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**EFFECT OF SOIL MOISTURE AND HOST PLANTS ON  
BEHAVIOUR AND SURVIVAL OF THE COMMON CUTWORM,  
*AGROTIS SEGETUM* (DENIS & SCHIFFERMÜLLER)  
(LEPIDOPTERA: NOCTUIDAE).**

by

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for the degree

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University of the Orange Free State  
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## DECLARATION

I, Khathutshelo Mabuda declare that the dissertation, Effect of soil moisture and host plants on behaviour and survival of the common cutworm, *Agrotis segetum* (Denis & Schiffermüller) hereby submitted by me for the Magister Scientiae (Entomology) degree at the University of the Orange Free State is my own independent work and has not previously been submitted at any other university/faculty. I furthermore cede copyright of the dissertation in favour of the University of the Free State.

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Signed: K. Mabuda

15 November 2001



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## ABSTRACT

The common cutworm, *Agrotis segetum* (Denis & Schiffermüller) is an important pest of various crops including maize in South Africa. Since cutworms are nocturnal their activity is affected by light. During the day, larvae remain below the soil and emerge at night to feed. Cutworms oviposit on weeds in uncultivated fields and larvae then survive on weeds between successive crops. The ability of newly emerged *A. segetum* larvae to survive on various weeds as well as the associated rate of development may be important to predict outbreaks and potential damage.

Behavioural responses of *A. segetum* larvae to light, moisture and host plants were evaluated. Since *A. segetum* is nocturnal, a marking technique for larvae was developed to study behaviour at night. A 1:1 Humbrol paint and fluorescent powder mixture was found to have no effect on larval survival and behaviour. The marker was easy to apply, available in several colours, fluoresced well in the dark and lasted for one instar before it was lost during ecdysis. Dusting larvae with fluorescent powder also proved useful in detecting and tracking movement for short range studies. Powder adhering to larvae left clear trails for a maximum distance of up to two meters before wearing off.

To evaluate the effect of different sources of light on *A. segetum*, larvae were illuminated with incandescent, infrared and UV light after periods of 24, 48, 72 and 96 hours of starvation. Significantly more larvae that had been starved for 72 and 96 hours remained on the soil surface after an hour of illumination with infrared and UV light. Dark and light adaptation periods of 24, 48 and 72 hours also had an effect on larval activity. When illuminated with UV light under field conditions, larvae moved towards the light possibly perceiving it as open space.

Significantly more above-ground than below-ground plant sections of *Chenopodium carinatum* R. Br., *Portulaca oleracea* L. and *Zea mays* L. were severed under both dry and wet soil conditions in a greenhouse study. This however remains to be verified under field conditions. It is known that the black cutworm severs plants below the soil surface in dry soil, under field conditions.

In the absence of food, *A. segetum* larvae survived for approximately one week at soil moisture levels 10, 20, 40, 60 and 100 %. When sections of *Amaranthus hybridus* L. and *P. oleracea* were buried separately in pots at moisture levels 0, 10 and 80 %, all larvae remained alive for up to 10 days at the 80 % moisture level in the presence of each weed species evaluated. Survival of *A. segetum* larvae was lowest at 0 % soil moisture regardless of the availability of food. Development was supported until pupation on *A. hybridus* at the 80 % moisture level. The highly succulent *P. oleracea* supported larvae for a longer period, even in the absence of soil moisture. Most eggs were laid on *A. hybridus*, *Ipomoea purpurea* (L.) Roth. and *P. oleracea* in a multi-choice experiment when moths were simultaneously presented with six plant species. Significantly more eggs were laid on the stems than on leaves. When presented with three grass species, viz. *Pennisetum purpureum* (K.) Schumach., *Vetiveria zizanioides* (L.) Nash and *Z. mays* there was no significant difference in oviposition between them. However, significantly more eggs were laid on dead plant tissue. Survival and mass gain of first instar larvae fed on *A. hybridus* and *C. album* was significantly higher than those fed on *Datura stramonium* L., *I. purpurea*, *P. oleracea* and *Z. mays*. Larvae fed on *P. purpureum* and *V. zizanioides* had the lowest mass gain and survival compared to the last mentioned species. *Chenopodium album* was a more suitable host plant for larval development relative to all the plant species evaluated. Types and densities of leaf trichomes were evaluated as a possible explanation for oviposition and first instar larval survival but could not account for the observed differences.

