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RESEARCH ARTICLE

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Biological control agents and levels of parasitism of *Agrotis segetum* (Lepidoptera: Noctuidae) in grain production regions of South Africa

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The management of the cutworm, *Agrotis segetum* (Denis & Schiffermüller) (Lepidoptera: Noctuidae), is challenging since the larvae spend most of their life cycle hiding underneath weeds or in the soil. Crop producers often report poor efficacy of chemical control, necessitating the development of alternative control strategies. Although many species of parasitoids and entomopathogenic nematodes (EPNs), have been reported from around the world where this pest occurs, no comprehensive list of these species exists, and little is known about their occurrence and impact as biological control agents in South Africa. A literature search yielded 75 parasitoid species, and six EPN species that parasitise *A. segetum* eggs and larvae. To assess the levels of parasitism in South Africa, cutworm populations were sampled from 14 different geographical regions, reared in a laboratory and monitored for parasitism and other mortality factors. The overall parasitism level recorded in this study was high (43.6%), with *Macrocentrus collaris* (Spinola) (Hymenoptera: Braconidae) being the most common (39.2%) parasitoid species, followed by *Gonia bimaculata* Wiedemann (Diptera: Tachinidae) (3.2%) and *Periscepsia carbonaria* (Panzer) (Diptera: Tachinidae) (1.2%). Entomopathogenic viruses were responsible for 26.1% of larval mortalities, while EPNs (Mermithidae) and entomopathogenic fungi caused 15.7% and 3.2% of mortalities, respectively. The incidence of parasitism, particularly by *M. collaris*, suggest that parasitoids could play a role in the suppression of *A. segetum* populations.

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INTRODUCTION

Cutworms (*Agrotis* spp.) are polyphagous and cause damage to crops such as maize (*Zea mays*), potatoes (*Solanum tuberosum*), tomatoes (*Solanum lycopersicum*), turnips (*Brassica rapa*) and many other host plants (Van den Berg 2024; 2025). The two *Agrotis* species that are considered the most important, are *Agrotis ipsilon* (Hüfnagel) (Lepidoptera: Noctuidae) which has a worldwide distribution, and *Agrotis segetum* (Denis & Schiffermüller) which occurs in Africa, Europe, the Middle East and Southeast Asia (Blair 1976; Drinkwater 1980; Bowden et al. 1983; Hülbert and Süss 1983; Esbjerg and Sigsgaard 2014; Rodingpuia and Lalthanzara 2021). *Agrotis segetum* is the dominant cutworm species and most important pest of maize seedlings in South Africa (Du Plessis 2000; Van den Berg et al. 2014; Drinkwater 2017).

Weeds play an important role in the ecology and pest status of cutworms. *Agrotis segetum* moths do not go into diapause, are active throughout the winter and lay their eggs on winter weeds which provide food and shelter for slow-developing larvae (Drinkwater 1980; Bowden et al. 1983; Drinkwater 2017). These overwintering larvae attack emerging maize seedlings during spring and early summer (Drinkwater 2017). The removal of host plants (weeds) from crop fields at least five weeks prior to planting, is recommended to reduce habitat suitability for larval survival and to ensure that larvae starve to death before the crop is planted (Drinkwater and Janse van Rensburg 1992, Van den Berg et al. 2014, Drinkwater 2017).

Soil applications of pyrethroids, at or just after planting, are commonly done for cutworm control. These applications are often reported to be ineffective and pose risks to the environment and non-target organisms such as parasitoids and predators of crop pests. There is, however, no information available on the diversity and role of natural enemies in the suppression of cutworm populations in South Africa.

Predators, parasitoids, entomopathogenic fungi, viruses and nematodes are promising biological control agents of cutworms (Wennmann et al. 2015; Salim et al. 2016; Staude et al. 2022). Carabid beetles have been reported to reduce cutworm numbers in crop fields in the USA as they prey on the eggs, larvae and pupae of these pests (Best and Beegle 1977; House and Alzugaray 1989; Frank and Shrewsbury 2004). Entomopathogenic fungi (EPFs) have been reported to cause mortality of cutworms in Northern Europe (Steenberg and Øgaard 2000), England, Wales (Sherlock 1983) and Egypt (El-Hawary and Abd El-Salam 2009; Ahmed et al. 2022). Similarly, entomopathogenic viruses (EPVs) can infect cutworms and cause mortality under laboratory and field conditions (Allaway and Payne 1983; Boughton et al. 1999; El-Salamouny et al. 2003; Bourner and Cory 2004; Jakubowska et al. 2006; Wennmann et al. 2015). Cutworms are highly susceptible to entomopathogenic nematodes (EPNs) (Morris and Converse 1991). Nematodes of the Mermithidae family have been reported to parasitise cutworm larvae in the USA (Puttler and Thewke 1971; Puttler et al. 1973) and China (Chen et al. 1989; Wang and Wang 1990; Li et al. 1993).

Many parasitoids have been recorded for *Agrotis* spp. worldwide, mainly from larvae (Schoenbohm and Turpin 1977; Sajap et al. 1978; Levine and Clement 1981; Foster and Ruesink 1984; El-Heneidy and Hassanein 1987; Khan and Özer 1988; Caballero et al. 1989; Caballero et al. 1993; Kara and Tschorsnig 2003; Gözüaçik et al. 2009; Cerretti and Tschorsnig 2010; Lee and Han 2010; Lekin et al. 2016; Salim et al. 2016; El-Hawagry 2018; Hou et al. 2018; Lutovinovas et al. 2018). In Spain, for example, the most important of these were *Periscepsia carbonaria* (Panzer) (Diptera: Tachinidae) and *Macrocentrus collaris* (Spinola) (Hymenoptera: Braconidae) (Caballero et al. 1989). The tachinid larval-pupal parasitoid, *Gonia bimaculata* Wiedemann (Diptera: Tachinidae) have also been recorded in Spain and Turkey (Caballero et al. 1989; Gözüaçik et al. 2009). In other parts of the world, cutworm infestations and their damage are significantly reduced when levels of parasitism are high (Schoenbohm and Turpin 1977; Sajap et al. 1978; Caballero et al. 1993). The lack of information on parasitoid-host associations in southern Africa is highlighted by the fact that only four records exist of Braconidae species (unidentified) that parasitise *A. segetum* among those that have been recorded for 66 Lepidoptera families in southern Africa (Staude et al. 2022).

Little information exists regarding which *Agrotis* species dominate in maize fields and the occurrence of biological control agents in South Africa. The following cutworm species have been listed to occur in maize fields: *Agrotis subalba* Walker, the grey cutworm; *A. ipsilon*, the black cutworm; *Agrotis longidentifera* (Hampson), the brown cutworm; and the common cutworm, *A. segetum* (Drinkwater 2017).

Therefore, the aim of this study was to conduct a survey of the diversity and incidence of biological control agents and to determine which *Agrotis* spp. occur in grain crop fields in South Africa, and to compile a checklist of parasitoids that have been recorded for *A. segetum* in other parts of the world.

MATERIALS AND METHODS

Collection sites

Larvae of *A. segetum* populations were collected from maize, soybean and sunflower fields at the localities listed in Table 1. The maize production region was classified into three regions based on their overall environmental conditions and soil type (Haarhoff et al. 2020). The regions are: (i) Western (35% of total annual maize production), (ii) Eastern (45%), and (iii) KwaZulu-Natal (KZN) (10%). The Western and Eastern areas are located on the South African inland plateau (1 500–1 800 m above sea level) (Adisa et al. 2018), with hot summers and very cold winters. The KZN region is known for long hot summers and mild winters, with an average annual rainfall of 500–800 mm (Adisa et al. 2018).

Larvae were sampled in October, November, January and February during the 2023/24 and 2024/25 cropping seasons. At each location, areas with seedling stand loss was identified within fields since the likelihood of finding cutworm larvae in these areas was high. Insecticides were applied at all the collection sites prior to larval collection, except at Kokstad, Mooirivier, Underberg, and Harrismith. This was because collections were only made at localities where producers reported cutworm infestations and because they did not postpone insecticide applications for a few days until larvae could be collected. If any evidence of cutworm damage to maize seedlings, weeds or cover crop plants were evident, the surrounding topsoil (3–10 cm) was carefully searched, and any observed larvae were collected. Nearly all larvae (> 98%) that were collected were in the 5th or 6th instar. Larvae that are in earlier stages of development do not easily sever seedings and are not often observed in the field. Larvae were placed inside plastic containers aerated with plastic mesh-infused lids (380 mm × 270 mm × 140 mm) and provided with weedy plants retrieved from the collection sites as a temporary food source. Different quantities of larvae were collected from each collection site and then transported to the Entomology laboratory at the North-West University, Potchefstroom, South Africa. Larvae were in transit for the minimum time feasible (< 36 hrs).

Rearing conditions and causes of mortality of cutworm larvae

After the larvae arrived at the laboratory, they were removed from the plant material and transferred into individual plastic containers with aerated mesh-infused lids (50 mm × 50 mm × 50 mm). Larvae were reared on artificial diet inside these containers until they either pupated, parasitoids emerged, or died. Stonefly *Heliothis* Premix Diet (Ward's Natural Science Establishment, LLC, USA) was provided as food for larvae. To prevent starvation of larvae, food was provided ad libitum. The containers were kept in an insect rearing room at 28 ± 1 °C, 65 ± 5% humidity and a 14L:10D photoperiod.

