Literature Generated Fall Armyworm (*Spodoptera frugiperda*) Thresholds for New Zealand Maize and Sweet Corn Growers

Fall armyworm thresholds for New Zealand maize and sweet corn growers

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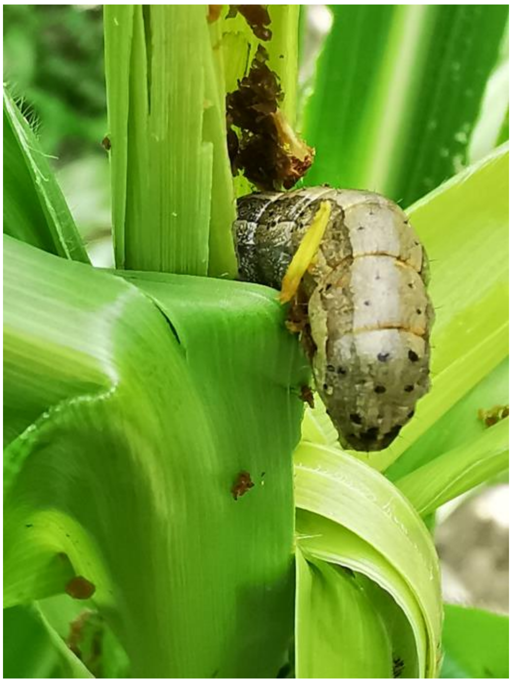

Report for Foundation for Arable Research

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Contents

1. Executive Summary

Fall armyworm (FAW), *Spodoptera frugiperda* Smith & Abbot, 1797 (Lepidoptera: Noctuidae), is a pest of corn/maize and other crops that is native to the Americas and has reached Africa, India, China, Japan, SE Asia, Indonesia and Australia (IPPC-Secretariat 2021). It was first detected in New Zealand (NZ) in Tauranga in March 2022 and is now known to be established over widespread areas of the North Island and the Tasman and West Coast regions of the South Island.

This pest species is highly polyphagous and has been reported as attacking over 350 commercial and non-commercial hosts across 76 plant families. Despite this wide host range FAW shows a distinct preference for graminaceous plants. The fall armyworm's preference for graminaceous plants makes it a major pest for crops such as corn (*Zea mays*), sorghum (*Sorghum bicolor*), rice (*Oryza sativa*), wheat (*Triticum aestivum*) and sugar cane (Saccharum spp.).

Severe fall armyworm damage to maize and sweet corn crops can reduce production by more than 70%.

Due to the potential threat to New Zealand maize (silage and grain) and Sweet corn crops we undertook a literature search within Scopus using the following terms;

1. "*Spodoptera frugiperda* AND (yield OR impact OR damage OR econom* OR losses)", and**;**
2. "*Spodoptera frugiperda* AND (pesticide OR insecticide OR management) AND yield"

These search terms yielded 2,197 (Search 1) and 284 (Search 2) peer-reviewed journal articles, respectively. Following a examination of each of the titles and abstracts 105 of the articles were followed up for further examination. Of these publications three, Overton et. Al (2021), Bilbo *et al.* 2020 and She *et al.* 2023 contributed very heavily to the conclusions in this report. Overton *et al*. reviewed all available scientific literature related to global crop impacts, yield losses and action thresholds for fall armyworm. This seminal review, and reference contained within has formed the basis for currently used action thresholds in maize and sweet corn crops globally. Bilbo *et al.* (2020) while not included in Overton et. al (2021) contributed to the formulation of FAW treatment thresholds in late planted BT and non-BT maize crops. And finally, the recent publication of Shi et al. (2023) resulted in a better understanding of the impacts of FAW larval feeding in sweet corn crops.

When compared to the results of the literature search the Foundation of Arable Research's (FAR) current recommended FAW treatment threshold recommendations (see below) for maize and sweetcorn were fall within the range of those previously reported. The conclusion of this review is that FAR's published recommendations are fit for purpose.