# CHAPTER 1

## INTRODUCTION

Maize is a vital crop in the diet of many South Africans and accounts for more than 40 % of the total cereal production in Sub-Saharan Africa (Anonymous, 2001). It is undoubtedly South Africa's most important field crop, since more than a rugby field of maize is planted for every South African family per year (Anonymous, 2001). Insect pests cause significant damage to maize crops. The most important are maize stalkborer, *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae), cutworms, *Agrotis* spp. (Lepidoptera: Noctuidae), black maize beetle, *Heteronychus arator* F. (Coleoptera: Scarabaeidae), army worms, *Spodoptera* spp. (Lepidoptera: Noctuidae) and African bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) (Barrow & Bell, 1993). These insects are mainly African species that moved over to maize from related grasses (Annecke & Moran, 1982). *Agrotis* spp. is the second most important pest in the maize production areas of South Africa (Smit, 1964; Barrow & Bell, 1993).

### Distribution

Cutworms are cosmopolitan and occur in the U.S., Europe, Canada, Japan, New Zealand, South Africa, South America and the Pacific (Kessing & Mau, 1991; Blair, 1976). The black cutworm, *Agrotis ipsilon* (Hufnagel) is known to occur in all continents while *A. segetum* (Denis & Schiffermüller) is present throughout Africa, Europe, the Middle East and South East Asia (Annecke & Moran, 1982). Other cutworm species that occur in South Africa are grey cutworm *Agrotis subalba* (Walker) and brown cutworm *Agrotis longidentifera* (Hampson) (Annecke & Moran, 1982). The most commonly encountered species throughout the entire maize production area of South Africa is the common cutworm, *A. segetum* (Drinkwater, 1980; Annecke & Moran, 1982).

### Damage

Cutworms are polyphagous and feed on almost any succulent plant ranging from crops such as maize, sorghum, soya bean, sunflower, marijuana and cotton as well as some

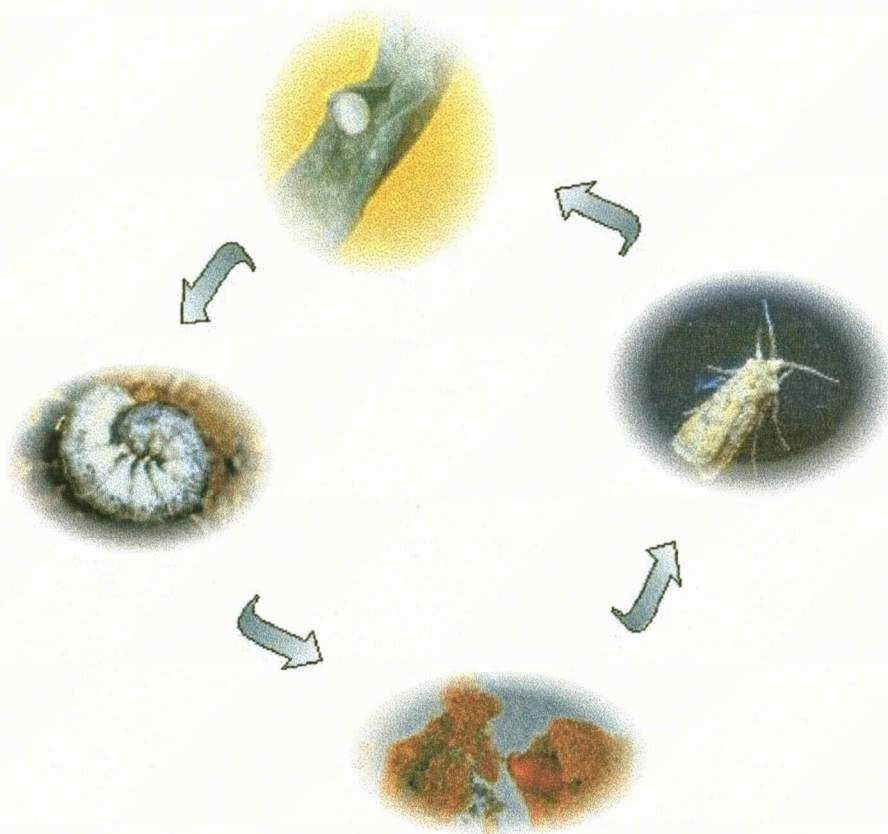
weed species (Smit, 1964; Reese & Beck, 1976; Mc Partland, 1996; Anonymous, 2000). Larvae are usually associated with stem damage of most crops which predominantly occurs during spring and early summer months (Barrow & Bell, 1993). Feeding larvae attack young plants below, on and above the soil surface often causing the plants to die (Metcalf & Metcalf, 1993). Feeding on the stem of older plants often results in a clean hole and neatly chewed stem unlike that of the black maize beetle, *H. arator* and false fire worm, *Gonocephalum* spp. and *Mesomorphus* spp. (Coleoptera: Tenebrionidae) which has a frayed appearance (Drinkwater, 1980). Larvae hide below the soil surface close to their host plant and only emerge during the night to feed (Annecke & Moran, 1982). Although they can feed during the day, they avoid direct sunlight (Barrow & Bell, 1993).

