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Evaluation of *Doru lineare* (Dermaptera: Forficulidae) effectiveness against *Spodoptera frugiperda* (Lepidoptera: Noctuidae) and its potential protection of maize seedlings

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Evaluación de la efectividad de *Doru lineare* (Dermaptera: Forficulidae) contra *Spodoptera frugiperda* (Lepidoptera: Noctuidae) y su potencial protección de plántulas de maíz

RESUMEN. El "gusano cogollero", *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), es una plaga importante de muchos cultivos, particularmente del maíz. Para su control, las plantas modificadas genéticamente y los plaguicidas sintéticos son las principales estrategias empleadas, lo que ha provocado la aparición de poblaciones resistentes a ambos métodos. La tijereta *Doru lineare* (Eschscholtz) (Dermaptera: Forficulidae) ha sido observada en Argentina consumiendo tanto huevos como larvas de los primeros estadios de *S. frugiperda*. Para contribuir a la implementación de un sistema de manejo racional de plagas, se realizaron pruebas en jaulas de campo para evaluar la eficiencia de *D. lineare* como depredador contra *S. frugiperda* y su potencial protección de las plántulas de maíz de la plaga. Los resultados de las pruebas mostraron que la tasa de supervivencia de las larvas de *S. frugiperda* se vio significativamente afectada por la presencia de tijeretas. Cuando se liberaron dos tijeretas en una jaula que contenía diez plántulas de maíz infestadas con veinte larvas de *S. frugiperda*, después de diez días, el peso seco de las plantas fue significativamente mayor y el nivel de daño fue significativamente menor en comparación con aquellas sin liberación de tijeretas. Estos resultados confirman el efecto protector de *D. lineare* contra *S. frugiperda*, lo que sugiere que las tijeretas deben considerarse depredadores prometedores en las estrategias de control por conservación para cultivos de maíz.

PALABRAS CLAVE. Consumo de presas. Gusano cogollero. Nivel de daño. Tijeretas. *Zea mays*.

ABSTRACT. The "fall armyworm", *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), is a significant pest of many crops, particularly maize. To control it, genetically modified plants and synthetic pesticides are the main strategies employed, which has led to the emergence of resistant populations to both methods. The earwig *Doru lineare* (Eschscholtz) (Dermaptera: Forficulidae) has been observed in Argentina consuming both eggs and early instars *S. frugiperda* larvae. To contribute to the implementation of a rational pest management system, field cage tests were conducted to assess the efficiency of *D. lineare* as a predator against *S. frugiperda* and its potential protection of maize seedlings from the pest. The results of the tests showed that the survival rate of *S. frugiperda* larvae was significantly affected by the presence of earwigs. When two earwigs were released into a cage containing ten maize seedlings infested with twenty *S. frugiperda* larvae, after ten days, the dry weight of the plants was significantly higher and the level of damage was significantly lower compared to those without earwig release. These results confirm the protective effect of *D. lineare* against *S. frugiperda*, suggesting that earwigs should be considered as promising predators in conservation control strategies for maize crops.

KEYWORDS. Earwigs. Fall armyworm. Level of damage. Prey consumption. *Zea mays.*

INTRODUCTION

The “fall armyworm”, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) (FAW), is native to the American continent and causes significant yield losses to various economically important crops, such as corn, rice, and cotton (Cokola et al., 2021; Higo et al., 2022; Kenis et al., 2022). Recently, it has invaded almost the entire African continent, China, south-eastern Asia, Korean Peninsula, Japanese Archipelago, and Oceania (CABI, 2022; EPPO, 2022; Kenis et al., 2022). Due to its broad host plant range and polyphagous habits, FAW is considered one of the most destructive pests of maize in the Americas, and likely worldwide (Assefa & Ayalew, 2019; Kenis et al., 2022).