Table 1: Maize production region and localities at which ***Agrotis segetum*** larvae were collected during the 2023/24 and 2024/25 cropping seasons.

Region	Nearest town	Geographical reference	Date of collection
2023/2024			
Eastern	Hendrina	25°44'10.2" S; 30°02'05.0" E	20/11/2023
	Wakkerstroom	27°10'17.2" S; 30°04'43.1" E	10/11/2023
	Bronkhorstspruit	25°51'55.1" S; 28°31'19.2" E	29/01/2024
Western	Parys	27°01'29.6" S; 27°12'47.9" E	25/10/2023
	Kroonstad	27°48'18.1" S; 27°01'10.9" E	29/11/2023
KwaZulu-Natal	Underberg	29°48'29.7" S 29°26'17.4" E	18/11/2023
	Winterton	28°50'12.1"S; 29°39'51.4" E	09/11/2023
2024/2025			
Eastern	Bothaville	27°23'29.6" S; 26°33'10.9" E	06/11/2024
	Harrismith	28°24'03.6" S; 29°09'03.0" E	22/10/2024
	Vrede	27°23'13.5" S; 29°01'25.6" E	14/11/2024
KwaZulu-Natal	Kokstad	30°31'23.7" S; 29°14'02.2" E	14/11/2024
	Newcastle	28°07'40.8" S; 29°53'08.6" E	14/11/2024
	Mooirivier	29°09'14.9" S; 30°00'26.0" E	18/10/2024
Western	Lichtenburg	26°13'11.6" S; 26°22'05.2" E	12/02/2025

Larvae were inspected every second day and those that appeared sick or parasitised were removed and kept separately to identify the possible causes of mortality. Parasitoids that emerged were kept separately for each larva. Pupae were kept inside containers until moths or parasitoids emerged. The number of parasitoid pupae that were present in each container after the larvae died was determined for one of the parasitoid species, while the numbers of parasitoid cocoons per container was determined for another. The mean number of parasitoids that emerged per larvae was then calculated. Parasitoids were then identified to species level.

Entomopathogenic nematodes that emerged from larvae were placed in 70% ethanol. The number of EPNs per parasitised cutworm larva was recorded. Dead larvae that had a dark brown appearance and from which no parasitoids emerged were considered to have died from an EPV infection. Dead larvae covered with white or green spores were considered to have died from an EPF infection. The number of dead larvae exhibiting symptoms of EPVs or EPFs were also recorded. If the cause of larval death could not be identified, these were indicated as unknown.

Species identification and compiling of checklist

The parasitoid species reared from larvae were identified by means of the taxonomic keys of Crosskey (1984), Emden (1960) and O'Hara and Cerretti (2016). Voucher specimens of the Tachinidae were deposited in The National Museum, Bloemfontein, South Africa, and the Braconidae in the Iziko South African Museum, Cape Town, South Africa (https://www.waspweb.org/Ichneumonoidea/Braconidae/Macrocentrinae/Macrocentrus/Macrocentrus_collaris.htm). A literature search was conducted to compile a comprehensive list of *A. segetum* parasitoids. This search included CABI abstracts, Google Scholar and published literature on this pest.

Data analysis

Descriptive analyses were used. The percentage contribution of each of the mortality factors to overall larval mortality at each of the sampling localities were determined.

RESULTS

Incidence of larval mortality

A total of 2 723 larvae were collected from all the sites. The mean mortality of larvae from all sampling localities was 63.2% (n = 1 663). Larval mortality ranged from 41.6% to 92.1% for the different localities (Table 2). The overall mean incidence of larval parasitism was 43.6% and the overall mean incidence of larvae that died due to EPF and EPV infections were 3.2% and 26.1% respectively. The overall mean incidence of mortality due to EPNs were 15.7% while 11.4% of larvae died of unknown causes.

Biological control agents of *Agrotis segetum*

Three parasitoid species were encountered during this study, two that emerged from larvae and one that emerged from pupae. These species were *Periscepsia carbonaria* (Panzer) (Diptera: Tachinidae), *Gonia bimaculata* Wiedemann (Diptera: Tachinidae) and *Macrocentrus collaris* (Spinola) (Hymenoptera: Braconidae). Photos of the voucher specimens of these three species are provided in Figure 1. An EPN species (Mermithidae) was also identified from larvae. The percentage contribution of different biocontrol agents to overall mortality of *A. segetum* larvae and pupae is provided in Figure 2.

Macrocentrus collaris occurred at all sites (Figure 2) and was responsible for the highest overall incidence of mortality (39.2%). The highest incidence of parasitism by *M. collaris* at a single site was at Kroonstad (75.5%) and the lowest at Harrismith (4.6%). The number of parasitoids that emerged per cutworm larvae ranged between 20 and 130 (mean = 68).

Periscepsia carbonaria was recorded at three of the fourteen sites, i.e., Wakkerstroom, Parys and Winterton, and was responsible for 1.2% of the overall larval mortality (Figure 2). The highest incidence of parasitism by *P. carbonaria* was at Parys (10.0%) and the lowest at Winterton (1.5%). The number of parasitoids that emerged per larva ranged from 1 to 4 (mean = 2).

Gonia bimaculata was recorded at five of the fourteen sites, i.e., Wakkerstroom, Parys, Kroonstad, Bronkhorstspruit and Lichtenburg (Figure 2) and contributed to 3.2% of the overall larval mortality. The highest incidence of parasitism was recorded at Bronkhorstspruit (22.2%) and the lowest at Kroonstad (0.5%).

The mermithid nematode occurred at six of the fourteen sites (Figure 2) with the highest incidence of parasitism recorded at Vrede (73.9%) and the lowest at Kokstad (14.9%).

The number of EPNs that emerged per cutworm larva ranged from 1 to 41 (mean = 5). EPFs were recorded from seven of the fourteen sites (Figure 2). The highest incidence of infection was recorded at Newcastle (11.9%) and the lowest at Kroonstad (1.1%). Larvae with EPV infections were recorded from 10 of the fourteen sites (Figure 2) with the highest incidence of EPV infected larvae being recorded at Underberg (71.0%) and the lowest at Harrismith (7.7%).

Table 2: Overall mortality of ***Agrotis segetum*** larvae collected at different sites during the 2023/24 and 2024/25 growing seasons.

Collection site	Number of larvae collected	Larval mortality (%)
Lichtenburg	89	41.6
Kokstad	108	43.5
Hendrina	63	46.0
Newcastle	383	46.2
Wakkerstroom	189	46.6
Harrismith	384	50.8
Mooirivier	143	62.9
Kroonstad	593	63.4
Underberg	201	68.7
Vrede	37	73.0
Bronkhorstspruit	56	80.4
Parys	48	83.3
Winterton	391	86.7
Bothaville	38	92.1

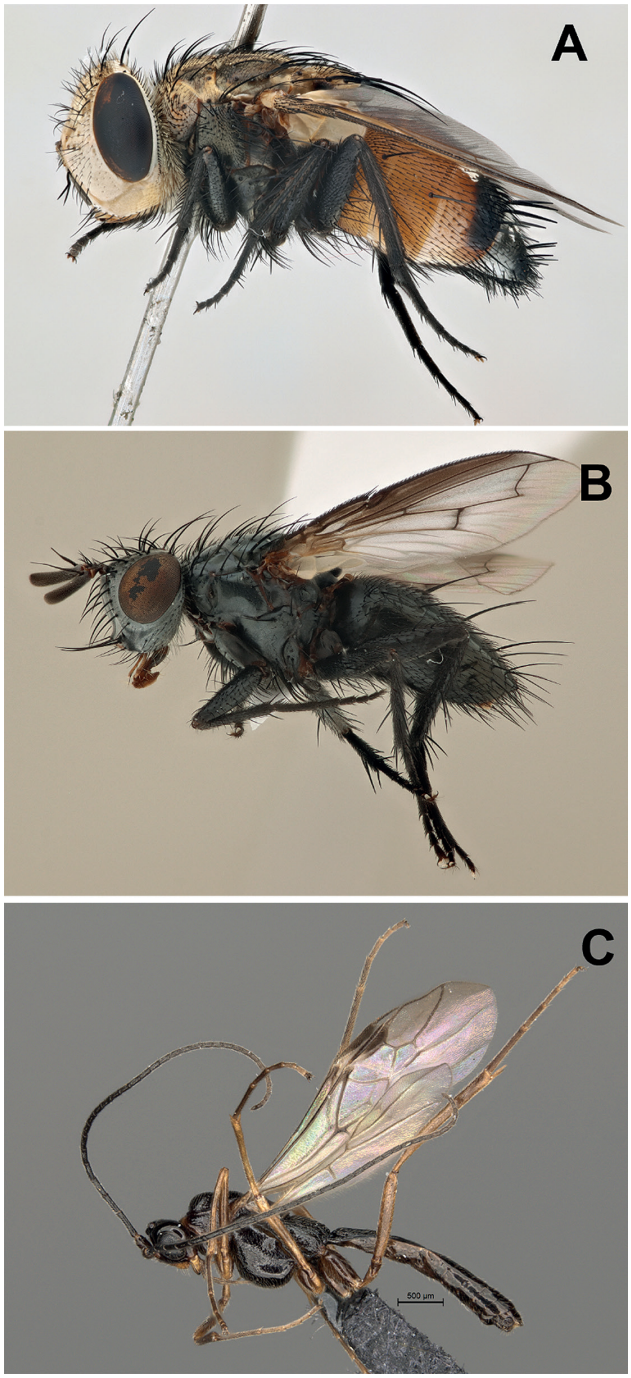

Figure 1: A) *Gonia bimaculata*, B) *Periscepsia carbonaria*, and C) *Macrocentrus collaris*.
Source: A & B) The National Museum, Bloemfontein, South Africa, Photo credit: B. Muller, C) Iziko South African Museum, Cape Town, South Africa, Photo credit: S. van Noort. https://www.waspweb.org/Ichneumonoidea/Braconidae/Macrocentrinae/Macrocentrus/Macrocentrus_collaris.htm.