Cutworms can be highly destructive since one larva can cut off a number of plants in a single night (Matthee, 1974). *Agrotis ipsilon* has been reported to cause severe damage (removal of all leaf tissue) in the early stages of corn development resulting in a significant impact on subsequent plant growth (vegetative, reproductive and phenological) of the damaged plant (Santos & Shields, 1998). Damage inflicted by cutworms may sometimes cause significant reduction in plant stand such that the farmer may have to replant (Metcalf & Metcalf, 1993).

### **General biology**

The life cycle of *A. segetum* varies across many parts of the world (Blair, 1976). In southern Africa, larvae are known to have six instars (Annecke & Moran, 1982). Adult females of *A. segetum* lay 1 000 or more eggs which can be laid singly or in groups on the soil or on the leaves of weeds and cultivated plants (Annecke & Moran, 1982). Hatching time of eggs and the duration of subsequent stages is influenced by environmental conditions such as temperature and ranges from 10-14 days (Anonymous, 1979, Annecke & Moran, 1982). When eggs are laid in autumn and winter, various sizes of larvae overwinter in the soil until spring. They then remain active under winter weeds

and develop slowly until they reach the last larval instar (van den Berg, Drinkwater & du Plessis, 2000). During August and September, these larvae develop into pupae in pupal cells in the soil (du Plessis, 2000) (Fig. 1).



**Figure 1:** Life cycle of *A. segetum*.

First generation moths for the new season then emerge approximately two weeks after pupation, lay eggs and the second generation follows (Fig.1) (Barrow & Bell, 1993). During summer the life cycle takes approximately 50 days to complete (du Plessis, 2000). Several generations may occur during the year but overwintering larvae and the first generation in spring are the most damaging (Barrow & Bell, 1993).



## **Management**

Cutworms are often difficult to control, especially when populations are in epidemic proportion (Kessing & Mau, 1991). Various control methods for cutworm larvae are currently being used (du Plessis, 2000). Studies conducted by Farnesa in the Northern Province of South Africa indicated that burning concoction of roots and leaves of certain plants can serve as a repellent for cutworms (Farnesa, 1999). Biocontrol agents such as parasites, predators and disease causing organisms do not provide adequate control of larvae (Kessing & Mau, 1991). In small gardens, larvae are controlled through manual collection (Anonymous, 1979). Bait can be used where cutworms are already present in fields prior to planting and synthetic pyrethroids where damage is observed after planting (du Plessis, 2000). Cultural control through removal of weeds and volunteer plants from fields six weeks before planting is recommended to reduce the number of larvae in the soil (Drinkwater, 1980). However, since numerous cutworm larvae can be found under one plant, severe infestations can occur if only small numbers of preferred weed species are present.

## **Objectives**

Tracking the movement of insects in their natural environment is essential for understanding basic biology (Hagler & Jackson, 2001). Marking is therefore fundamental for recognition of insects. Marking techniques are not universal and unique markers have to be developed for different insect species as a result of differences in their biology and the nature of the surface to which the mark is to be applied (Taft & Agee, 1962; Winewriter & Walker, 1984; Hagler & Jackson, 2001). Paints and inks have been applied to individual insects with various degrees of success (Hagler & Jackson, 2001). No literature is available on marking of cutworm larvae.

An insect is constantly subjected to stimuli such as light, moisture and temperature in its environment. These stimuli may affect the insect and contribute to its survival (Beck, 1968). Dark and light periods serve as a clock by which activities such as mating and

feeding are regulated (Romoser & Stoffolano, 1981). Phototactic responses of cutworm species *Tryphaena pronuba* L. and *Amathes c-nigrum* L. have been reported (Madge, 1964; Olson & Rings, 1969). Behavioural studies of the phototactic responses of the spotted cutworm, *A. c-nigrum* showed 4<sup>th</sup> instar larvae to be photopositive at lower intensities and photonegative at higher intensities of light (Olson & Rings, 1969). Light therefore influences the activities of *A. c-nigrum*. However, little work has been done on the phototactic responses of *A. segetum* (Blair, 1975).