Typically, the larvae cause significant damage to maize by consuming its leaves, reducing the plant’s photosynthetic area and potential yield. The most severe damage, however, occurs when they attack seedlings, as they can affect the meristematic tissues, resulting in a decrease in plant stand and maize production (Ayala et al., 2013). During seasons with drought, the FAW larva can damage the plants in V_4-V_5 (four to five unfolded leaves) vegetative stage, by feeding as an endophyte inside the stem of the collar region. The destruction of the whorl can result in seedling death or the loss of the primary tiller and the formation of secondary tillers, as well as a change in plant architecture (Buntin, 1986). The larva of *Spodoptera frugiperda* can also directly damage the grains during the reproductive stages of the plants, such as when the ears are developing (Buntin, 1986; Kenis et al., 2022).

FAW has traditionally been controlled through the use of synthetic insecticides (Campos et al., 2011; Kenis et al., 2022) and transgenic crops that produce insecticidal proteins from *Bacillus thuringiensis* (Bt) (Kenis et al., 2022). However, the efficacy of these methods is limited for several reasons: a) larvae often hide deeply within the maize whorl, making them difficult to reach with insecticides; b) some populations have evolved resistance to various insecticides, rendering them less effective; and c) it has also developed field-evolved resistance to Bt maize in highly productive areas (Storer et al., 2010; Carvalho et al., 2013; Farias et al., 2014; Huang, 2021; Kenis et al., 2022).

Dermaptera, commonly known as “earwigs”, are common in agroecosystems and have been considered both harmful (as phytophagous organisms) and useful (as predators of pest species) due to their euryphagous habits (Dib et al., 2020; Kirstová et al., 2019; Romero Sueldo & Virla, 2009a). Several species of Forficulidae, such as *Forficula auricularia* Linnaeus, *Doru taeniatum* Dorhn, *D. lineare* (Eschscholtz), and *D. luteipes* (Scudder), have been shown to be efficient predators in various cropping systems (Cañellas et al., 2005; Dib et al., 2016; Jones et al., 1988; Naranjo-Guevara et al., 2017; Romero Sueldo et al., 2014; Weiss & McDonald, 1998). For example, *D. taeniatum* and *D. luteipes* have been found to be the most abundant predators collected on maize plants in both southern Mexico and Brazil, respectively (Campos et al., 2011; Chapman et al., 2000). Additionally, some earwig species, such as *D. luteipes*, have been shown to tolerate novel insecticides better than their preys (i.e., FAW) (Campos et al., 2011). On the other hand, earwigs that feed on infected FAW larvae can spread diseases, like the nucleopolyhedrovirus (Castillejos et al., 2001).

The earwig *D. lineare* is widely distributed in agricultural regions of South America. Several aspects of its biology are known, and an artificial breeding methodology has been reported (Romero Sueldo & Dode, 2001; Romero Sueldo & Virla, 2009b). This earwig is an opportunistic omnivore [according to Coll & Guerson’s (2002) definition], and laboratory studies (Romero Sueldo & Virla, 2009a) show that its behavior is biased toward zoophytophagy (i.e., plant-feeding carnivores). *Doru lineare* has been observed preying on FAW egg masses in corn crops (Mariani et al., 1996), and laboratory functional response studies have demonstrated its effectiveness as a predator of small FAW larvae (Romero Sueldo & Virla, 2009a; Romero Sueldo et al., 2010). Laboratory tests showed that *D. lineare* has a marked preference for consuming FAW eggs and larvae, and can also feed on the pollen of corn plants. However, leaf consumption was not observed (Romero Sueldo & Virla, 2009a). Nymphs can eat an average of 316.5 eggs or 315.5 neonate FAW larvae as they develop (Romero Sueldo & Virla, 2009a), and a single adult can eat up to 20 first-instar larvae in two hours when the density of the worms in the arena [6 cm (diameter) by 0.5 cm (depth) Petri dishes] is lower than 100 larvae (Romero Sueldo et al., 2010). In the northwest area of Argentina, farmers associate the presence of this earwig in subsistence corn crops with lower FAW attack levels and lower yield losses (Romero Sueldo & Virla, pers. obs.).