Checklist of *Agrotis segetum* parasitoids

The literature search yielded 57 parasitoid species, belonging to the Hymenoptera and Diptera. These were 12 species of Braconidae, 13 species of Ichneumonidae and 28 species of Tachinidae. The three parasitoid species recorded during this study have previously been recorded on *A. segetum* in other parts of the world (Table 3). Six species of entomopathogenic nematodes (Mermithidae and Steinernematidae) were recorded (Table 3).

DISCUSSION

Macrocentrus collaris was the most abundant parasitoid (29.2%) recorded across all the entire maize production region. This parasitoid was also recorded in Russia where it was abundant and widespread on *A. segetum* in cotton fields (Ragimov and Rustamova 1977). *Macrocentrus collaris* was also recorded as a parasitoid of cutworms in Spain (Caballero et al. 1989). *Macrocentrus* spp. are all koinobiont endoparasitoids of lepidopteran larvae. Although a few of these species attack noctuids such as cutworms that feed on roots or inside stems of plants, they are most frequently observed to attack Pyralidae and Tortricidae that feed in shoots or rolled leaves (Shaw and Huddleston 1991). Hosts of *Macrocentrus* spp. are easily attacked during movement between plants and the middle-instars are largely targeted. Oviposition takes place into any part of the haemocoel of the overwintering host. The parasitoid larvae feed on the host before emerging from it to complete their feeding externally and moult into the final instar. Individual brownish cocoons are spun and arranged within a communally spun outer envelope on the surface of the larva (Shaw and Huddleston 1991).

The second most abundant parasitoid was *G. bimaculata* (3.2%). This parasitoid has also been reported to parasitise *A. segetum* in Egypt, Italy, Korea, China, Spain and Turkey (Caballero et al. 1989; Gözüaçik et al. 2009; Lee and Han 2010; El-Hawagry 2018; Hou et al. 2018). Other tachinids that were reported as parasitoids of *Agrotis* spp., including *A. ipsilon*, are *Gonia chinensis* (Wiedemann) (Diptera: Tachinidae), *Gonia ornata* Meigen (Diptera: Tachinidae) in China and Italy (Lee and Han 2010; Hou et al. 2018), *Linnaemya comta* (Fallén) (Diptera: Tachinidae) in the USA, Spain and Turkey (Levine and Clement 1981; Caballero et al 1989; Kara and Tschorsnig 2003; Stireman et al. 2006) and *Tachina magnicornis* (Zetterstedt) (Diptera: Tachinidae), *Spallanzania hebes* (Fallén) (Diptera: Tachinidae), *Peleteria rubescens* (Robinaeau-Desvoidy) (Diptera: Tachinidae) and *Phryxe vulgaris* (Fallén) (Diptera: Tachinidae) were recorded as parasitoids of *Agrotis* spp. in Italy (Cerretti and Tschorsnig 2010).

Gonia spp. incubates microtype eggs in which ova are ingested by hosts as they feed. These eggs hatch within the gut of the host larvae, and the emerging first-instar parasitoid larva burrows into the haemocoel (Stireman et al. 2006). *Gonia bimaculata* seem to be monophagous on *Agrotis* species since no records were found in the literature of it parasitising other lepidopteran hosts.

In the current study, the least abundant parasitoid (1.2%) was the tachinid fly, *P. carbonaria*. *Periscepsia carbonaria* was also found as a parasitoid of *A. segetum* in cotton fields in Russia (Ragimov and Rustamova 1977) and multi-parasitism of up to four parasitoids emerging from a single host-larva has been recorded. This is similar to observations made during this study where three to four parasitoids emerged from each parasitised *A. segetum* larva. *Periscepsia carbonaria* has also been confirmed as a parasitoid of *A. segetum* in other countries such as Pakistan (Khan 1989; Khan 2002), Turkey (Kara and Tschorsnig 2003; Gözüaçik et al. 2009; Lekin et al. 2016; Lutovinovas et al. 2018), Spain (Caballero et al. 1989) and India (Kumari and Chandla 2010; Chandel et al. 2022).

Larvae from *P. carbonaria* eggs are laid externally on *A. segetum* larvae, after which they infest the host during their first instar (Zethner et al. 1987). The parasitoid larvae move freely in the haemocoel for five to six days before forming a respiratory tunnel through its integument. It progresses through two additional larval instars after which the parasitoid larvae leave the host to pupate. *Periscepsia carbonaria* parasitises *A. segetum* and *A. ipsilon* larvae and older larvae (L4–L6) are less parasitised compared to younger larvae (L1–L3) (Khan 2002). Similar to *G. bimaculata*, *P. carbonaria* also seem to be monophagous on *Agrotis* spp. since no records were found in the literature of it parasitising other lepidopteran hosts.

The second highest overall incidence of mortality was caused by entomopathogenic viruses (26.1%). Although the viruses were not identified in this study, other studies reported that cutworms are susceptible to EPVs (Zethner et al. 1987; Bourner et al. 1992).

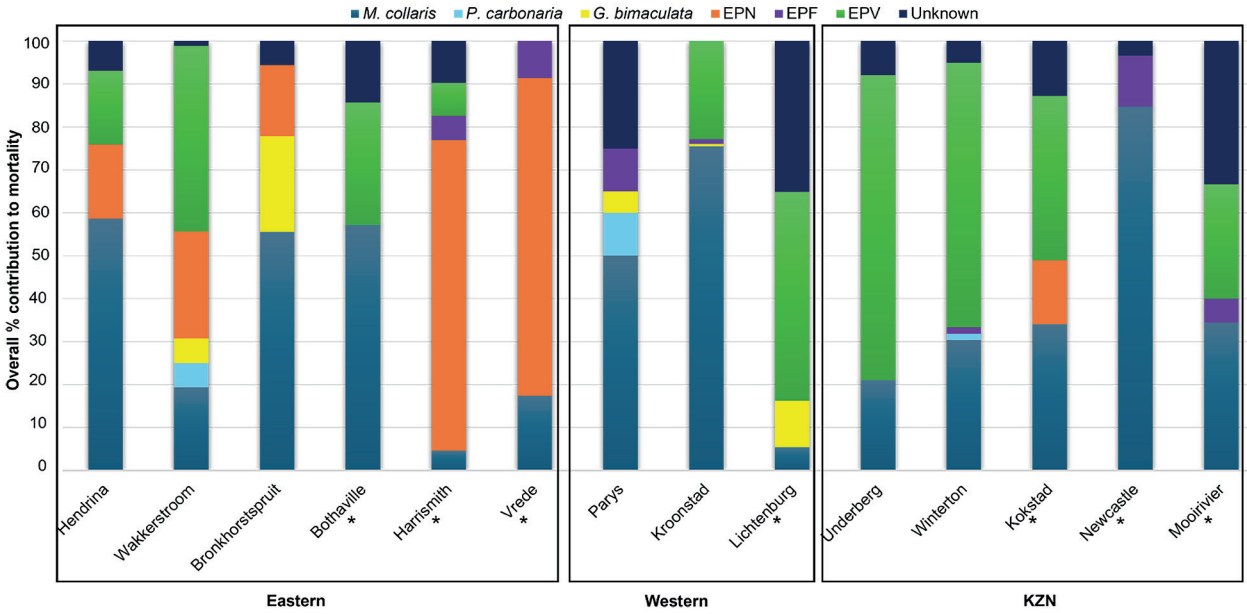

Figure 2: Percentage contribution of different biocontrol agents to overall mortality of ***Agrotis segetum*** larvae and pupae collected from maize production regions in South Africa during the 2023/24 and 2024/25 cropping season. Sites at which sampling was done during the 2024/25 season are indicated by asterisks.

Table 3: List of parasitoid species and entomopathogenic nematodes of *Agrotis segetum*.

