Biological Forum – An International Journal **15(10): 112-115(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Assessing Pest Control Strategies for *Spodoptera frugiperda* in Maize

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(Received: 18 July 2023; Revised: 16 August 2023; Accepted: 14 September 2023; Published: 15 October 2023)
(Published by Research Trend)

ABSTRACT: Maize has become a primary food and feed crop in recent years due to its ability to provide sufficient quantity and quality for human consumption, animal and aquaculture production, and bioenergy production. The insect pest armyworm, *Spodoptera frugiperda*, has become a worldwide pest, causing tremendous losses to the maize crop. In our study, a resistant maize variety was used to evaluate a variety of conventional and unconventional control measures aimed at reducing armyworm infestations. Our findings demonstrated that chemical treatments such as Delegate and Coragen are highly effective, with Delegate exhibiting a significant dose-dependent response. Surprisingly, dry sand emerged as an environmentally friendly counter measure, reducing pest damage significantly. Our findings highlight the importance of multifaceted strategies that emphasize both effectiveness and sustainability in order to protect maize crops from the relentless fall armyworm.

Keywords: *Spodoptera frugiperda*, Maize, Pest Control, Sustainability, Effectiveness.

INTRODUCTION

Maize (*Zea mays* L.) is a pillar of global agriculture, serving as both a fundamental food crop and an essential source of animal fodder. Furthermore, maize's importance goes beyond mere sustenance. It has established its worth in the global biofuel industry and is increasingly being recognized for its industrial potential (Revilla *et al*., 2022). However, with this growing importance, particularly in countries such as India, where maize is essential for both livestock feed and crop residue utilization, comes a slew of new challenges. Among these, armyworms, particularly *Spodoptera frugiperda*, have been particularly damaging. Maize production has increased dramatically in recent years.

Maize, now the leading cereal crop in terms of production volume, is expected to dominate the global crop cultivation landscape by 2030 (Erenstein *et al*., 2022). Maize's numerous applications, which include food, feed, industrial utilities and biofuels are driving up demand. Maize's versatility is further demonstrated by its increasing use as a raw material for starch, ethanol, and a variety of other industrial products. Maize's demand as feed outpaces its consumption as a human food in the realm of livestock sustenance, particularly for poultry and pigs. Furthermore, maize is heavily relied on in sub-Saharan Africa and Latin America, emphasizing its contribution to nutritional sustenance and food security (Noort *et al*., 2022).

Rapid advancements in breeding technologies can be attributed to the commendable increase in maize yield potential. The domain has been transformed by advances in sequencing, genotyping, transformation, genome editing, and doubled haploid technology. These tools enable breeders to develop high-yielding maize varieties that are resistant to both biotic and abiotic stresses. Dive deeper into maize genomics to learn about the intricate genetic underpinnings that govern complex traits like drought resistance, disease resilience, and grain quality.

The Armyworm Adversary. While technological advancements provide cause for optimism, maize cultivation is not without its difficulties. Adversities caused by climate change have exacerbated pest and disease pressures on maize crops. The fall armyworm, an invasive pest, has emerged as a primary antagonist, with the potential to significantly reduce yields. To combat this pestilence, integrated pest management strategies including resistant varieties biological control measures cultural practices and insecticides have become critical (Matova *et al*., 2020).

However, the persistent threat of armyworms, particularly the insidious *Spodoptera frugiperda*, dominates much of Asia. The appetite of this noctuid moth for young maize shoots has resulted in yield losses exceeding 30% in some areas in a single season (Makgoba *et al*., 2021). Their onslaught manifests in two ways: direct consumption of maize plants and indirect contamination of stored grains, affecting yield and quality. They cause visible damage such as webbing between maize leaves, stunting vegetative growth, and reducing kernel formation (Chisonga *et al*., 2023). Their feeding frenzy can cause plant wilting and leaf rolling, which can lead to plant death.