Soil moisture influences survival of insects that spend a part of their life cycle in the soil (Villani & Wright, 1990). Soil moisture also regulates feeding of *A. ipsilon* and *A. orthogonia* (Morrison) on maize, under field conditions (Berry & Knacke, 1987; Anonymous, 2000). Since *A. segetum* spends a part of its life below the soil surface it is consequently influenced by soil moisture.

In the absence of crops, larvae overwinter in the soil under weeds (Drinkwater & van Rensburg, 1992). Crop residues and weeds on agricultural fields can result in cutworm attack to the following crop (Blair, 1975). Weeds, crop residues and debris act as hosts for oviposition and a source of food for overwintering larvae. After hatching, first instar *A. segetum* larvae remain and feed on plants oviposited on by the female (du Plessis, 2000). The ability of young larvae to survive on various plant species and the associated rate of development are useful to predict potential damage and population outbreaks in certain fields. Presence of certain weeds in uncultivated maize fields therefore enhances cutworm infestations due to their suitability as hosts for larval development. Plant morphological characters such as tissue toughness and leaf pubescence can act as barriers to normal feeding and oviposition by insects (Smith *et al.*, 1994). No information concerning factors that inhibit or favour feeding of newly emerged *A. segetum* larvae on its host plants is available.

The main objective of this study was therefore to investigate the effect of soil moisture and host plants on the behaviour of *A. segetum*. Further objectives were to develop a marker to detect *A. segetum* larvae in the dark and to investigate the influence of various light sources on larval activity.

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# CHAPTER 2

# **A MARKING TECHNIQUE AND BEHAVIOURAL RESPONSES OF *AGROTIS SEGETUM* (DENIS & SCHIFFERMÜLLER) (LEPIDOPTERA: NOCTUIDAE) LARVAE TO VARIOUS LIGHT SOURCES**

## **ABSTRACT**

Since cutworms are nocturnal, a marking technique was developed to detect and distinguish cutworms from each other in the dark. Fluorescent powders of different colours mixed with white Humbrol paint fluoresced well in the dark and did not affect larval survival and behaviour. Walking trails of larvae dusted with fluorescent powder could be detected for a distance of up to two meters when irradiated with UV light. Larvae were illuminated with light from different sources and subjected to various starvation times in the laboratory and under field conditions to identify the effects of light on behaviour. Significantly more larvae that had been starved for 72 hours and 96 hours remained above the soil surface for longer periods relative to unstarved, 24 hour starved and 48 hour starved larvae, when irradiated with UV and infrared light. Orientation of 96 hour starved larvae towards UV light under field conditions was also evaluated. These larvae tended to move towards the direction of light when illuminated with UV light under field conditions. The influence of different light sources on cutworm larval behaviour could not really be established. Starvation and dark adaptation were the main factors influencing larval activity.

**Key words:** activity, behaviour, fluorescent, light, marker, night, starvation.



## INTRODUCTION

Daily behaviour patterns such as feeding, mating, and oviposition occur at different times of the day in various insect species (Beck, 1968). This is governed by daily cycles of temperature, humidity and light intensity. Insects generally possess an internal physiological rhythm and an exogenous, internal rhythm of day-night alteration which is synchronized by the sun's motion (Mazokhin-Porshnyakov, 1969). The natural rhythm of daylight and darkness provides a link between the organism and its environment (Beck, 1968). Insects have extensively exploited the patterns of photoperiod in their evolution of ecological, physiological, morphological and behavioural adaptations (Beck, 1968). Their behaviour is to a large extent determined by visual stimulation since they are able to see an object and find their way towards it or away from it. Light allows this discrimination and recognition of objects since it transmits information about them through changes in intensity, spectral composition, polarization and other physical characteristics of the luminous radiation. It therefore determines the insect's reaction to objects (Mazokhin-Porshnyakov, 1969). Light acts as a stimulus cue guiding the insects to situations where it may find optimal conditions for living (Mazokhin-Porshnyakov, 1969). Most adult insects are attracted to light, particularly artificial light (Youdeowei, 1977; Glick & Hollingsworth, 1954). However, most immature insects avoid light (Anonymous, 2000). During the day, larvae of the common cutworm, *Agrotis segetum* (Denis & Schifferrmüller), occur beneath the soil surface from where they emerge to be active nocturnally. At night, feeding larvae attack young plants moving from one plant to another, cutting them near ground level causing the plants to die (Annecke & Moran, 1982). This nocturnal behaviour has drawn the attention of many entomologists (Blair, 1975), necessitating a marking technique for observations in the dark. A requirement for such a technique is that it must not affect the longevity or behaviour of the organism (Hagler & Jackson, 2001).