Genus/species	Life stage	References
Arthropoda		
Braconidae		
Aleiodes dimidiatus (Spinola)	Larva	Eremenko and Sem'yanov (1981), Madatyan et al. (1987), Caballero et al. (1989)
Aleiodes pallidator (Thundberg) (= *Rogas pellucens* Telenga)	Larva	Alekseev (1972)
Cotesia congregate (Say)	Larva	Beyarslan and Çakici (2021)
Cotesia telengai (Tobias) (= *Apenteles telengai* (Tobias))	Larva	Madatyan et al. (1987), Caballero et al. (1989), Caballero et al. (1993)
Cotesia tibialis (Curtis) (= *Apenteles congestus* Nees)	Larva	Moir et al. (2007)
Habrobracon hebetor (Say) (= *Bracon hebetor* Say; = *B. juglandis* Ashmead)	Larva	Jumaev and Rustamov (2022)
Macrocentrus collaris (Spinola)	Larva	Chandel et al. (2022), Pospielov (1913), Caballero et al. (1989),
Meteorus rubens (Nees)	Larva	Foster and Ruesink (1984), Caballero et al. (1989), Dekhtyarev et al. (1926)
Microplitis spectabilis (Haliday) (= *Microgaster spectabilis* Haliday)		Madatyan et al. (1987), Eremenko, (1972)
Microplitis mediator (Haliday)	Larva	Khan and Özer (1988), Khan (1999), Birova (1973), Salim et al. (2016)
Ichneumonidae		
Amblyteles armatorius (Förster)	Larva	Masnadi-Yazdinejad and Jussila (2008).
Amblyteles vadatorius (Förster)	Larva	Popov (1931), Rambousek and Stranák (1920)
Banchus dilatatorius (Thunberg) (= *Banchus compressus* (Fabricius)		Moir et al. (2007)
Banchus falcatorius (Fabricius)	Larva	Moir et al. (2007)
Campoletis annulatus (Gravenhorst)	Larva	Caballero et al. (1989), Caballero et al. (1990)
Campoletis cognata (Tschek)	Larva	Gavloski and Hervet (2013), Salamov (1974)
Ctenichneumon panzer (Wesmael)	Larva	Salamov (1974), Aliev (1981), Masnadi-Yazdinejad and Jussila (2008)
Diphyus mercatorius (Fabricius)	Larva	Masnadi-Yazdinejad and Jussila (2008)
Diphyus ochromelas (Gmelin)	Larva	Masnadi-Yazdinejad and Jussila (2008)
Enicospilus merdarius (Gravenhorst)	Larva	Patel et al. (1991), Broad and Shaw (2016)
Erigorgus cerinops (Gravenhorst) (= *Anomalon cerinops* Gravenhorst)	Larva	Rambousek and Stranák (1920)
Eutanyacra picta (Schrank)	Larva	Masnadi-Yazdinejad and Jussila (2008)

Ichneumon proletarius Wesmael	Larva	Masnadi-Yazdinejad and Jussila (2008)
Ichneumon sarcitorius L.	Larva	Salamov (1974), Masnadi-Yazdinejad and Jussila (2008), Humala et al. (2023)
Netelia fuscicornis (Holmgren)	Larva	Zhumanov (1986)
Obtusodonta equitatoria (Panzer)	Larva	Masnadi-Yazdinejad and Jussila (2008)
Ophion luteus (L.)	Larva	Broad et al. (2015)
Pimpla rufipes Brulle (= *Pimpla instigator* (F.))	Larva	Salamov (1974)
Pimpla turionellae (L.)	Larva	Uğur et al. (1987)
Tachinidae		
Blondelia nigripes (Fallén)	Larva	Tschorsnig (2017)
Exorista civilis (Rondani)	Larva	Tschorsnig (2017)
Exorista japonica (Townsend)	Larva	Tschorsnig (2017)
Exorista larvarum (L.) (= *Tachina larvarum* L.)	Larva	Popov (1931), Cerretti and Tschorsnig (2010), Tschorsnig (2017)
Exorista xanthaspis (Wiedemann)	Larva	Tschorsnig (2017)
Gonia atra Meigen	Larva	Moir et al. (2007)
Gonia bimaculata Wiedemann (= *Gonia cilipeda* Rondani)	Larva, Pupa	Madatyan et al. (1987), Caballero et al. (1989), Kara and Tschorsnig (2003), Cerretti and Tschorsnig (2010), Tschorsnig (2017)
Gonia capitata (De Geer)	Larva, Pupa	Dekhtyarev et al. (1926), Tschorsnig (2017)
Gonia ornata Meigen	Larva	Tschorsnig (2017)
Linnaemya comta (Fallén)	Larva	Yang Wen et al. (1965), Kara and Tschorsnig (2003) Hubenov (2025)
Lydella thompsoni Herting	Larva	Tschorsnig (2017)
Nemoraea piligena Mesnil	Larva	Tschorsnig (2017)
Nilea hortulana (Meigen)	Larva	Hubenov (2025), Tschorsnig (2017)
Pales pavida (Meigen)	Larva	Moir et al. (2007), Tschorsnig (2017)
Peletieria nigricornis Meigen	Larva	Moir et al. (2007)
Peleteria rubescens (Robineau-Desvoidy)	Larva	Caballero et al. (1989), Jørgensen (1978), Kara and Tschorsnig (2003)
Periscepsia carbonaria (Panzer)	Larva	Ragimov and Rustamova (1977), Bayram and Kılınçer (1987), Caballero et al. (1989), Khan (2002), Kara and Tschorsnig (2003)
Phryxe vulgaris (Fallén)	Larva	Rambousek and Stranák (1920), Popov (1931), Tschorsnig (2017)
Pseudogonia rufifrons (Wiedemann)	Larva	Tschorsnig (2017)
Siphona collini Mesnil	Larva	Birova (1973), Tschorsnig (2017)
Siphona cristata (Fabricius)	Larva	Tschorsnig (2017)
Spallanzania hebes (Fallén)	Larva	Zhumanov (1981), Tschorsnig (2017)
Tachina albidopilosa (Portshinsky)	Larva	Tschorsnig (2017)
Tachina magnicornis (Zetterstedt)	Larva	Tschorsnig (2017)
Tachina rohdendorfi Zimin	Larva	Tschorsnig (2017)
Turanogonia chinensis (Wiedemann)	Larva	Kalra (1984), Kalra (1992), Chandel et al. (2022)
Trichogrammatidae		
Trichogramma chilonis Ishii		Jumaev and Rustamov (2022)
Trichogramma evanescens Westwood	Eggs	Nazirov and Ĕgamnazarov (1985)
Trichogramma embryophagum (Hartig)	Eggs	Özder and Kilinçer (1996a)
Trichogramma pallida Meyer	Eggs	Telenga (1956)
Trichogramma pintoi Voegelé	Eggs	Jumaev and Rustamov (2022)
Trichogramma turkeiensis Kostadinov	Eggs	Özder and Kilinçer (1996b)
Nematoda		
Mermithidae		
Mermis gigantea Artyukhovski & Lisikova	Larva	Matchanov et al. (1982)
Heterorhabditis bacteriophora Poinar	Larva	Chandel et al. (2009)
Steinernematidae		
Steinernema carpocapsae (Weiser)	Larva	Goudarzi et al. (2015), Ebrahimi et al. (2019)
Steinernema kraussei (Steiner)	Larva	Gökçe et al. (2013)

Steinernema feltiae (Filipjev)	Larva	Yüksel et al. (2022)
Steinernema websteri Cutler & Stock	Larva	Cutler and Stock (2003), Gökçe et al. (2013)
Steinernema weiseri Mrácek, Sturhan, Reid	Larva	Unlu et al. (2007)
Neoaplectana bibionis Bovien	Larva	Lössbroek and Theunissen (1985)

The incidence of larval mortality due to the mermithid nematode was low (15.7%) in comparison with other studies. In Illinois (USA), 64.5% larvae of an *A. ipsilon* population collected from maize fields were parasitised by *Hexamermis arvalis* (Poinar & Gyrisco) (Nematoda: Mermithidae) (Puttler et al. 1973). Furthermore, in China, parasitism of up to 63% of *A. ipsilon* by *Hexamermis* spp. was reported (Chen et al. 1989). In the present study, *A. segetum* larvae were often parasitised by more than one nematode, which is similar to reports of up to three or four larvae of *Hexamermis agrotis* (Nematoda: Mermithidae) recorded from a single *A. segetum* larva (Li et al. 1993).

The overall incidence of mortality caused by EPFs was low (3.2%). In Northern Europe, 50 to 100% mortality of overwintering *A. segetum* larvae were ascribed to infection by a rare fungal pathogen, *Tolypocladium cylindrosporum* (Hypocreales: Ophiocordycipitaceae) (Steenberg and Øgaard 2000). Other authors have also reported EPFs as significant biological control agents of *Agrotis* spp. In Europe, two naturally occurring fungal pathogens, *Entomophthora megasperma* (Entomophthorales: Entomophthoraceae) and *Fusarium solani* (Hypocreales: Nectriaceae), were reported to infect mature *A. segetum* larvae, prepupae and pupae (Sherlock 1983). Studies conducted in Egypt reported 100% larval mortality of *A. ipsilon* after treatment with an EPF product (Priority, *Isaria fumosorosea* (Hypocreales: Cordycipitaceae)) (El-Hawary and Abd El-Salam 2009), 50% mortality of *A. ipsilon* larvae caused by *Beauveria bassiana* and *Metarhizium anisopliae* (Gabarty et al. 2014) and 100% mortality by *B. bassiana* (Ahmed et al. 2022).