Sustainable and strategic cultivation practices are critical for mitigating the effects of armyworms and other adversities. Planting maize in well-drained, irrigated soils capable of vigorous tillering is critical. Another important consideration is proper plant spacing, which reduces weed competition while increasing plant productivity. Historically, chemical and biological methods were heavily relied on to control armyworms. However, these pests are becoming increasingly resistant to traditional insecticides. Additionally, the potential health consequences of chemical residues in maize grain have raised concerns about increased cancer risks. As a result, the search for alternative and effective pest control methods is critical. While various alternatives have been proposed, ranging from bio-pesticides to organic solutions, none have consistently demonstrated superior efficacy. As a result, this study aims to assess the effectiveness of different chemical (including bio-pesticides, inorganic, and organic) and biological control measures against armyworm infestations in maize crops.

In essence, maize cultivation is undergoing a dynamic evolution driven by challenges and innovations. While pests such as armyworms threaten its productivity, technological advances in breeding offer hope. As maize solidifies its position as a global agricultural mainstay, continuous research and adaptive strategies will be required to ensure its long-term growth and contribution to global food security.

MATERIAL AND METHODS

The research was conducted within the research and development area of Suncrop Science Pvt Ltd in Hyderabad. The experimental setup consisted of ten treatment blocks, each measuring 3 meters in width and 1.8 meters in length. These blocks were separated by irrigation channels with a width of 90 centimetres. Each block housed two dosage-based treatment groups, each replicated thrice and the plants were spaced 45 centimetres apart.

The study aimed to evaluate the efficacy of various chemicals, including inorganic and biological pesticides, against the fall armyworm, explicitly utilizing the Sun-Ratna variety of maize. The planting was carried out using seeds known for their high germination rates. Generally, two seeds were sown per hill, maintaining a spacing of approximately 35 centimetres between them. Carbofuran granules were applied to provide initial protection to the sown seeds, which were then covered with soil. Subsequently, the experimental unit received irrigation.

A critical preparatory phase was carried out prior to the start of treatment to ensure the best possible conditions for the experiment to identify a model framework for treatment optimization. The designated study terrain was subjected to a comprehensive irrigation regimen, ensuring the essential balance of soil saturation required for facilitating the optimal uptake of the applied interventions by *Zea mays* L. To avoid potential anomalies caused by physiological disorders, the experimental unit was given supplied with fertiliser as per recommendation standards set by ICAR. This meticulous regimen was designed to maintain the plants physiological vigour and thus reduce experimental variability. This strategy ensures the credibility and reproducibility of the findings. This meticulous approach aimed to maintain the health and vitality of the plants, reducing variability, and enhancing the reliability of the research findings. The treatment application timing was carefully orchestrated considering prevailing weather conditions. Special attention was paid to avoid treatment runoff due to rain, as this could compromise the accuracy of the assessment. Treatments were strategically administered either early in the morning or late evening, aligning with weather patterns to ensure the treatments adherence and effectiveness.

The experiment was conducted with meticulous attention to detail, encompassing pre-treatment soil preparation precise fertilization, weather-sensitive treatment scheduling and strategic application timing to facilitate a robust and scientifically sound evaluation of the selected pesticides' efficacy against the fall armyworm.

Table 1: Treatment applied and their dosage.

	Treatment	Dosage (per ltr water)
T1	**Nirma powder**	5grms
T2	**Delegate**	0.7ml
T3	**Harpic**	9ml
T4	**Coragen**	0.4ml
T5	**Acid**	9ml
T6	**Control**	0
T7	**Nirma+ Neem oil**	5grms+6.5ml
T8	**Dry sand**	2grms
T9	**Acephate**	5grms
T10	**Neem Oil**	6.5ml

The study assessed the efficacy of various treatments against pests, particularly the fall armyworm. Nirma Powder at 5 grams per litre is traditionally used as a washing detergent. It has intriguing insecticidal properties, particularly against aphids and whiteflies. Its effectiveness is enhanced when combined with neem oil, which reduces pest populations in crops such as okra. Delegate is the commercial name for Spinetoram, a spinosad offshoot. It is administered at 0.7ml per litre. Its mode of action primarily disrupts pest nervous systems, making it particularly effective against armyworms and other lepidopteran pests.

