of Bt technology are equitably distributed (Reganold and Wachter, 2016; Kranthi and Stone, 2020).

7 Concluding Remarks

The application of *Bacillus thuringiensis* (Bt) crops has shown significant benefits in pest management and agricultural sustainability. The widespread adoption of Bt maize has led to regional pest suppression, reducing the need for insecticidal applications and decreasing crop damage in both Bt and non-Bt fields, including vegetable crops. Bt crops have also reduced insecticide usage and increased farmers' profits. However, the evolution of pest resistance to Bt traits remains a critical challenge, necessitating integrated pest management strategies to delay resistance. Additionally, while Bt crops have shown efficacy in pest control, their performance can be compromised under environmental stress conditions.

Bt crops play a crucial role in sustainable agriculture by reducing the reliance on chemical insecticides, thereby promoting environmental health and biocontrol services. They help lower pest management costs and increase crop yields, thus boosting farmers' profits. Bt crops have also been proven to provide indirect benefits to neighboring non-Bt crops by reducing pest pressure, which is particularly beneficial for organic farming systems. Despite the lower yields and higher variability in organic farming, integrating Bt crops can enhance the overall sustainability of agricultural practices by balancing productivity with environmental and economic benefits.

Future research should focus on several key areas to enhance the benefits of Bt crops in organic farming and reduce their limitations. Investigate and develop strategies to delay pest resistance to Bt crops, such as increasing the prevalence of refuges and employing integrated pest management practices. Conduct comprehensive studies to understand the impact of various environmental stressors on the efficacy of Bt crops and develop robust predictive models for their performance under extreme climatic conditions. Additionally, explore the interactions between Bt crops and non-target organisms, including beneficial insects and aquatic ecosystems, to ensure that Bt crop adoption does not inadvertently harm these populations. By addressing these research areas, we can optimize the use of Bt crops in organic farming systems, ensuring their benefits are maximized while minimizing potential drawbacks.

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Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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