Although parasitoids can parasitise *Agrotis* larvae during all phases of their life cycle, the effectiveness and consequences of parasitism fluctuate depending on larval instar. Studies have shown that, under laboratory conditions, parasitism rates can be as high as 87.5% in 1st instars and 100% in 3rd instars, with early instars (L1–L3) being the most vulnerable (Caballero et al. 1993). In contrast, later instars show a significant reduction in susceptibility, with parasitism ranging from 34% in the 5th-instar to 4% in 6th-instar larvae (Caballero et al. 1993). Since 3rd and 4th instars provide optimum conditions for parasitoid development, parasitoids tend to favour these stages. Since L1–L3 larvae are largely active during the day (Blair 1975) and parasitoids are associated with flowering weeds which provide nectar as food (Foster and Ruesink 1984), the likelihood exists that the L5–L6 larvae collected during this study were parasitised during winter months, or at least several weeks before planting. Although parasitism in the late instars is less common, when it does occur, parasitoids emerge from the late 5th or early 6th instar when the latter stop feeding and ultimately perish (Schoenbohm and Turpin 1977). This suggests a close relationship between parasitoid and host development, with increased parasitism rates that occur when environmental conditions, such as higher temperatures during the planting season, occur (Caballero et al. 1993).

The development of parasitoids within *Agrotis* larvae results in reduced feeding activity and altered behaviour (Sajap et al. 1978). Initially, they behave exactly like non-parasitised larvae, remaining active and feeding normally until just before the emergence of the parasitoids (Sajap et al. 1978). However, the feeding period is greatly shortened by parasitism, with parasitised larvae still feeding for an average period of 4.5 days as opposed to 10.8 days for non-parasitised larvae of the same age (Sajap et al. 1978). Parasitised larvae damage an average of 4.4 plants, whereas non-parasitised larvae may damage 13.9 plants (Sajap et al. 1978). Parasitism restricts feeding by 6th instar larvae, which normally consumes 77–86% of a larva's total food consumption during its life cycle (Schoenbohm and Turpin 1977). This is ascribed to the cessation of feeding and decreasing larval activity. Similar to healthy pupating larvae, parasitised larvae tunnel into the soil before parasitoid emergence. When, in the case of *M. collaris*, parasitoid larvae emerge, they build cocoons close to the host's body, which prevents the host from pupating and ultimately results in its death (Sajap et al. 1978).

It is important to note that nearly all the larvae collected in this study were sampled from fields on which one to three insecticide applications had been applied for cutworm control, prior to sampling. However, no information is available on the level of exposure of the larvae to insecticides.

Compared to *Agrotis* spp. parasitoid diversity reported in other countries (Schoenbohm and Turpin 1977; Sajap et al. 1978; Levine and Clement 1981; Foster and Ruesink 1984; El-Heneidy and Hassanein 1987; Khan and Özer 1988; Caballero et al. 1989; Caballero et al. 1993; Kara and Tschorsnig 2003; Gözüaçik et al. 2009; Cerretti and Tschorsnig 2010; Lee and Han 2010; Lekin et al. 2016; El-Hawagry 2018; Hou et al. 2018; Lutovinovas et al. 2018), the diversity in South Africa seems to be low (Staude et al. 2022). The low parasitoid diversity recorded on *A. segetum* could indicate that this species has spread into southern Africa where it became naturalised. However, the three species recorded during this study (*P. carbonaria, M. collaris* and *G. bimaculata*) are also the dominant species that parasitise *A. segetum* in other regions of the world.

The overall mean incidence of larval parasitism at the different localities in this study was high (mean: 43.6%; range: 4.6–75.5%). This shows that parasitoids have the potential to supress cutworm numbers in crop fields. However, the beneficial effects of parasitism come into effect too late since parasitised larvae continue to damage seedlings. Cultural control strategies such as the removal of host plants (weeds) from fields to starve larvae to death before the crop is planted, is recommended for cutworm management (Drinkwater 1980). This will result in a reduction in the use of insecticides and protection of beneficial organisms at the start of the cropping season. Development of conservation biocontrol strategies, on the other hand, remains challenging. It is well known that plant species diversity influences the natural occurrence of biological control agents, specifically parasitoids. The host plants (weeds) that ensures survival of the pest are also critical for the survival of the parasitoids which utilise their pollen and nectar. The role that weeds play with regards to the presence and longevity of natural enemies have been reported by several authors (Foster and Ruesink 1984; Foster and Ruesink 1986a, 1986b; Pavuk and Stinner 1992; Capinera 2005). These interactions complicate the development of conservation biocontrol strategies for cutworms, since removal of weeds to control the pest also implies the removal of the resources used by parasitoids.

CONCLUSIONS

This study showed that several species of parasitoids, as well as an EPN species, attack or infect *A. segetum* in South Africa, and that these agents are responsible for high levels of mortality. The high incidence of mortality ascribed to EPFs, EPNs and viruses warrant further investigation to identify possible biocontrol agents for use in the management of *A. segetum*. Further studies should include more localities within the grain production

regions of South Africa and focus on the environmental conditions and cultivation practices that might have an influence on the abundance of biological control agents.

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DATA STATEMENT

All data are provided in the paper.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

JvdB and HdP conceived and designed the study. ZvE conducted all field work, data curation and basic statistical analyses. ZvE and JvdB wrote the manuscript. BM identified the dipeterna parasitoids. JvdB, ZvE and BM prepared the manuscript for submission. All authors read and approved the final manuscript.

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REFERENCES

Adisa OM, Botai JO, Hassen A, Darkey, D, Adeola AM, Tesfamariam, E, Bota CM, Adisa AT. 2018. Variability of satellite derived phenological parameters across maize producing areas of South Africa. Sustainability. 10(9):3033. https://doi.org/10.3390/su10093033.

Ahmed AAI, Khalil SSH, Sahab AF. 2022. Identification and evaluation of isolated entomopathogenic fungus from Egyptian soil against the black cutworm larvae of *Agrotis ipsilon* (Hüfnagel) (Lepidoptera: Noctuidae). Egyptian Journal of Biological Pest Control. 32(1):67–75. https://doi.org/10.1186/s41938-022-00564-0.

Alekseev YI. 1972. The biology of two closely related species of Braconids, *Rogas pellucens* Tel. and *Rogas testaceus* Spin. (Hymenoptera, Braconidae) in Turkmenia. Izvestiya Akademii Nauk Turkmenskoi SSR. Biologicheskikh Nauk. 4:58–61. (Abstract only).

Aliev AA. 1981. Toward the knowledge of the fauna of ichneumonids (Hymenoptera, Ichneumonidae) of Azerbaidzhan. Trudy Vsesoyuznogo Entomologicheskogo Obshchestva. 63:108–110.

Allaway GP, Payne CC. 1983. A biochemical and biological comparison of three European isolates of nuclear polyhedrosis viruses from *Agrotis segetum*. Archives of Virology. 75:43–54. https://doi.org/10.1007/BF01314126.

Bayram Ş, Kılınçer N. 1987. Investigations on the development of *Periscepsia carbonaria* (Panz.) (Diptera: Tachinidae) in the larvae of *Agrotis segetum* (Den-Schiff.) (Lepidoptera: Noctuidae). Türkiye 1. Entomoloji Kongresi, İzmir. 521–530. (Abstract only).

Best RL, Beegle CC. 1977. Consumption of *Agrotis ipsilon* by several species of carabids found in Iowa. Environmental Entomology. 6(4):532–534. https://doi.org/10.1093/ee/6.4.532.

Beyarslan A, Çakici M. 2021. Contribution to the Rogadinae (Hymenoptera, Braconidae) fauna of Turkey. Natura Somogyiensis. 37:65–78. https://doi.org/10.24394/NatSom.2021.37.65.

Birova H. 1973. On knowledge of the natural enemies (Hymenoptera & Diptera) of some injurious Noctuids. Biologicke Prace. 19(7):79–81. (Abstract only).

Blair BW. 1975. Behavioural studies on the larvae of *Agrotis segetum* (Denis and Schiffermüller) and *A. ipsilon* Hüfnagel (Lepidoptera: Noctuidae): towards better pest management. In: Durr HJR, Giliomee JH, Neser S, editors. Proceedings of the First Congress of the Entomological Society of Southern Africa. Stellenbosch. South Africa: Entomological Society of Southern Africa; pp. 19–33.

Blair BW. 1976. Comparison of the development of *Agrotis ipsilon* (Hüfnagel) and *A. segetum* (Denis & Schiffermüller) (Lepidoptera: Noctuidae) at constant temperatures. Journal of the Entomological Society of Southern Africa. 39(2):271–277.

Boughton AJ, Harrison RL, Lewis LC, Bonning BC. 1999. Characterization of a nucleopolyhedrovirus from the black cutworm, *Agrotis ipsilon* (Lepidoptera: Noctuidae). Journal of Invertebrate Pathology. 74(3):289–294. https://doi.org/10.1006/jipa.1999.4901.