Given the annual damage caused by the FAW, the economic, environmental, and food safety impacts of using pesticides for its control, the development of insecticide resistance, and the need to develop alternative strategies for its control, the aim of this study was to assess the effectiveness of *D. lineare* against FAW and its potential protective effect on maize seedlings. In this context, it is predicted that the presence of the earwig will significantly reduce the number of alive FAW larvae and, as a result, the damage to maize plant.

MATERIAL AND METHODS

Insect source and rearing

Colonies of both FAW and *D. lineare* were established from specimens collected in the summer 2012 from a cornfield located in El Manantial, Tucuman province, Argentina (26°49'50.2"S, 65°16'59.4"W, 495 m a.s.l.). The collection of these specimens was carried out with permission (permit nº 71-11, Tucumán province).

Adults of the FAW were housed in cylindrical polyethylene terephthalate (PET) cages (30 cm high x 10 cm in diameter). A nylon mesh fabric was used to cover the top for ventilation. These cages contained pieces of paper for females to rest and lay eggs on, and a cotton wick saturated with a honey and water solution (1:1 vol/vol) was provided as food. The cages were checked daily for egg masses, which were collected and placed in glass tubes (12 cm high x 1.5 cm in diameter). After hatching, the neonate larvae were placed in 250-cc plastic pots containing an artificial diet made up mainly of bean flour, wheat germ, and beer yeast (Romero Sueldo et al., 2010). The pots were covered with a nylon mesh cloth until the larva reached the third instar, at which point they were isolated in glass tubes (12 cm high x 1.5 cm in diameter) to prevent cannibalism.

Specimens of *D. lineare* were reared following the protocol described by Romero Sueldo & Virla (2009b). Earwig colonies were kept in plastic cages (30 x 25 x 8 cm) with corrugated cardboard pieces as shelters. Food was provided in the form of commercial cat food and a cotton wick saturated with a solution of honey and water (1:1 vol/vol) (Romero Sueldo & Virla, 2009b). A maximum of twenty couples were kept in each cage to prevent cannibalism. The cages were checked daily, and eggs were carefully transferred with the female to a 250-cc plastic pot closed with a cotton plug, containing a plastic soda cup filled with wet cotton. Nymphs were moved to larger plastic cages (as described above) ten days after hatching to continue their development.

The insect cultures were carried out in the laboratory at a temperature of 26 ± 2 °C, a photoperiod of 14:10 (L:D), and a relative humidity of 70%.

Experimental design

The trials were conducted in 60 x 60 cm plots that had previously been weeded and sieved to eliminate any geophilic pests. The plots were covered with cages (60 x 60 x 50 cm) made of 1.3 cm PVC pipes and covered with organdy cloth. In each plot, 10 corn plants (Leales 25 plus® variety) were homogeneously sown.

When the maize seedlings reached the V_2 (two unfolded leaves) phenological stage, approximately ten days after sowing, the following treatments were applied: 1- control (healthy, uninfested plants); 2- infested control (plants infested with two neonate FAW larvae each); 3- a density of one adult earwig for every 20 FAW larvae; and 4- a density of two adult earwigs for every 20 FAW larvae. A total of 10, 20, 20, and 20 replicates were performed for each treatment, respectively.

To generate the “infested plants”, two neonate FAW larvae (first instar larvae less than 12 h old) were placed on each plant using a fine paintbrush to simulate a high level of infestation (see discussion section). In the treatments involving predator evaluation, female earwigs were released into cages 24 hours after maize plants were infested. The earwigs were randomly chosen from the breeding colony and starved for 48 hours before the experiments to ensure that they were in a similar physiological state.

Ten days after the treatments were set up (the release of earwigs), the cages were carefully examined and the following actions were carried out: a) the number of alive larvae was recorded to assess predatory activity; and b) the aerial parts of each plant were cut off at ground level with a razor blade, labeled, bagged, and transported to the laboratory for both visual damage assessment and dry weight determinations.