Marking of insects is important in behavioural studies in distinguishing insects from each other and dates back to 1928 when researchers used paints, dyes and stains in population dynamics studies (Hagler & Jackson, 2001; Chamberlain *et al.*, 1977). Paints and inks have been applied to individual insects with various degrees of success (Hagler & Jackson, 2001). Non-soluble paints are the most durable of paints and inks evaluated on the surfaces of two cricket and one beetle species (Winewriter & Walker, 1984). Fluorescent dusts have been widely used for release-recapture studies in a number of insects (Hogsette, 1983) and certain marking materials such as fluorescent inks glow strongly when subjected to black-light irradiation (Taft & Agee, 1962; Porter & Jorgensen, 1980).

The objectives of this study were to develop a marker for cutworm larvae that can be detected in the dark and to evaluate the effect of the marker on larval survival. Larval activity when exposed to various light sources and the influence of starvation on larval activity were also evaluated.

## **MATERIAL AND METHODS**

### **1. Marking technique**

Twenty laboratory reared fourth instar cutworm larvae were marked with a 1:1 white Humbrol paint (a commercially available paint used for painting model aircrafts) and Helecon fluorescent powder mixture. A highly adhesive substance had to be used since cutworms have a smooth and greasy cuticle. Cutworms were hand held to prevent escape while the marker was applied to the dorsal surface of the abdomen with a matchstick. After drying in a tray individual larvae were placed in plastic containers (7 cm in diameter) with soil, provided with artificial diet and allowed to burrow into the soil. The control consisted of twenty unmarked fourth instar larvae. Marked larvae were observed for adhesion and fluorescence of the marker as well as for abnormal behaviour. Survival

was recorded daily for a period of 20 days. A two-sample t-test was used to determine differences in survival between marked and unmarked larvae (Statgraphics Plus 5.0).

## **2. Larval response to artificial light**

A laboratory study was conducted to evaluate the response of cutworm larvae to ultraviolet (UV) and infrared light. The study was conducted in a dark room and exposure to incandescent (household) light (937.5 lm) served as the control treatment. Larvae were subjected to the following subtreatments: unstarved, 24 hour-starved, 48 hour-starved, 72 hour-starved and 96 hour-starved. For the UV light (4600 lm) treatment, ten larvae per treatment were each marked with a 1:1 mixture of white Humbrol paint and various colour fluorescent powders. Larvae for the infrared and control treatments were left unmarked. Ten fourth instar larvae were placed at the center of a circular basin (55 cm in diameter) half-filled with sand. For the different treatments illumination was done with a UV (4600 lm), infrared (750 lm) and incandescent light respectively at 10 minute intervals for one hour. The number of larvae that remained above the soil surface was recorded and behaviour of the larvae observed. Infrared light was directed through a clear beaker filled with water when illuminated to absorb infrared wavelengths and to minimize heating effects of infrared light (Shields, 1989). Water in the beaker was changed regularly to dissipate the heat. Data was subject to analysis of variance and means separated using Tukey's test at the 95% level of significance (Statgraphics Plus 5.0).

## **3. Larval movement and orientation**

Ten fourth instar larvae starved for 96 hours, were dusted with fluorescent powder of different colours. Cutworm larvae were individually placed in a closed container with 0.5g of fluorescent powder. The container was slowly rolled for one minute. Dusted larvae were placed at the centre of a 5 x 5 m<sup>2</sup> plot under natural conditions at night and illuminated with UV light for an hour. Number of larvae on the soil surface as well as orientation towards light and movement at 10 minute intervals were recorded. When

dusted with fluorescent powder, larvae left a trail which could be detected with UV light in the dark. Walking trails and distance traveled were recorded after a period of 10 minutes.