Bourner TC, Cory JS. 2004. Host range of an NPV and a GV isolated from the common cutworm, *Agrotis segetum*: pathogenicity within the cutworm complex. Biological Control. 31(3):372–379. https://doi.org/10.1016/j.biocontrol.2004.05.008.

Bourner TC, Vargas-Osuna E, Williams T, Santiago-Alvarez C, Cory JS. 1992. A comparison of the efficacy of nuclear polyhedrosis and granulosis viruses in spray and bait formulations for the control of *Agrotis segetum* (Lepidoptera: Noctuidae) in maize. Biocontrol Science and Technology. 2(4):315–326. https://doi.org/10.1080/09583159209355247.

Bowden J, Cochrane J, Emmett BJ, Minall TE, Sherlock PL. 1983. A survey of cutworm attacks in England and Wales, and a descriptive population model for *Agrotis segetum* (Lepidoptera: Noctuidae). Annals of Applied Biology. 102(1):29–47. https://doi.org/10.1111/j.1744-7348.1983.tb02663.x.

Broad G, Schnee H, Shaw MR. 2015. The hosts of *Ophion luteus* (Linnaeus) (Hymenoptera, Ichneumonidae, Ophioninae) in Europe. Journal of Hymenoptera Research. 46:115–125. https://doi:10.3897/JHR.46.5347.

Broad GR, Shaw MR. 2016. The British species of *Enicospilus* (Hymenoptera: Ichneumonidae: Ophioninae). European Journal of Taxonomy. 187:1-31. https://doi.org/10.5852/ejt.2016.187.

Caballero P, Alamo S, Vargas-Osuna E, Santiago-Alvarez C, Lipa JJ. 1993. Biology of *Cotesia* (= *Apanteles*) *telengai* (Hymenoptera: Braconidae) on its natural host *Agrotis segetum* (Lepidoptera: Noctuidae). Biocontrol Science and Technology. 3(4):481–489. https://doi.org/10.1080/09583159309355303.

Caballero P, Vargas-Osuna E, Santiago-Alvarez C. 1989. Presence of gray worms on various crops in Andalusia and Extremadura and their associated parasites and pathogens. Boletin de Sanidad Vegetal Plagas. 15:3–7.

Caballero P, Vargas-Osuna E, Santiago-Alvarez C. 1990. Development of *Apanteles telengai* (Hym., Braconidae) and *Campoletis annulata* (Hym., Ichneumonidae) in granulosis virus (GV) infected *Agrotis segetum* (Lep., Noctuidae) larvae. Journal of Applied Entomology. 110(4):358–364. https://doi.org/10.1111/j.1439-0418.1990.tb00133.x.

Capinera JL. 2022. Black Cutworm, *Agrotis ipsilon* (Hüfnagel) (Insecta: Lepidoptera: Noctuidae). EENY-395. University of Florida, FL, USA.

Cerretti P, Tschorsnig, HP. 2010. Annotated host catalogue for the Tachinidae (Diptera) of Italy. Stuttgarter Beiträge zur Naturkunde A, Neue Serie. 3:305–340.

Chandel YS, Kapoor S, Kumar S. 2009. Virulence of *Heterorhabditis bacteriophora* (Poinar) against cutworm, *Agrotis segetum* (Denis and Schiffermüller). Journal of Biological Control. 23(4):409-415.

Chandel RS, Verma KS, Rana A, Sanjta S, Badiyala A, Vashisth S, Kumar R, Baloda, AS. 2022. The ecology and management of cutworms in India. Oriental Insects. 56(2):245–270. https://doi.org/10.1080/00305316.2021.1936256.

Chen GS, Wang YW, Li GQ, Tan CF, Chen BY, Jin YS, Li WZ. 1989. Small plot trials of using *Hexamermis* spp. (Nematoda: Mermithidae) to control *Agrotis ipsilon* (Lepidoptera: Noctuidae). Chinese Journal of Biological Control. 5(3):125–126. (Abstract only)

Crosskey RW. 1984. Annotated keys to the genera of Tachinidae (Diptera) found in tropical and southern Africa. Annals of the Natal Museum. 26(1):189–337. https://hdl.handle.net/10520/AJA03040798_481.

Cutler GC, Stock SP. 2003. *Steinernema websteri* sp. n. (Rhabditida: Steinernematidae), a new entomopathogenic nematode from China. Nematologia Mediterranea. 31:215–224.

Dekhtyarev NS, Aextrpbob MC, Kharkov ZR. 1926. On the parasites of *Euxoa segetum* Schiff, in 1925. Protection of Plants in Ukraine. 2:50–53. (Abstract only).

Drinkwater TW. 1980. Cutworms in maize. Farming in South Africa. Maize Series. D5/1980: 1–4.

Drinkwater TW. 2017. Insekteplae van mielies in Suid-Afrika. LNR-Instituut vir Graangewasse-Potchefstroom. 78–85. ARC-Grain Crops Institute. Potchefstroom, South Africa.

Drinkwater TW, Janse Van Rensburg JB. 1992. Association of the common cutworm, *Agrotis segetum* (Lepidoptera: Noctuidae), with winter weeds and volunteer maize. *Phytophylactica*. 24:25–28. https://journals.co.za/doi/pdf/10.10520/AJA03701263_1456.

Du Plessis H. 2000. Common cutworm, a pest of grain crops. ARC Crop Protection series nr. 19. ARC-Grain Crops Institute. Potchefstroom, South Africa.

Ebrahimi L, TanhaMaafi Z, Sharifi P. 2019. First report of the entomopathogenic nematode, *Steinernema carpocapsae*, from Moghan region of Iran & its efficacy against the turnip moth, *Agrotis segetum*. Egyptian Journal of Biological Pest Control. 29:66. https://doi.org/10.1186/s41938-019-0168-y.

El-Hawagry MS. 2018. Catalogue of the Tachinidae of Egypt (Diptera: Oestroidea). Egyptian Journal of Biological Pest Control. 28:46. https://doi.org/10.1186/s41938-018-0042-3.

El-Hawary FM, Abd El-Salam AME. 2009. Laboratory bioassay of entomopathogenic fungi on *Spodoptera littoralis* (Boisd.) and *Agrotis ipsilon* (Hüfnagel) larvae (Lepidoptera: Noctuidae). Egyptian Academic Journal of Biological Sciences. 1(1):1–6. https://eajbsf.journals.ekb.eg/article_17547_c5eff311c414d625fc003399080002ad.pdf.

El-Heneidy AH, Hassanein FA. 1987. Survey of the parasitoids of the greasy cutworm, *Agrotis ipsilon* Rott. (Lepidoptera, Noctuidae) in Egypt. Journal of Pest Science. 60:155–157. https://doi.org/10.1007/BF01907546.

El-Salamouny S, Lange M, Jutzi M, Huber J, Jehle JA. 2003. Comparative study on the susceptibility of cutworms (Lepidoptera: Noctuidae) to *Agrotis segetum* nucleopolyhedrovirus and *Agrotis ipsilon* nucleopolyhedrovirus. Journal of Invertebrate Pathology. 84(2):75–82. https://doi.org/10.1016/j.jip.2003.08.005.

Emden FI. 1960. Keys to the Ethiopian Tachinidae—III Macquartiinae. Proceedings of the Zoological Society of London. 134:313–487. https://doi.org/10.1111/j.1469-7998.1960.tb05596.x.

Eremenko TS. 1972. Nectar-bearing plants & the rise in the effectiveness of insect enemies of *Agrotis segetum*. Zashchita Rastenii. 17(1):23. (Abstract only).

Eremenko TS, Sem'yanov VP. 1981. Biocoenotic relations of parasites of the winter moth in the cotton agrocoenosis. Noveĭshie Dostizheniya Sel'skokhozyaĭstvennoĭ Ėntomologii. 70–73. (Abstract only).

Esbjerg P, Sigsgaard L. 2014. Phenology and pest status of *Agrotis segetum* in a changing climate. Crop Protection. 62:64–71. https://doi.org/10.1016/j.cropro.2014.04.003.

Foster MA, Ruesink WG. 1984. Influence of flowering weeds associated with reduced tillage in corn on a black cutworm parasitoid, *Meteorus rubens* (Nees von Esenbeck). Environmental Entomology. 13(3):664–668. https://doi.org/10.1093/ee/13.3.664.

Foster MA, Ruesink WG. 1986a. Impact of common chickweed, *Stellaria media*, upon parasitism of *Agrotis ipsilon* (Lepidoptera: Noctuidae) by *Meteorus rubens* (Nees von Esenbeck). Journal of the Kansas Entomological Society. 59(2):343–349. https://www.jstor.org/stable/25084777.

Foster MA, Ruesink WG. 1986b. Modeling black cutworm-parasitoid-weed interactions in reduced tillage corn. Agriculture, Ecosystems & Environment. 16(1):13–28. https://doi.org/10.1016/0167-8809(86)90072-1.

Frank SD, Shrewsbury PM. 2004. Consumption of black cutworms, *Agrotis ipsilon* (Lepidoptera: Noctuidae), and alternative prey by common golf course predators. Environmental Entomology. 33(6):1681–1688. https://doi.org/10.1603/0046-225X-33.6.1681.