Harpic, which contains primarily hydrochloric acid and is used at 9ml per litre, is more commonly known as a toilet cleaner. However, been tested against pests such as cockroaches and mosquitoes, with promising results. Coragen is the brand name for chlorantraniliprole, an insecticide that paralyzes insects by interfering with their muscle functions and has proven effective against armyworms and other pests.

The study also looked at the effects of acids at a dosage of 9ml per litre. Organic variants such as citric and acetic acids are known to have pesticidal properties against pests such as aphids and mites. However, extreme caution is advised because excessive use may harm beneficial insects and plant life. For comparison, no insecticides were used in the control group. Another

notable combination tested was Nirma with Neem Oil which was dosed at 5 grams plus 6.5 ml per litre. The duo is well-known for its extensive pest-control capabilities, with neem oil, derived from neem tree seeds, proving effective against pests such as beetles and mites.

Furthermore, 2 grams per litre of dry sand was used as a physical pest control medium. Though it acts as a barrier against pests such as snails and ants, its effect on soil moisture balance may have implications for plant growth. At 5 grams per litre, acephate is an organophosphate insecticide known for its effectiveness against pests such as aphids and caterpillars due to its effect on their nervous systems. Finally, in the evaluations, neem oil stood out as a broad-spectrum botanical insecticide when used alone and dosed at 6.5ml per litre.

RESULT AND DISCUSSION

Given the fall armyworm (*Spodoptera frugiperda*)'s global threat to maize crops, its management has become a top priority for agriculturalists and researchers alike. A wide range of materials, both conventional and unconventional, were tested to determine their efficacy against this pest. The need for such an effort stems from the fall armyworm's insidious nature, which, in our study, manifested its presence only 16 days after maize crop sowing, echoing the findings of Varshney *et al*. (2021).

Nirma Powder: Despite popular belief in the insecticidal properties of some detergents, the Nirma treatment showed no discernible reduction in armyworm infestation. Furthermore, leaf damage indicated that plant health was compromised. Regarding density and canopy growth, the overall plant vitality appeared inferior to the other treatments. This finding calls into question the use of such detergents as a sole line of defence against pests.

Delegate: The Delegate treatment demonstrated remarkable efficacy in our study. The superior plant density and potent pest management abilities are consistent with Roy *et al*. (2021) findings. Our data also suggests a dose-dependent relationship, with 1.5 ml applications being more potent than 0.7 ml counterparts.

Harpic: While the reduction in pest attacks following this treatment is encouraging, the appearance of dark stripes on border plants is concerning. This anomaly suggests that potential phytotoxic effects should be investigated further. However, the superior performance of lines R1 and R2 indicates the potential benefits of early pest intervention.

Coragen: According to the findings of Varshney *et al*. (2021), Coragen demonstrated commendable efficacy. Early-stage application appeared to be critical in suppressing the pest and subsequent applications only accentuated this effect. Importantly, as evidenced by robust canopy growth, these advantages did not jeopardize plant health.

Acid: While the acid treatment may somewhat deter pests, it may also harm plant health. The cellular damage at the leaf tips is reminiscent of phytotoxic reactions, which is a limitation to its potential use.

Nirma + Neem oil: The combination of Nirma and Neem oil appeared to exacerbate plant health issues. While studies like Siazemo & Simfukwe (2020) recommend Neem oil for its pesticidal properties, its combination with Nirma may have unintended consequences. While Neem oil has been lauded for its pesticidal properties, as demonstrated by Siazemo & Simfukwe (2020), our data suggests that its mode of action may be more preventive than curative.

Dry Sand: Our findings with dry sand highlight its potential as a non-chemical countermeasure. According to Chawanda *et al*. (2023), dry sand is an effective non-chemical countermeasure against fall armyworms in maize. The study discovered that applying dry sand to maize plants disrupts larvae feeding and movement, dehydrates them, and reduces their survival and growth.

Acephate: Acephate demonstrated commendable efficacy among non-insecticidal competitors. Its ability to reduce crop damage and control pest populations reaffirms its reputation as a potent insecticide.

Control Treatment: As expected and consistent with several literature reports, the untreated control was a testament to the fall armyworm's unrelenting wrath, emphasizing the critical need for effective management strategies. While chemical insecticides such as Delegate and Coragen have proven effective against the fall armyworm, their environmental and potential health consequences must not be overlooked.