Fall armyworm treatment threshold recommendations as proposed by the Foundation of Arable Research. Research.

Fall armyworm treatment threshold recommendations		
	Crop growth stage	**Threshold**
Maize	Seedling	≥5% of plants are cut.
	Early whorl (knee high)	≥20% of plants are infested.
	Late whorl (Shoulder high)	≥40% of plants are damaged, and larvae are present
	Tasselling/early silking	≥20% of plants are infested
Sweetcorn	Seedling	≥5% of plants are cut.
	Early whorl (knee high)	≥20% of plants are infested.
	Late whorl (Shoulder high)	≥40% of plants are damaged, and larvae are present
	Tasselling/early silking	≥5% of plants are infested

2. Background

2.1 Background 1

Fall armyworm (FAW), Spodoptera frugiperda Smith & Abbot, 1797 (Lepidoptera: Noctuidae), is a pest of corn/maize and other crops that is native to the Americas and has recently reached Africa, India, China, Japan, SE Asia, Indonesia and Australia (IPPC-Secretariat 2021). It was first detected in New Zealand (NZ) in Tauranga in March 2022 and is now known to be established over widespread areas of the North Island and the Tasman and West Coast regions of the South Island. Due to long range flight behaviour FAW is also commonly observed through out the late summer in the lower North Island and eastern areas of the upper South Island during late summer and Autumn but is highly unlikely to be overwintering regions.

Fall armyworm is a highly polyphagous pest that has been reported as attacking over 350 commercial and non-commercial hosts across 76 plant families. Despite this wide host range FAW shows a distinct preference for r graminaceous plants. The fall armyworm's preference for graminaceous plants makes it a major pest for crops such as corn (*Zea mays*), sorghum (*Sorghum bicolor*), rice (*Oryza sativa*), wheat (*Triticum aestivum*) and sugar cane (Saccharum spp.) (Luginbill 1928, Pashley 1988). It feeds primarily on whorl leaves, and in corn, it may also infest the ears, especially during large infestations (Buntin 2008). Throughout FAW's native and invasive range this feeding causes significant economic losses to crop producers (Overton *et al.* 2021). These losses can be classified into four categories: (1) direct and indirect yield loss, (2) cost of management, (3) quality loss, and (4) impacts on trade arising from phytosanitary measures required by importing countries (Murray *et al.*, 2013; Day *et al.*, 2017).

Maize and sweet corn are the two crops most likely to be impacted by FAW in New Zealand. In 2024 approximately 72, 550 ha (21,630 ha grain crops, 50,920ha silage crops) of maize (Anon 2024a) and 3300 ha of sweet corn (Anon 2024b) were grown in New Zealand. If significant FAW infestations occur in these crops during periods of susceptibility, there is potential for significant damage and associated economic losses to occur. Data from other countries in which FAW is present shows that the economic losses to maize and sweet corn crops caused by the FAW attack can be between 15 and 76% (Guo *et al.* 2018; Hruska and Gould 1997, Marenco *et al* 1992.). The wide range of reported impacts is due to the complex interactions host crop use e.g. grain verses silage, plant growth stage, FAW ecology and population phenology, and the environmental (Buntin *et al.* 1986).

To ensure that crops remain profitable crop yield needs to be maximised while other inputs such as insecticide treatments are keep to a minimum. Apart from the economic costs it is also important to keep insecticide inputs to a minimum to minimise the evolution of insecticide resistance, and environmental, and non-target impacts. The former is particularly important as maize and sweet corn growers currently only have access to a singe registered active for the control of FAW. Pesticide resistance has rapidly evolved in FAW populations e.g. GUI *et al.* (2022). Multiple applications of a single insecticide group for control of FAW across growing seasons will rapidly lead to the loss of the only registered insecticide for control of FAW. Effective FAW treatment thresholds enable growers to make informed decisions that can reduce they cost of growing maize and sweet corn while preserving ecosystem services e.g. parasitoid and the effectiveness of insecticides.