Gabarty A, Salem HM, Fouda MA, Abas AA, Ibrahim AA. 2014. Pathogenicity induced by the entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* in *Agrotis ipsilon* (Hüfnagel). Journal of Radiation Research and Applied Sciences. 7(1):95–100. https://doi.org/10.1016/j.jrras.2013.12.004.

Gavloski J, Hervet V. 2013. *Euxoa ochrogaster*, redbacked cutworm, & others. In: Biological Control Programmes in Canada 2001–2012. Wallingford, UK: CABI. pp. 164–175. https://doi.org/10.1079/9781780642574.0164.

Gökçe C, Yilmaz H, Erbaş Z, Demirbağ Z, Demir I. 2013. First record of *Steinernema kraussei* (Rhabditida: Steinernematidae) from Turkey and its virulence against *Agrotis segetum* (Lepidoptera: Noctuidae). Journal of Nematology. 45(4):253–259. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3873901/.

Goudarzi M, Moosavi MR, Asadi R. 2015. Effects of entomopathogenic nematodes, *Heterorhabditis bacteriophora* (Poinar) and *Steinernema carpocapsae* (Weiser), in biological control of *Agrotis segetum* (Denis & Schiffermüller) (Lepidoptera: Noctuidae). Turkish Journal of Entomology. 39(3):239–250. https://doi.org/10.16970/ted.43220.

Gözüaçik C, Mart C, Kara K. 2009. Parasitoids of several lepidopterous pests in maize plantations in the Southeast Anatolian Region of Turkey. Turkish Journal of Zoology. 33(4):475–477. https://doi.org/10.3906/zoo-0811-8.

Haarhoff SJ, Kotzé TN, Swanepoel, PA. 2020. A prospectus for sustainability of rainfed maize production systems in South Africa. Crop Science. 60(1):14–28. https://doi.org/10.1002/csc2.20103.

Hou P, Li X, Yang D, Zhang C. 2018. Taxonomic study of *Gonia meigen* (Diptera: Tachinidae) from China. Zoological Systematics. 43(3):294–308. https://www.zootax.com.cn/CN/article/downloadArticleFile.do?attachType=PDF&id=216.

House GJ, Alzugaray MDR. 1989. Influence of cover cropping and no-tillage practices on community composition of soil arthropods in a North Carolina agroecosystem. Environmental Entomology. 18(2):302–307. https://doi.org/10.1093/ee/18.2.302.

Hubenov Z. 2025. Review of the hosts of the family Tachinidae (Diptera: Insecta) in Bulgaria. Acta Zoologica Bulgarica. 77(1):131–144. https://doi.org/10.71424/azb77.1.002812.

Hülbert D, Süss A. 1983. Biology and economic importance of the winter cutworm, *Scotia* (*Agrotis*) *segetum* Schiffermüller (Lepidoptera: Noctuidae). Beiträge zur Entomologie. 33(2):383–438.

Humala AE, Kolesova NS, Belova YN. 2023. Annotated list of Darwin wasps of Vologda Province. Entomological Review. 103(3):298–319. https://doi.org/10.1134/S0013873823030077.

Jakubowska AK, Peters SA, Ziemnicka J, Vlak JM, Van Oers MM. 2006. Genome sequence of an enhancin gene-rich nucleopolyhedrovirus (NPV) from *Agrotis segetum*: collinearity with *Spodoptera exigua* multiple NPV. Journal of General Virology. 87(3):537–551. https://doi.org/10.1099/vir.0.81461-0.

Jørgensen AS. 1978. The species of cutworms (*Agrotis* spp.) found in Danish crops. Zeitschrift für Angewandte Entomologie. 87(1–4):76–81. https://doi.org/10.1111/j.1439-0418.1978.tb02427.x.

Jumaev R, Rustamov A. 2022. Representatives of Lepidoptera groups in the biotecenosis of Uzbekistan and their effective parasite-entomophage types. IOP Conference Series: Earth and Environmental Science. 1068(1):012026. https://doi.org/10.1088/1755-1315/1068/1/012026.

Kalra VK. 1984. Record of *Turanogonia chinensis* Wiedemann as a parasite of *Agrotis segetum*. Indian Journal of Agricultural Sciences. 54:694. (Abstract only).

Kalra VK. 1992. Parasitism of *Agrotis segetum* by *Turanogonia chinensis* Wied. on Brassica cultivars in Haryana. Journal of Insect Science. 1:86–87.

Kara K, Tschorsnig HP. 2003. Host catalogue for the Turkish Tachinidae (Diptera). Journal of Applied Entomology. 127(8):465–476. https://www.academia.edu/download/68809510/j.0931-2048.2003.00786.x20210819-15733-1id9b8y.pdf.

Khan SM. 1989. Biology of *Periscepsia carbonaria* (Diptera: Tachinidea) a parasitoid of *Agrotis segetum*. Gomal University Journal of Research. 9(2):1–7. https://acrobat.adobe.com/id/urn:aaid:sc:EU:d325c53a-5a93-4eae-b6c7-afdda778d2f4.

Khan SM. 1999. Effectiveness of *Microplitis mediator* (Hym: Braconidae) against its hosts *Agrotis segetum* & *A. ipsilon*. Pakistan Journal of Biological Sciences. 2(2):344–346. https://doi.org/10.3923/pjbs.1999.344.346.

Khan SM. 2002. Effectiveness of *Periscepsia carbonaria* (Diptera: Tachinidae) against *Agrotis segetum* and *Agrotis ipsilon* (Lepidoptera: Noctuidae). Scientific Khyber (Pakistan). 15(1). (Abstract only).

Khan SM, Özer M. 1988. Biology of *Microplitis mediator* (Hymenoptera: Braconidae) a gregarious endoparasite of *Agrotis segetum* (Lepidoptera: Noctuidae). Entomophaga. 33(2):211–217. https://doi.org/10.1007/BF02372656.

Kumari N, Chandla VK. 2010. Save parasites and microbes of cutworms, *Agrotis segetum* (Schiff) pest of potato in Shimla hills. Uttar Pradesh