The effectiveness of *D. lineare* as a predator was determined by dividing the number of surviving FAW larvae at the end of the assay by the initial number of FAW larvae at the beginning of the assay (survival rate). The level of damage and loss of biomass (i.e., the epigeal part of the plant's dry weight) of each maize plant was used to determine the potential protective effect of *D. lineare*. To do this, each maize plant was carefully examined for FAW larval damage and assigned a damage level using an adapted version of a visual scale for maize damages proposed in a previous study (Table I) (Fernández & Expósito, 2000). Damage levels 4 and 5 are the most significant because they involve injuries to the apical meristem and are associated with significant yield losses. To determine the dry weight, maize seedlings were dehydrated in an oven at 50 °C for five days until they reached a constant weight. The dry weight of each maize plant was then recorded using a digital precision scale (Shimadzu AUY220).

Table I Visual scale to estimate the damages caused by *Spodoptera frugiperda* to maize plant. Modified from Fernández & Expósito (2000)

Damage level	Leaf damage characteristics
0	No damages
1	Only 1-3 damages, like small windows (i.e., less than 5mm each)
2	1-3 damages between 5 and 10 mm each
3	More than 4 damages less than 10 mm and/or 1-3 damages greater than 10 mm.
4	4-6 damage greater than 10 mm and/or whorl destroyed more than 50%.
5	7 or more damages greater than 10 mm and/or whorl destroyed.

The experiments were conducted in the field of PROIMI-Biotechnology, Biocontrol Division (CONICET), located in San Miguel de Tucumán, Tucumán, Argentina) (26°48´36´´S, 65°14´27´´W, 464 m a.s.l.). The average temperature recorded during the trial was 27.9 ºC ± 2.73, and the average relative humidity was 57.8% ±13.15.

Insect voucher specimens were deposited in the Instituto Fundación "Miguel Lillo" collection (IFML), San Miguel de Tucumán, Argentina.

Statistical analysis

Because generalized linear mixed models (GLMMs) can handle data that is not independent and deal with missing measurements and different numbers of measurements per subject (Gurka & Edwards, 2011), they were used in the current study. To determine the effectiveness of *D. lineare* on FAW larvae, a GLMM with a binomial distribution and logit link function was performed. In addition, the dry weight of the maize plants and the visual damage to the maize plants were analyzed using a GLMM with both normal and binomial distributions, respectively, and a log link function. The fixed component of the model was the treatment, while subject id and plots (i.e., maize plants and experimental units, respectively) were included as random effects. After the analysis, LSD (≤ 0.05) tests were used to determine mean segregation. Statistical analyses were performed using IBM SPSS (2013).

RESULTS

Effectiveness of *Doru lineare* against *Spodoptera frugiperda* larvae

The analysis showed that the FAW larval survival rate was significantly affected by the treatments (Wald F= 60.63; df: 2, 47; p<0.01). The highest FAW larval survival rate was observed in the infested control treatment, followed by treatments with a density of one earwig/20 FAW larvae and two earwigs/20 FAW larvae densities, which differed significantly from each other. In other words, both densities of *D. lineare* significantly reduced the number of alive FAW larvae compared to the infested control treatment in maize plants (Fig. 1, Table II). At the end of the trial, more than 70% of the surviving FAW larvae recovered from all treatments were in the 4th instar.