In this report we will review the available scientific literature on economic action thresholds for the control of FAW on maize and sweet corn crops. If needed the results will be used to reformulate the currently recommended FAW treatment thresholds for New Zealand maize and sweet corn crops.

3. Methods

To identify the impact of FAW on the yield loss of crops, we broadly followed the methodology of Overton et. Al (2021). We used the following search terms in Scopus and if needed Google Scholar: The time period examined in Scopus ran from 1971 to January 2025

(1) "*Spodoptera frugiperda* AND (yield OR impact OR damage OR econom* OR losses)"

(2) "*Spodoptera frugiperda* AND (pesticide OR insecticide OR management) AND yield"

(3) "Spodoptera frugiperda AND (maize or OR corn) AND (yield OR impact OR damage OR econom* OR losses)"

(4) "Spodoptera frugiperda AND (maize or corn) AND (pesticide OR insecticide OR management) AND yield"

The literature searches were conducted between August and December 2024, respectively. **and** yielded which yielded 2,197 **(1)** and 284 **(2)** peer-reviewed journal articles, respectively. We conducted a second literature search terms 3 and 4 to further narrow our results. Search terms 3 and 4 narrowed the number of records to 1123 and 183 respectively. This resulted in 1123 The titles, abstracts and if needed methods of this subset of records was then read to to identify which articles examined insecticide efficacies against FAW, typically included a positive control (i.e. an insecticide previously identified to have high efficacy, or the yield derived from a plot that was not infested with FAW), which could then be used to calculate yield loss. Yield loss data were extracted or, when not explicitly provided, calculated based on the available information. Calculations of the proportion of yield loss were determined by dividing the observed yield by the positive control (or uninfested plot) yield. If a yield loss range was expressed (e.g. 20–50%), we calculated the mean yield loss (e.g. 35%).

Within each article, we scrutinised the text and reference list to identify other potential references which may not have been captured through our Web of Science search. To identify industry reports or resources. Data that was relevant to this review of literature was then compiled in Table 1 to enable it to be compared to current control threshold recommendations.

4. Results and Discussion

As of 2025 the Scopus literature search using terms 1 and 2 identified 2481 unique publications. This is an increase of 1175 records between 2021 and January 2025. This rapid increase in the number of publications reflects the speed at which FAW has invaded new areas around the globe. However, while there was a vast increase in the number of manuscripts containing the appropriate search terms being published, the number of those which are designed to elucidate economic injury and treatment thresholds remains small. As such the gold standard review publication in this area or research is still Overton *et al.* (2021) (and the references contained within). Results of studies published between 2021-2025 which do give reliable thresholds and damage estimates (e.g. Shi *et al.* (2023), Qi *et al.* (2024)) are comparative to those Outlined in Overton *et al.* (2021).

4.1 Damage to Maize

As with Overton *et al.* (2021) we found no studies reliably quantifying yield losses from FAW prior to 1980. Since then, the impacts of FAW feeding in maize were reported a broad geographic range over both it's native and invasive ranges. Regional publishing spikes in damage reports can be used as a proxy for range expansion. For instance, since the first observation of FAW in China in late 2018 133 manuscripts were identified as being published between 2010 and January 2025 using the maize limited search terms outlined in the methods section). Generally, there was a large variation in the mean reported crop losses of between 17% and 35.0% (Table 1). FAW yield losses were highest in maize where management practices were not specified (i.e. management was unknown 34% followed by unmanaged non-genetically modified crops 25.0%, and non-genetically crops managed with insecticides. Many studies where management practices were unspecified were derived from farmer surveys. Mean yield losses were low for GM maize managed with and without insecticides 11% and 13%, respectively (Table 1).