Journal of Zoology. 30(1):21-25. https://mbimph.com/index.php/UPJOZ/article/view/229.
Lee HS, Han HY. 2010. A systematic revision of the genus *Gonia meigen* (Diptera: Tachinidae) in Korea. Animal Cells and Systems. 14(3):175–195. https://doi.org/10.1080/19768354.2010.50434.
Lekin N, Kara K, Atay, T. 2016. Tachinidae (Diptera) species from some uplands in Tokat province (Turkey). Journal of Agricultural Faculty of Gaziosmanpaşa University (JAFAG). 33(1):56–63.
Levine E, Clement SL. 1981. Effect of parasitism by *Bonnetia comta* (Diptera: Tachinidae) on larvae of *Agrotis ipsilon* (Lepidoptera: Noctuidae). Journal of the Kansas Entomological Society. 54(2):219–222. https://www.jstor.org/stable/25084152.
Li FC, Nie GF, Feng Y, Xia, ZM. 1993. Study on *Hexamermis agrotis* Wang et al. – an important natural enemy of cutworms. Entomological Knowledge. 30(1):40–42. (Abstract only).
Lössbroek TG, Theunissen J. 1985. The entomogenous nematode *Neoaplectana bibionis* as a biological control agent of *Agrotis segetum*. Entomologia Experimentalis et Applicata. 39(3):261–264. https://doi.org/10.1111/j.1570-7458.1985.tb00468.x.
Lutovinovas E, Tschorsnig HP, Barták M, Kubík Š, Dursun O, Civelek HS, Kara K. 2018. Contribution to the tachinid fauna of southwestern Turkey (Diptera: Tachinidae). Annales de la Société Entomologique de France. 54(4):335–366. https://doi.org/10.1080/00379271.2018.1468724.
Madatyan AV, Eremenko TS, Nabikhanova SK. 1987. Parasitoids of the turnip moth. Zashchita Rasteniy. 6:34–35. (Abstract only).
Masnadi-Yazdinejad A, Jussila R. 2008. Contribution to the knowledge of ichneumonid wasps of Iran. Subfamilies Ichneumoninae, Pimplinae and Diplazontinae. Entomofauna. 29:1–28.
Matchanov NM, Lysikova ĖA, Mavlyanova RD. 1982. The biology of *Mermis gigantea* (Mermithida, Nematoda). Ėntomopatogennye Mikroorganizmy I Ikh Primenenie V Sel'skom I Lesnom Khozyaĭstve. 137–142. (Abstract only).
Moir M, Szito A, Botha JH, Grimm M. 2007. Turnip moth, *Agrotis segetum* Denis & Schiffermüller 1775 (Lepidoptera: Noctuidae). Pest Datasheet/Pest Risk Review for the Grains Industry. Plant Health Australia. https://www.researchgate.net/publication/308253294.
Morris ON, Converse V. 1991. Effectiveness of steinernematid and heterorhabditid nematodes against noctuid, pyralid, and geometrid species in soil. Canadian Entomologist. 123(1):55–61. https://doi:10.4039/Ent12355-1.
Nazirov Kh.N., Ėgamnazarov AP. 1985. Trichogramma on seed crops of kenaf. Zashchita Rasteniĭ. 5:37 015038
O'Hara JE, Cerretti P. 2016. Annotated catalogue of the Tachinidae (Insecta, Diptera) of the Afrotropical Region, with the description of seven new genera. ZooKeys. 575:1–344. https://doi.org/10.3897/zookeys.575.6072.
Özder NA, Kilinçer N. 1996a. Investigations on some biological relations between *Agrotis segetum* (Denis and Schiff)(Lepidoptera, Noctuidae) and *Trichogramma embryophagum* (Hartig) and *T. turkeiensis* Kostadinov (Hymenoptera, Trichogrammatidae). Türkiye Entomoloji Dergisi. 20(1):35–49. (Abstract only).
Özder NA, Kilinçer N. 1996b. The effect of *Agrotis segetum* (Denis and Schiff) (Lepidoptera, Noctuidae) egg age, and pattern, food and temperature on longevity, fecundity, progeny and parasitism rate of *Trichogramma embryophagum* (Hartig) and *T. turkeiensis* Kostadinov (Hymenoptera, Trichogrammatidae). Türkiye Entomoloji Dergisi. 20:83–92. (Abstract only).
Patel AG, Yadav DN, Patel RC. 1991. Natural enemies of *Agrotis* spp. from Gujarat. Gujarat Agricultural University Research Journal. 17(1):130–131 (Abstract only).
Pavuk D M, Stinner BR. 1992. Influence of weed communities in corn plantings on parasitism of *Ostrinia nubilalis* (Lepidoptera: Pyralidae) by *Eriborus terebrans* (Hymenoptera: Ichneumonidae). Biological Control. 2:312–316. https://doi.org/10.1016/1049-9644(92)90024-8.
Popov PV. 1931. Some notes on the biology of *Euxoa segetum* Schiff. Zashchita Rastenii ot vreditelei, Leningrad 7: 227–234 [in Russian].
Pospielov V. 1913. Experiments on the artificial infection of *Euxoa seqetum*, Schiff., by its parasites in the Government of Kiev. Herald of the Sugar Industry. 11 pp. (Abstract only).
Puttler B, Thewke SE. 1971. Field and laboratory observations of *Hexamermis arvalis* (Nematoda: Mermithidae) a parasite of cutworms. Annals of the Entomological Society of America. 64(5):1102–1106. https://doi.org/10.1093/aesa/64.5.1102.
Puttler B, Sechriest RE, Daughtery DM. 1973. *Hexamermis arvalis* parasitizing *Agrotis ipsilon* in corn and the origin of the pest infestation. Environmental Entomology. 2(5):963–964. https://doi.org/10.1093/ee/2.5.963.
Ragimov ZA, Rustamova MR. 1977. Parasites of *Agrotis segetum*. Zashchita Rastenii. 9. (Abstract only).
Rambousek F, Stranák F. 1920. A Contribution to the study of *Euxoa segetum*. Zemedelske Archive v Praze. 1:24–34.
Rodingpuia C, Lalthanzara H. 2021. An insight into black cutworm (*Agrotis ipsilon*): a glimpse on globally important crop pest. Science Vision. 2:36–42. https://doi.org/10.33493/scivis.21.02.02.
Sajap ASB, Beegle CC, Lewis LC. 1978. Effect of parasitism by *Microplitis kewleyi* on the cutting ability of its host, *Agrotis ipsilon*. Environmental Entomology. 7(3):343–344. https://doi.org/10.1093/ee/7.3.343.
Salamov TS. 1974. Ichneumonids as parasites of *Agrotis segetum*. Zashchita Rastenii. 4. (Abstract only).
Salim M, Gökçe A, Naqqash MN, Bakhsh A. 2016. An overview of biological control of economically important lepidopteron pests with parasitoids. Journal of Entomology and Zoology Studies. 4(1):354–362. https://www.entomoljournal.com/archives/2016/vol4issue1/PartF/4-1-7.pdf.
Schoenbohm RB, Turpin FT. 1977. Effect of parasitism by *Meteorus leviventris* on corn foliage consumption and corn seedling cutting by the black cutworm. Journal of Economic Entomology. 70(4):457–459. https://doi.org/10.1093/jee/70.4.457.
Shaw MR, Huddleston T. 1991. Classification and biology of braconid wasps. In: Handbook for the Identification of British Insects, Royal Entomological Society of London. 7(11):1–126.
Sherlock PL. 1983. The natural incidence of disease in the cutworm *Agrotis segetum* in England and Wales. Annals of Applied Biology. 102(1):49–56. https://doi.org/10.1111/j.1744-7348.1983.tb02664.x.
Staude HS, Maclean M, Mecenero S, Pretorius RJ, Oberprieler RG, van Noort S, Sharp A, Sharp I, Balona J, Bradley S, Brink M, Morton AS, Botha MJ, Collins SC, Grobler Q, Edge DA, Williams MC, Sihvonen P. 2022 (v1). An overview of Lepidoptera-host-parasitoid associations for southern Africa, including an illustrated report on 2 370 African Lepidoptera-host and 119 parasitoid-Lepidoptera associations. Metamorphosis. 31(3):1–20. https://doi.org/10.4314/met.v31i3.1.
Steenberg T, Øgaard L. 2000. Mortality in hibernating turnip moth larvae, *Agrotis segetum*, caused by *Tolypocladium cylindrosporum*. Mycological Research. 104(1):87–91. https://doi:10.1017/S0953756299001318.
Stireman III JO, O'Hara JE, Wood DM. 2006. Tachinidae: evolution, behavior, and ecology. Annual Review of Entomology. 51(1):525–555. https://doi.org/10.1146/annurev.ento.51.110104.151133.
Telenga NA. 1956. Investigations on *Trichogramma evanescens* Westw. and *T. pallida* Meyer (Hymenoptera, Trichogrammatidae) and their use for the control of injurious insects in the USSR. Entomologicheskoe Obozrenie. 35(3):599–610.
Tschorsnig HP. 2017. Preliminary host catalogue of Palaearctic Tachinidae (Diptera). http://www.nadsdiptera.org/Tach/WorldTachs/CatPalHosts/Home.html.
Uğur A, Kansu İA, Kedici R. 1987. Ege Üniversitesi Atatürk Kültür Merkezi, Bornova/Izmir, Turkey, Türkiye I. Entomoloji Kongresi Bildirileri, Ege Üniversitesi, Bornova, Izmir. (Abstract only).
Unlu IO, Ehlers RU, Susurluk A. 2007. Additional data and first record of the entomopathogenic nematode *Steinernema weiseri* from Turkey. Nematology. 9(5):739–741. https://doi.org/10.1163/156854107782024857.
Van den Berg J. 2024. *Agrotis ipsilon* (Black cutworm). https://www.cabidigitallibrary.org/doi/full/10.1079/cabicompendium.3801.
Van den Berg, J. 2025. *Agrotis segetum* (turnip moth). https://www.cabi.org/isc/datasheet/3797.
Van den Berg J, Erasmus A, Van Rooyen M. 2014. Maize. In: Prinsloo GL, Uys VM, editors. Insects of Cultivated Plants and Natural Pastures in Southern Africa. Pretoria, South Africa: Entomological Society of Southern Africa; pp. 88–118.
Wang J, Wang YW. 1990. Two new species of *Hexamermis* (Enoplina: Mermithidae) parasites of black cutworm. Acta Zootaxonomica Sinica. 15(1):10–17. (Abstract only).
Wennmann JT, Alletti GG, Jehle JA. 2015. The genome sequence of *Agrotis segetum* nucleopolyhedrovirus B (AgseNPV-B) reveals a new baculovirus species within the *Agrotis* baculovirus complex. Virus Genes. 50(2):260–276. https://doi.org/10.1007/s11262-014-1148-7.

Yang Wen YW, Kuo CY, Yeh TF. 1965. Studies on the biology of *Linnaemyia compta* (Diptera, Larvaevoridae). Acta Entomologica Sinica. 14(5):446–460. (Abstract only).

Yüksel E, Imren M, Özdemir E, Bozbuğa R, Canhilal R. 2022. Insecticidal effect of nematodes & their symbiotic bacteria against *Agrotis segetum*. Egyptian Journal of Biological Pest Control. 32(1):54. https://doi.org/10.1186/s41938-022-00555-1.

Zethner O, Khan BM, Chaudhry MI, Bolet B, Khan S, Khan H, Gul H, Øgaard L, Zaman M, Nawaz G. 1987. *Agrotis segetum* granulosis virus as a control agent against field populations of *Agrotis ipsilon* and *A. segetum* [Lep.: Noctuidae] on tobacco, okra, potato and sugar beet in northern Pakistan. Entomophaga. 32(5):449–455. https://doi.org/10.1007/BF02373513.

Zhumanov BZ. 1981. On the biology of *Spallanzania hebes* – a parasite of the winter cutworm in Tajikistan. (Abstract only). Izvestiya Akademii Nauk Tadzhikskoi SSR, Biologicheskikh Nauk. 2(79):67–73.

Zhumanov BZ. 1986. A study of the biology of *Netelia fuscicornis* in Tajikistan. Vestnik Zoologii. 6:32–37. (Abstract only).