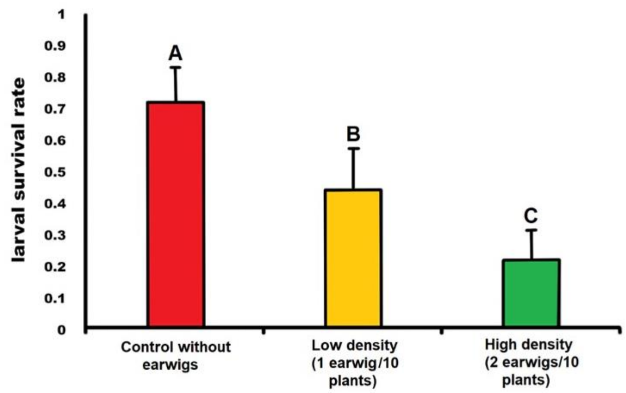

Fig. 1. Average *Spodoptera frugiperda* larval survival rate (mean + SD) exposed to the earwig *Doru lineare*. Infested control: plant infested only with 20 *S. frugiperda* larvae (2/plant); low density and high-density treatments: plants infested by two *S. frugiperda* larvae exposed to densities of one and two earwigs/cage, respectively, for 10 days. Different letters denote statistical significance among treatments (LSD test p<0.05).

Table II. Predator activity determined by initial and final densities of *Spodoptera frugiperda* (FAW) larvae per plant released in the boxes and potential protective effect of *Doru lineare*, estimated by both plant dry weight (g) and visual damage by the larvae for 10 days.

Treatment	Initial FAW density (larvae/plant)	Final FAW density (larvae/plant)	Dry weight (g)	Level of visual damage [(1)]
Infested control	2.00	1.42 ± 0.13 a	0.23 ± 0.010 a	4.09 ± 0.29 d
One earwig/cage	2.00	0.88 ± 0.09 b	0.28 ± 0.013 ab	2.83 ± 0.15 c
Two earwigs/cage	2.00	0.46 ± 0.09 c	0.36 ± 0.017 b	2.36 ± 0.13 b
Healthy control	--	--	0.65 ± 0.037 c	0.00 ± 0.00 a

Mean ± SE. Different letters in each column denote statistical significance among treatments (LSD test p<0.05). [(1)] See Table I for level values

Protective effect of *Doru lineare* for maize seedlings

Dry weight

The potential protective effect of *D. lineare* against FAW larvae was indirectly evaluated by measuring the dry weight of plants exposed to the trophic activity of the pest. As shown in Table II, healthy control plants (i.e., those that were not exposed to FAW larvae) exhibited significantly higher dry weights than FAW-infested plants exposed to one or two predators, and even higher than the ones in the infested control. The analysis confirmed the significant statistical differences in maize plants' dry weights (Wald F= 11.37; df: 3, 38; p<0.01). The analysis revealed, on the one hand, differences in dry weight between the healthy control plants (not infested) and the three infested plant treatments, and, on the other hand, that plants protected by a density of two earwigs/20 larvae had significantly higher dry weight than infested and unprotected plants (Table II).

Visual damage estimation

The protective effect of *D. lineare* on maize plants was evaluated using a visual scale of plant damage (Fig. 2). The infested control plants had the highest level of damage, represented by classes 4 and 5, at 74.5%. In contrast, plants exposed to one or two earwigs had significantly lower levels of significant damage, at 32.5% and 23.2%, respectively. On the other hand, plants with no damage or very limited damage, represented by classes 0, 1, and 2, were found at higher frequencies in the one earwig/cage and two earwigs/cage treatments, at 47.5% and 32%, respectively, compared to the infested control plants, which had a frequency of only 8%. Statistical analysis revealed a significant difference in maize plant damage among the treatments (Wald F= 11.87; df: 2, 50; $p<0.01$). The results show that two earwigs per cage were more effective at reducing maize plant damage than one earwig per cage, and all treatments significantly differed from each other (Table II).

