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Resistance monitoring of FAW maize in India – A Need

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Abstract:

The fall armyworm (FAW) *Spodoptera frugiperda (*J.E. Smith) is a significant invasive pest that threatens maize cultivation in India and across the globe. Understanding and monitoring the resistance of FAW to chemical control measures are critical for developing effective pest management strategies. The review covers resistance monitoring efforts in regions such as the Americas, Africa, China, Australia, and India, revealing diverse resistance levels and mechanisms. Despite the reliance on novel insecticides in India, evidence of resistance has emerged, pointing to the spread of resistance alleles and the need for robust Integrated Resistance Management (IRM) strategies. We highlighted the importance of continuous monitoring, establishing baseline susceptibility standards for bioassays, and implementing IRM to address resistance development and safeguard crop yields.

Keywords: *Spodoptera frugiperda,Resistance, Integrated Resistance Management (IRM), baseline susceptibility, bioassays*

Introduction:

Monitoring resistance in invasive insect species is crucial in developing effective management strategies. In India, the fall armyworm (FAW), *Spodoptera frugiperda* is a significant invasive insect pest posing a threat to maize farming. Understanding FAW's resistance to current chemical control tactics is vital for safeguarding the nation's agriculture. This article presents a comprehensive overview of the evolution of resistance monitoring in *S. frugiperda* and elucidates resistance mechanisms. The objective is to provide valuable insights for managing FAW in India and to support early-stage resistance monitoring and research in this domain.

Fall armyworm chemical control – a global scenario

The fall armyworm (*Spodoptera frugiperda*) has been extensively targeted for control measures, with a reliance on chemical intervention being predominant. Although integrated pest management (IPM) strategies have been developed, chemical control has

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been the primary approach. In the mid-20th century, organophosphates and carbamates were the recommended insecticide groups for managing fall armyworm in native American states. However, the focus has shifted towards synthetic pyrethroids in both native and invaded areas in response to changing trends in chemical control. Since the early 21st century, new-generation insecticides and novel molecules have come to the forefront in fall armyworm control globally and in India. Alongside the evolving landscape of insecticidal usage, resistance developments in fall armyworm populations have been reported for the majority of insecticides. Reports of resistance in fall armyworm can be traced back to the initial observation of differential feeding on Carbaryl-treated plants. Subsequently, resistance emerged against many organophosphates and synthetic pyrethroids in the native regions of fall armyworm. In the early 1980s, populations of *S. frugiperda* collected in Hammond, USA, displayed substantial resistance, with a 113-fold resistance to methyl parathion, 41-fold resistance to carbaryl, 31-fold resistance to trichlorfon, and 17-fold resistance to permethrin compared to laboratory strains. In invaded regions such as Africa, China, and Asia, resistance to major insecticide groups, including neonicotinoids, diamides, and other newer molecules, has been well-documented in fall armyworm. According to reports from the Arthropod Pesticide Resistance Database, fall armyworm has developed resistance to 42 active ingredients, resulting in almost 182 recorded cases of insecticide resistance worldwide. Despite the implementation of IPM strategies and reports of resistance, chemical control remains an effective management option for mitigating fall armyworm damage.

Resistance monitoring in Fall armyworm - Worldwide

The emergence of resistance in pest species to insecticides is a direct result of widespread insecticide application, leading to selective pressure on the targeted pests. It is imperative to conduct systematic monitoring of resistance development in insect pest species to effectively recommend insecticides and develop integrated resistance management (IRM) strategies. The surveillance of resistance in FAW was initiated in the early 1990s in American countries and has persisted to the present day. In China, FAW was first reported in December 2018 to January 2019, prompting the initiation of monitoring studies by June 2019 for most recommended insecticides. Over a five-year period, the African FAW population exhibited reduced susceptibility to major chemical insecticides, with Lambda-cyhalothrin being one of the affected compounds. However, limited

information is available from Africa and the Middle East. Shifting focus to Southeastern countries, FAW was first reported in Australia on January 31, 2020, with monitoring studies revealing initial populations with resistance levels 10 to 28 times higher than those observed in other countries. To the best of our knowledge, information on resistance monitoring in FAW from Southeast Asian countries remains scarce. This underscores the necessity of expanding resistance monitoring efforts to ensure effective pest management strategies and safeguard agricultural yields.