The diverse outcomes of the various treatments shed light on the complexities of pest control, particularly against the formidable fall armyworm. The efficacy of Delegate and Coragen, both chemical insecticides demonstrates the potency of these formulations (Deshmukh *et al*., 2020). Delegate's (Spinetoram) dose-dependent response underscores the need for fine-tuning applications to maximize benefits while potentially lowering associated risks. However, while these insecticides are effective, they may have negative environmental and health consequences (Kumar *et al*., 2022).

The unexpected efficacy of Dry Sand reveals a potentially eco-friendly and cost-effective solution. Dry sand acts as a physical barrier against infestation by obstructing the respiratory passages of larvae (Chawanda *et al*., 2023). This solution is especially appealing in areas where access to sophisticated insecticides may be limited, or for farmers looking for sustainable pest management techniques. Overall, the botanical performance was disappointing. Both Nirma alone and in combination with Neem oil were ineffective against the pest, with the latter even having a negative impact on plant health. Despite its effectiveness in preserving plant health, neem oil did not significantly reduce pest populations. This raises concerns about the practical applicability of these treatments against the fall armyworm in maize, particularly when compared to the noticeable results of chemical insecticides and even dry sand.

The notable performance of acephate demonstrates its potential role in combating severe infestations. Its low cost and ease of use may make it an appealing option

for large-scale applications, but more research is needed to understand any long-term implications. While Harpic showed some promise, the appearance of dark stripes on some plants after treatment may warrant additional research to determine any latent phytotoxic effects. Similarly, despite being ineffective against the pest the Acid treatment caused cellular damage in some plants, emphasizing the need for caution and highlighting the challenges of repurposing household substances for agricultural interventions.

The experiment's comprehensive evaluation highlights the urgent need for additional research to confirm these findings, calibrate dosages and uncover any potential risks. The variety of results, combined with the ever-increasing threat of the fall armyworm, emphasizes the importance of multifaceted strategies that combine chemical, physical, and botanical interventions. Furthermore, the overarching goal should be to establish sustainable and safe methodologies supporting crop health and yield.

CONCLUSIONS

The increasing risk posed by the fall armyworm (*Spodoptera frugiperda*) to maize crops necessitates immediate and effective intervention strategies. Our evaluation of a range of conventional and unconventional treatments provided valuable insights into their effectiveness against this formidable pest. Conventional chemical insecticides particularly Delegate and Coragen demonstrated significant efficacy in controlling the armyworm, with Delegate's effect being dose-dependent. However, there are still concerns about these chemical solutions' environmental and health effects.

Interestingly, dry sand emerged as a promising environmentally friendly alternative demonstrating the potential of non-chemical pest management interventions. The use of household substances such as Nirma and Harpic, on the other hand raised concerns about plant health and practical applicability, emphasizing the complexities of repurposing such items for agricultural purposes. Although the pesticidal properties of Neem oil are well known, our findings called into question its efficacy as a curative measure, particularly when combined with certain detergents. Given its cost-effectiveness and potency, acephate's performance emphasized its potential for large-scale applications, albeit with a cautionary note on understanding its long-term effects.

Given our findings, it is clear that a comprehensive approach to managing the fall armyworm is required. This strategy should include a combination of chemical, physical, and botanical interventions, with a focus on sustainability, safety, and preserving the integrity of maize crops. The study emphasizes the ongoing need for research in this area, with the goal of protecting our crops and ensuring that our intervention strategies are in accordance with the environment.

FUTURE SCOPE

The promising treatment identified in this study will be suggested for further consideration in controlling pests in the maize yield and minimizing ecological loss.

Acknowledgement. The authors are thankful to Suncorp Private Limited for providing maize seeds and funding to carry out the experiments.

Conflict of Interest. None.

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How to cite this article: Ajay Bogati, Srushtideep Angidi and Sai Manogna Adapa (2023). Assessing Pest Control Strategies for *Spodoptera frugiperda* in Maize. *Biological Forum – An International Journal*, *15*(10): 112-115.