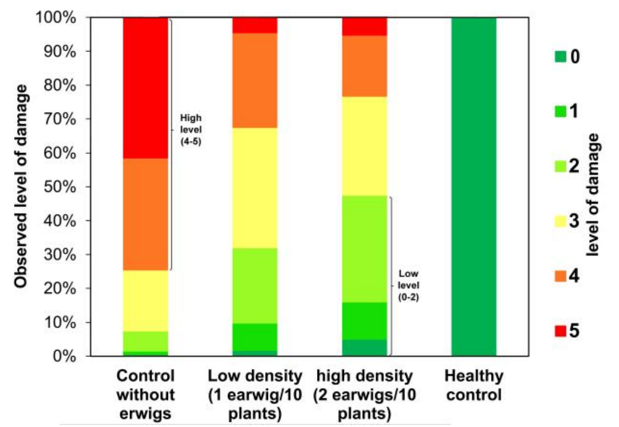

Fig. 2. Percentage of damage level (0–5) caused by *Spodoptera frugiperda* larvae on maize seedlings over ten days, both in the presence and absence of a natural earwig predator under semi-field conditions. Control without earwigs: plant infested only with 20 *S. frugiperda* larvae; low-density treatment: plants with 20 *S. frugiperda* larvae exposed to a density of one earwig/cage; high-density treatments: plants with 20 *S. frugiperda* larvae exposed to a density of two earwigs/cage. Plants were exposed for 10 days.

DISCUSION

This study demonstrates that *D. lineare* performs as a promising biological control agent against FAW, significantly reducing both the number of live FAW larvae and the level of damage to maize plants. In this regard, the current study confirms that this species, which is common in South America's subtropics, behaves similarly to *D. taeniatum* in Central America (Chapman et al., 2000) and *D. luteipes* in Brazil (Campos et al., 2011). Furthermore, a previous study found that as the abundance of the predator *D. luteipes* decreases, the field-level damage caused by FAW larvae on maize plants increases (Frizzas et al., 2014). As previously mentioned, farmers in Argentina's northwest associate the presence of earwigs in subsistence maize crops with decreased FAW attack levels and lower production losses.

Doru lineare has the ability to reduce the population of live FAW larvae on maize plants. In this study, the rate of FAW larval mortality was 55% (~11 dead larvae/cage) when using one *D. lineare*/cage, and reached 77.5% (~15.5 dead larvae/cage) when using two predators/cage. Previous research has shown that a single female *D. lineare* can prey on 20 to 42 first instar larvae under laboratory conditions, with satiation occurring at 39 eaten larvae (Romero Sueldo & Virla, 2009a; Romero Sueldo et al., 2010). These laboratory results are higher than those observed in the present study, which may be due to the larger size of the experimental arena and/or the lower prey density used in this study, as the adult female *D. lineare* would have had to spend more time searching for FAW larvae. However, further research is needed to confirm this. It should also be noted that both nymphs and adults of *D. lineare* are capable of preying on eggs and small larvae of the pest, as the FAW larvae do not defend themselves until they reach the third instar (Romero Sueldo & Virla, 2009a). The developmental time of FAW larvae from the first to the third instar is typically five to six days at 23-27 ºC (Doporto & Enkerlein, 1964; Murúa & Virla, 2004), so the observed mortality in this study likely occurred within the first five days after the release of the adult earwigs.

In the infested control treatment, a FAW larval mortality rate of approximately 28% was observed (with an average of 5.5 larvae/cage). This could be due to the cannibalistic behavior of third instar larvae, as well as the natural mortality that affects early instars of FAW (Murúa & Virla, 2004). Previous research has shown that cannibalism is a common and normal behavior in FAW larvae, allowing only the strongest larvae to survive per leaf whorl (Chapman et al., 2000; Morrill & Greene, 1973; Raffa, 1987). According to a previous study (Raffa, 1987), the cannibalism rate for 3rd instar larvae of FAW was less than 20% when fed on maize seedlings, but increased to 34% when food was scarce. Other research has also found that when different developmental larval instars interact, cannibalism increases further (Bentivenha et al., 2017; Chapman et al., 2000). This could have occurred in the present study, as the FAW larvae were left in field cages for 10 days, allowing some of them to develop faster and cannibalize smaller conspecifics.