**4. Response of cutworm larvae to natural light**

Fourth instar cutworm larvae were subjected to a range of starvation and light adaptation times i.e unstarved and dark adapted, 24 hour-starved and light adapted, 24 hour-starved and dark adapted, 48 hour-starved and light adapted, 48 hour-starved and dark adapted, 72 hour-starved and light adapted, 72 hour-starved and dark adapted. Starvation and adaptation to light were of equal duration. Ten cutworm larvae were placed at the centre of a 5 x 5 m<sup>2</sup> plot under natural conditions at daytime for each treatment. Dark-adapted larvae were placed in a dark room and light-adapted larvae were kept in a room where incandescent light conditions were constantly maintained. Number of larvae that remained above the soil surface was recorded at 10 minute intervals for an hour. Data was subjected to analysis of variance and means were separated using Tukey’s test at the 95% confidence level (Statgraphics Plus 5.0).

**RESULTS AND DISCUSSION**

**1. Marking technique**

Table 1: Percentage survival of marked and unmarked *A. segetum* larvae after 20 days.

Treatment	Mean ± S.D
Marked	0.80 ± 0.41 a
Unmarked	0.90 ± 0.31 a

Means within columns followed by the same letter do not differ significantly at P = 0.05.

Humbrol paint enhanced adhesion, while fluorescent powder rendered the larvae visible and distinguishable when illuminated with UV light under dark conditions. Cutworms could however only be detected when the marked dorsal surface was facing the light. There was no significant difference in survival ( $\alpha = 0.05$ ,  $P = 0.39$ ) between marked and unmarked cutworm larvae (Table 1). Neither abnormal behaviour nor abnormal feeding of the marked larvae was observed. The marker therefore did not affect survival and behaviour of the larvae. The only disadvantage for trials conducted over longer periods is that the mark is lost during ecdysis.

The marking technique developed for cutworms satisfies the requirements listed by Hagler & Jackson (2001) namely easy applicable, quick drying, lightweight, available in several colours, easily detected at night, retained for at least one instar and non-toxic to the larvae.

## 2. Larval response to artificial light

Table 2: Number of *A. segetum* larvae on the soil surface after illumination for an hour with different artificial light sources.

Treatment	Mean $\pm$ S.D.		
	Incandescent light	UV light	Infrared light
Unstarved	0.067 $\pm$ 0.21 a	0 a	0 a
24hr-starved	0.083 $\pm$ 0.24 a	0 a	0.03 $\pm$ 0.18 ab
48hr-starved	0.033 $\pm$ 0.18 a	0.03 $\pm$ 0.18 a	0.15 $\pm$ 0.36 b
72hr-starved	0.033 $\pm$ 0.18 a	0.13 $\pm$ 0.36 b	0.33 $\pm$ 0.48 c
96hr-starved	0.330 $\pm$ 0.48 b	0.40 $\pm$ 0.59 c	0.33 $\pm$ 0.48 c

Means within columns followed by same letter do not differ significantly at  $P = 0.05$ .

There were no significant differences in the mean number of larvae given the treatments unstarved, 24 hour-starved, 48 hour-starved and 72 hour starved when illuminated with incandescent light (Table 2). More larvae that had been starved for 96 hours remained on

the soil surface and numbers differed significantly from the other treatments. When illuminated with UV light, number of unstarved, 24 hour-starved and 48 hour-starved larvae all burrowed below the soil surface within an hour and did not differ significantly from each other (Table 2). Unstarved and 24 hour-starved larvae burrowed into the soil immediately when illuminated with infrared light. Significantly more larvae starved for 72 and 96 hours remained on the soil surface under infrared illumination (Table 2). In general, significantly more 96 hour-starved larvae remained on the soil surface relative to other treatments when illuminated with any of the three light sources. When larvae were confined to an enclosed environment, they tended to move around the container in all treatments, probably in search for food. Others moved around the edges of the container looking to escape.