4.2 Damage to Sweet corn

As with maize, sweet corn can experience significant yield losses due to FAW feeding (up to 76.9%; e.g. Marenco *et al.*, 1992, Shi *et al.* 2023), with a mean reported crop loss of approximately 25%. Feeding damage from FAW infestations during the early (V1-6) and mid-whorl stages (V7–V9), resulted in significant reductions in plant height, leaf area, and stalk diameter (e.g. Marenco *et al.*, 1992). Overton *et al.* (2021) observed that, protecting plants from FAW damage during the late whorl stage (V9-R1) by using insecticides results in higher yields and also reduced percentages of ears damaged, and was more important than protecting plants at the early (V1–V6) and mid whorl (V7–V9) stages.

Table 1: Summary of current New Zealand FAW treatment thresholds for maize and sweet corn and previous global studies previously used to derive FAW control recommendations.

Current New Zealand recommendations[1]	Crop growth stage	Threshold[1]
Maize	Seedling	≥5% of plants are cut.
	Early whorl[3] (knee high)	≥20% of plants are infested.
	Late whorl (Shoulder high)	≥40% of plants are damaged, and larvae are present
	Tasselling/early silking	≥20% of plants are infested
Sweetcorn	Seedling	≥5% of plants are cut.
	Early whorl (knee high)	≥20% of plants are infested.
	Late whorl (Shoulder high)	≥40% of plants are damaged, and larvae are present
	Tasselling/early silking	≥5% of plants are infested

Studies used to derive control recommendations[4]

Crop	Location	Crop growth stage	FAW Growth stage	Reported threshold
Maize	Maryland, USA	Mid-whorl and late-whorl	2nd instar	2 larvae/plant in 1988, 1989 and 1990
	Maryland, USA	Late-whorl	2nd instar	2 larvae/plant in 1988 and 1990
	Espinal, Colombia[5]		-	2.6 larvae per 10 plants
	Espinal, Colombia[5]		-	1.9 larvae per 10 plants
	Espinal, Colombia[6]		-	2.8 larvae per 10 plants
	Nicaragua		-	23-63% of plants infested
	Quevedo, Ecuador	Seedling (2 weeks after germination	-	15% of plants infested
	Quevedo, Ecuador	Seedling (3 weeks after germination	-	21% of plants infested
		Seedling (4 weeks after germination	-	23% of plants infested
		Seedling (5 weeks after germination	-	26% of plants infested
		Seedling (6 weeks after germination	-	50% of plants infested
	Nicaragua			2% of plants infested
	Brazil	Stages equal to or less than 30 days after planting		20% of plants with damaged leaves
	Brazil	Stages between 40 and 60 days after planting		10% of plants with damaged leaves
	Arkansas, USA			3 to 6 larvae per whorl of maize
	Africa	Early whorl		Damage/injuries reach 20%
	Africa	Late whorl		Damage/injuries reach 40%
	Africa	Tassel and silk stage		No effective treatment due to insecticide toxicty
	Africa	Early whorl		Damage/injuries reach 20% of plants
	Africa	Late whorl		Damage/injuries reach 40% of plants
	Africa	Tassel and silk stage		Damage/injuries reach 20% of plants
Sweetcorn	China[7]	V4-V6		7-15% of plants infested
		V8-V10		17-33% of plants infested
		V12-V14		25-46% of plants infested
		Vt-VR		12-14% of plants infested

[1]Treatments should ideally be targeted and small size larvae (Instars 1-3) as these live on the exposed parts of the plants and are easier to control; [2]Taken from grey literature e.g. FAR, (see references for links to webpages); [3]Once larger larvae (instars 3-5) enter the whorl it is difficult to control them due to both getting product to them and their larger size; [4] Table derived from Barrios *et al.* (2020), Overton *et al.* (2021) and Shi *et al.* (2023) and reference contained therein; [5]non-Bt maize; [6]Bt maize; [6]Thresholds for small holder farmers. [7]Preprint of Shi *et al.* 2023.