This study also found that *D. lineare* can protect corn plants from FAW larval attack by reducing the level of damage and preserving the amount of dry weight. The small differences in plant dry weight between the infested control and the lower predator density treatment may be due to the fact that *D. lineare* only preys on FAW eggs and small larvae (first and second instars) (Romero Sueldo & Virla, 2009a). As a result, all small FAW larvae that escaped predation during the first five days of the experiment were able to develop into the third instar and feed freely from maize plants until the end of the experiment. In this context, several studies report that as FAW larvae grow into their later instars, they increase their food intake, causing greater damage to the leaves (Assefa & Ayalew, 2019; Costa et al., 2006; Crócomo & Parra, 1985; de Sousa Ramalho et al., 2011) and reducing plant biomass. Furthermore, a previous study by Peralta (2014), indicated that in corn crops under FAW larvae attack and without pest control measures, maize plants go from level 1 to level 5 of damage in less than 15 days. Maize plants with fourth- and fifth-degree aerial damage also experience a significant reduction in crop yield and a 1.5% decrease in plant stand (Fernández, 2002). A field study conducted in northern Argentina also found that crops with 8% of maize plants showing fifth degree damage (whorl destroyed) had a total harvest reduction of approximately 5% (Ayala et al., 2013).

If the foregoing is considered, field monitoring is an essential tool for determining the levels of maize plant damage that allow the application of decision criteria. While the precise economic threshold levels for FAW control have not been determined (Kenis et al., 2022), McGrath et al. (2018) recommend implementing control measures when 10-30% of seedlings are infested. In Argentina, 20% of attacked plants showing damage levels of 2-3 is considered the intervention threshold for FAW control (Ayala, 2010). Despite demonstrating a global mean damage level near the intervention threshold, as some plants demonstrated damage levels higher than 2 or 3, our contribution demonstrated that two earwigs per cage are nearly sufficient to achieve this goal.

Doru lineare is a common species in South American tropical and subtropical agroecosystems and is often found in the weeds surrounding crops in Argentina. When crops, such as maize, reach a stage where they provide an adequate refuge, the earwigs will colonize them and establish significant populations (Romero Sueldo & Virla, 2009a). The field relative abundance of *D. lineare* has not yet been documented in scientific contributions, but Castillejos et al. (2001) mention that the related species *D. taeniatum* can be abundant in late-season maize crops in Mesoamerica, with densities surpassing 100 individuals per plant, and pest management may be unnecessary when earwig populations reach high densities. Furthermore, the presence of *D. taeniatum* was found to be positively correlated with the presence of FAW feeding damage on maize plants, suggesting that this predator is attracted to injured plants (Bell et al., 2020).

Insects that are zoophytophagous (omnivores), have some biological advantages over predators regarding their utility as agents of biological control. This is because, in the absence of prey themselves, they eat plants, which allows them to persist in agricultural habitats when preys are scarce (Kiman & Yeargan, 1985). It is debated whether having an omnivore in a crop is beneficial, as the positive effects of an omnivore that preys on and competes with pest species may be offset by any economic damage it may cause to the crop as an herbivore (Coll & Guershon, 2002). In this context, *D. lineare* plays a dual role: it behaves as a phytophagous by consuming only corn pollen, but when FAW eggs and small larvae are available, it turns its attention preferentially to FAW individuals (Romero Sueldo & Virla, 2009a).

Based on the findings of this study, the most effective strategy for utilizing *D. lineare* would be to include it in conservation biological control programs, allowing it to enter the crop early from surrounding vegetation and limiting the use of agrochemicals that may harm its populations. Managing *D. lineare* in maize crops could reduce the dependence on pesticides, which has implications for human health and environmental safety. Previous research has shown that certain commercial pesticides, which are harmless to other *Doru* species but effective against FAW (Campos et al., 2011), could be appropriate for use in Integrated Pest Management (IPM) programs as they can be sprayed while still preserving the natural biological control provided by this earwig. The high invasive capacity of FAW and the significant damage it can cause to agricultural productivity in newly colonized areas (Kenis et al., 2022; Mutyambai et al., 2022) highlight the need for improved FAW management strategies.

Further field research is needed to better understand *D. lineare*'s natural densities in corn fields throughout the crop's phenology, as well as its alternative prey, dispersion rates, and the relationship between field densities and FAW population numbers in relation to damage levels, among other things.

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