### 3. Larval movement and orientation

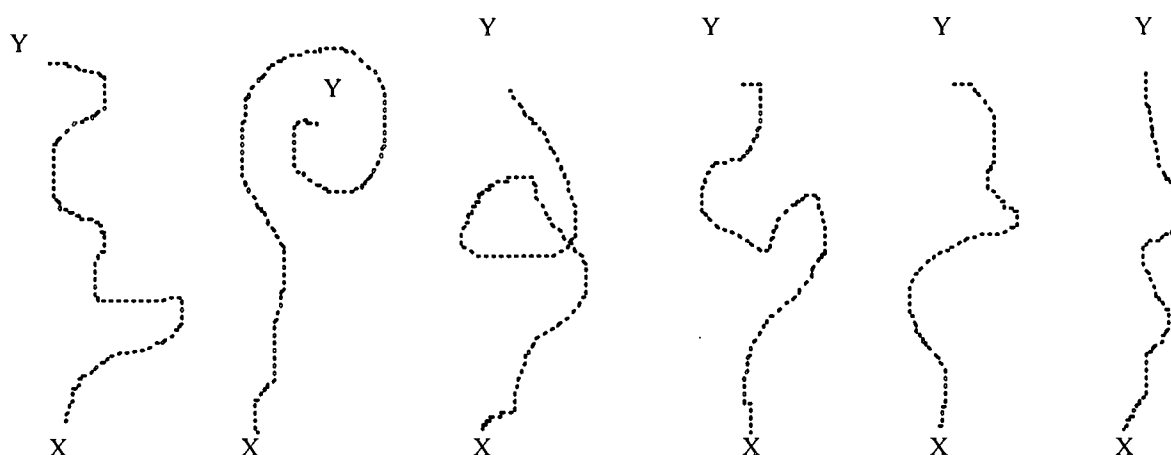


Figure 1: Ten minute walking tracks of six 96 hour-starved *A. segetum* larvae in the dark. Y: starting point, X: light position.

A major part of an insect's behaviour involves turning towards or away from factors like food, light and host plants (Mazokhin-Porshnyakov, 1969; Bell, 1985). Four of the ten larvae burrowed in the soil immediately after release. All larvae that remained on the soil surface tended to move away from the starting point in the direction of the light source

when illuminated with UV light (Fig. 1). Larvae were therefore attracted to UV light. Moreover, starvation urged the larvae to remain on the soil surface in search of food. Powder adhering to the larvae left clear trails for a maximum distance of two meters before wearing off.

The active movement of insects in relation to environmental resources is the means by which most organisms acquire resources such as food (Bell, 1985). A possible explanation for movement towards light when illuminated with UV light is that larvae perceived UV light as more typical of open space. Open space is richer in UV light than a secluded place (Mazokhin-Porshnyakov, 1969). The earth's surface mainly soil, strongly absorbs short wave radiations from UV light and reflects the long wave ones. The sun and sky are the main sources of ultraviolet radiations by day. At night or when the sun is not visible, the sky is the main source of short wave radiations (Mazokhin-Porshnyakov, 1969). When insects need open space they direct themselves towards the light, when they want to hide they avoid it. This explains the attraction of nocturnal insects to a lamp from a distance when the emitted light is richer in shortwave radiations, particularly UV (Mazokhin-Porshnyakov, 1969).

#### 4. Response of cutworm larvae to natural light

Table 3: Number of *A. segetum* larvae on soil surface after exposure for an hour to natural light.

Treatment	Mean $\pm$ S.D
Unstarved and dark adapted	0.033 $\pm$ 0.18 a
24hr-starved & light-adapted	0.017 $\pm$ 0.13 a
24hr-starved & dark-adapted	0.10 $\pm$ 0.30 ab
48hr-starved & light adapted	0.13 $\pm$ 0.34 ab
48hr-starved & dark adapted	0.62 $\pm$ 0.49 c
72hr-starved & light adapted	0.22 $\pm$ 0.42 b
72hr-starved & dark adapted	0.62 $\pm$ 0.49 c

Means within columns followed by same letter do not differ significantly at  $P = 0.05$ .

There were no significant differences in the time that larvae spent on the soil surface between treatments unstarved & dark adapted, 24 hour-starved & light-adapted, 24 hour-starved & dark adapted and 48 hour-starved & light adapted (Table 3). Larvae starved for 48 hours & dark adapted and 72 hour-starved & dark adapted larvae remained on the soil surface for a longer period relative to the other treatments. This therefore indicated that dark adaptation had an influence in larval activity. A change from positive to negative phototaxis in *A. segetum* and *A. ipsilon* larvae occur during the third instar (Blair, 1975). Since fourth instar larvae were evaluated, the determining factor for extended activity on the soil surface is starvation rather than positive phototaxis.