4.3 Are current treatment threshold recommendations fit for purpose

While almost all action thresholds and economic injury levels for FAW in maize and sweet corn have been generated for crops grown in subtropical and tropical climates (Table 1) they are still relevant in the New Zealand context. In current climates FAW are predicted to occur year-round in the northern third of the North Island and in warmer years may also persist year-round in some coastal parts of the southern North Island and northern South Island (Phillips et al. 2024). Except for Northland all areas of the North and South Islands of New Zealand where FAW occur are temperate (NIWA 2025). However, the summer temperature in the regions outside Northland will be warm enough to support populations of FAW should they arise.

Treatment thresholds for maize and sweet corn are not straight forward as they vary with crop growth stage (Overton et al. (2021). Generally, seedlings and developing reproductive structures on maize and sweet corn plants are the most vulnerable to FAW larval feeding and least able to recover from damage. While late whorl stage is mor resilient and better able to recover from attack. However, this can also be complicated by planting date with later crops being more at risk of significant FAW infestation due to locally generated and/or migratory flights of FAW adults and being unable to grow away from damage due to a short growing period being available (e.g. Olyme 2022; Reay-Jones 2025). Furthermore, the size (e.g. egg-2nd instar vs 3-prepupae) and feeding location (e.g. leaf or whorl or cob) of targeted FAW larvae can significantly impact upon the success of the intervention (e.g. insecticide). However, if crop scouting is carried out on a regular basis and growers remain vigilant to FAW this will enable the identification of problems while larvae are small and vulnerable. Table 1 shows that New Zealand threshold recommendations for all growth stages maize and sweet corn or fall within the ranges outlined in Overton *et al.* (2020) (and reference contained within)). Shifting of thresholds either up or down are unlikely to result in reduced damage to crops, or improvements in control and profitability.

5. Recommendations

When compared to the results of the literature search the Foundation of Arable Research's (FAR) current recommended FAW treatment threshold recommendations (Table 1) for maize and sweetcorn were fall within the range of those previously reported. The conclusion of this review is that FAR's published recommendations are fit for purpose and will provide for adequate control of FAW in maize and sweet corn crops throughout New Zealand. However, thresholds and control measures will need to be used in conjunction with the appropriate scouting techniques. Treatments will also need to be targeted at early FAW life stages preferably prior to them moving into concealed feeding sites such as the whorl.

6. Acknowledgements

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Appendices

6.1 Appendix 1

Data fields used to guide compilation of relevant experimentally derived or reported yield loss data as a result of fall armyworm infestation reported in the published and grey literature adapted from Overton *et al.* (2020).

Data field	Description
Scientific plant name	*Genus species*
Common plant name	Names commonly used to identify the plant
Context	Context of the plant: commercial/non-commercial
Proportion of yield loss reported	Yield loss (reported as a proportion)
Site	Site where yield loss was reported (if applicable; e.g. Name of experimental research station)
Climactic/topographic zone	The climactic/topographic zone where the yield loss was reported (if applicable)
Country	Country where yield loss was reported
Latitude	Latitude of the site
Longitude	Longitude of the site
First FAW detection	Year FAW was first detected at this location
Year	Year the experiment/yield loss was reported/determined
Assumptions	Any assumptions made to determine/calculate yield loss
Confidence level	Confidence level of the reported/calculated yield loss (**high** = yield loss has been experimentally derived, **medium** = a yield loss has been inferred from the damage levels assessed in the host OR surveys/reports of farmers perception of yield loss, **low** = personal communication of a yield loss reported in a journal article where no data is available or published to verify the accuracy of yield loss)
Management strategy	Management strategy/strategies used: insecticides, biological control, cultural, GM (*Bt*), variety (variety of crop sown), unmanaged, or unknown. Studies that were classified as ‘unknown’ were either due to the reported yield losses derived from review papers where the original articles could not be accessed, or they were mean yield losses reported from farmer surveys and did not capture the variety and extent of management strategies in place. For some studies, multiple management strategies were utilised (e.g. insecticide treatment in a GM crop).
Source/reference	Source of information

6.2 Appendix 2