Towards the resistance monitoring of Fall armyworm - India

In 2018, fall armyworm (FAW) was first detected in India, as documented by Kalleshwaraswamy et al. from Karnataka. During this period, insecticides from novel chemical groups had become more prominent in the management of insect pests, surpassing the traditional organophosphate and carbamate groups. In India, the control of fall armyworm primarily relied on novel insecticide compounds and synthetic pyrethroids. Although some other countries had reported instances of resistance to these compounds, the status of insecticide resistance in the Indian fall armyworm population remained a subject of debate. Few studies have been conducted to monitor the resistance levels of fall armyworm in India. These studies yielded mixed results, with some indicating no resistance development to recommended insecticides, while others highlighted resistance to specific insecticides like chlorpyrifos, flubendamide, and deltamethrin due to the presence of resistance alleles in the invading population in 2018, as reported by Sandeep and his group, and Kulye and his group in 2021.

To gain a comprehensive overview of fall armyworm chemical control in India, it's essential to consider the recommendations of the Central Integrated Pest Management Centre (CIB&RC). **Synthetic pyrethroids**, such as Lambda-cyhalothrin, had been extensively used against *Spodoptera frugiperda* (fall armyworm) in several regions, including native American states, China, and various Asian countries, following the decline in the use of organophosphates and carbamates. However, studies in China and India indicated reduced toxicity of Lambda-cyhalothrin compared to other insecticides. For instance, in India, Lambda-cyhalothrin showed only one-fold potency, while emamectin benzoate, chlorantraniliprole, and spinetoram exhibited much higher potency. **Benzoylureas** like Novaluron, Lufenuron, and Teflubenzuron were also reported to face resistance issues, with resistance to lufenuron documented in Brazil and cross-resistance to other chitin synthesis inhibitors (CSI) in the case of teflubenzuron. For fall armyworm control in

India, the **neonicotinoid** insecticide thiamethoxam, used as a seed treatment, was recommended, along with Cyantraniliprole (a diamide). Thiamethoxam + diamides were considered highly effective as a seed treatment in maize, with no reported control failures. However, in soybeans, thiamethoxam seed treatment was found to be less effective compared to diamides. Reports of resistance to Spinetoram, a key chemical in the **spinosyns group**, had emerged in Brazil, along with resistance to related compounds in the same group. Emamectin benzoate, an effective insecticide against lepidopteran pests globally, faced resistance issues in the Mexican fall armyworm population, with laboratory studies indicating significant resistance levels after extended selection pressure. **Diamide group** insecticides were considered primary contenders for fall armyworm control, both globally and in India. However, while there was no evidence of field-evolved resistance, laboratory studies revealed the presence of resistance alleles and cross-resistance mechanisms within the same group. Furthermore, it was observed that fall armyworm populations in different regions, such as China, India, and Australia, showed varying levels of resistance, with the Australian population reporting increased resistance compared to India. Additionally, different strains of *S. frugiperda* in India exhibited varying resistance levels, with corn strains differing from paddy strains, and a total of 14 haplotypes were reported in India, indicating a wide diversity in resistance mechanisms and levels.

Considering these factors, it becomes evident that the development of resistance to new classes of insecticides is a significant concern in fall armyworm management. This issue is compounded by the west-to-east movement of FAW populations, which has led to the spread of resistance alleles to countries like China, India, and Australia. In the on-ground reality, the efficacy of insecticides recommended for FAW control was depleting rapidly in India. Given that it has been around more than five years since the pest's initial appearance in India, there is an urgent need for effective Integrated Resistance Management (IRM) studies and continuous monitoring of resistance development in the Indian fall armyworm population. Additionally, standardizing baseline susceptibility for robust bioassay studies is essential in addressing this challenge.

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