In the dark an insect's eye gets more sensitive as it becomes dark adapted. A dark adapted insect is much more sensitive to light of low intensities than a light adapted insect (Chapman, 1980). After a period of illumination an insect's eye becomes light adapted, during this period the eye also becomes progressively less sensitive (Chapman, 1980). However, if the insect is placed in artificial conditions and the photoperiod is



changed then the inner clock will synchronise with the new photoperiod (Chauvin, 1967). When insect eyes are rapidly light-adapted, ultraviolet light causes a migration of the ommatidial protective pigments from nocturnal to a diurnal position, thus the visual sensitivity decreases by hundreds and thousand times (Bernhard & Ottoson, 1962). However, light and dark adaptation of larvae had no apparent effect on behaviour of *A. segetum* larvae, since no differences in activity were observed between light and dark adapted larvae. The duration of the adaptation also appeared to have no effect on activity. Exposure time or the light source was probably not sufficient to change the internal rhythm of the larvae. It can also be possible that the internal clock of *A. segetum* is dependent on soil temperature best suited for activity.

Increasing light intensity made the moth, *Anagasta kuhniella* Zeller (Lepidoptera: Pyralidae), larvae of the blowfly *Lucilia caesar* Linnaeus (Diptera: Sarcophagidae) and other insects more positively phototactic and decreasing intensity more negatively phototactic (Jander, 1963). Observed differences in larval activity in this study could be partially attributed to differences in light intensity in incandescent (935.5 lm), infrared (750 lm) and UV (4600 lm). When illuminated with infrared light significantly more larvae remained on the soil surface. The low intensity of infrared influenced larval activity. Larvae were less sensitive to infrared light and thus relatively more larvae remained on the soil surface. *Agrotis segetum* larvae were also positively phototactic in search of food.

Starvation of larvae however induced a stronger behavioural response than light conditions. Other factors such as physiological processes determine reactions of insects when exposed to light. The Colorado potato beetle, *Leptinotarsa decemlineata* Say (Coleoptera: Chrysomelidae), not only stops feeding and prepares for hibernation when exposed to a short photoperiod of 10 hours but also becomes negatively phototactic, with phototactic responses gradually disappearing (Jander, 1963). It was observed from these

studies dark adaptation had an influence on activity even when cutworms are given different light treatments.

## CONCLUSION

A 1:1 mixture of white Humbrol paint and fluorescent powder had no effect on cutworm behaviour and survival when applied on the dorsal surface of the larvae. The marker is adequate for marking of cutworm larvae since it is durable, can be easily applied, inexpensive, non-toxic to the larva and makes larvae easily distinguishable from each other. The fluorescent marking technique therefore has potential for use in short-term behavioural studies.

Starvation and dark adaptation urged larvae to remain on the soil surface. Larvae that had been starved for 72 and 96 hours remained on the soil surface for longer periods in search of food regardless of illumination from various light sources than unstarved, 24 hour starved and 48 hour starved cutworm larvae in both laboratory and field studies.

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# CHAPTER 3

# A LABORATORY STUDY ON THE EFFECT OF SOIL MOISTURE ON FEEDING AND SURVIVAL OF *AGROTIS SEGETUM* (DENIS & SCHIFFERMÜLLER) (LEPIDOPTERA: NOCTUIDAE) LARVAE<sup>1</sup>

## ABSTRACT

Feeding of fourth instar *Agrotis segetum* (Denis & Schiffermüller) larvae on weed species, *Chenopodium carinatum* R. Br. and *Portulaca oleracea* L. as well on *Zea mays* L. under dry and wet soil conditions was evaluated under greenhouse conditions. Significantly more above ground plant sections were severed in dry and wet soil conditions on the three plant species. Two other greenhouse experiments were also conducted to determine the effect of soil moisture on larval survival in both the absence and presence of decaying food. In the absence of food, soil moisture levels were maintained at 0, 10, 20, 40, 60, 80 and 100 %. Cutworms survived for approximately one week at a range of 10-100 % soil moisture levels when food was absent. Sections of two weed species, *Amaranthus hybridus* L. and *Portulaca oleracea* L. were buried in pots at three different moisture levels i.e. 0, 10 and 80 %. In the presence of food, all larvae remained alive for up to 10 days at the 80 % moisture level for both weed species. Larval survival was lowest at 0 % soil moisture regardless of the availability of food. However, the highly succulent *P. oleracea*, supported larvae for a number of days, even in the absence of soil moisture. After ploughing of crop fields, this weed species is often buried. It seems that this may contribute to cutworm survival under dry conditions. The cultural control recommendation to cultivate fields 35 days prior to planting is therefore sufficient in effectively reducing larval survival and protection of the crop against cutworm damage.

**Key words:** development, feeding, soil moisture, succulence, survival, weeds.

1. *African Plant Protection*, Submitted for publication (2001)

## INTRODUCTION

The common cutworm, *Agrotis segetum* (Denis & Schiffermüller) (Lepidoptera: Noctuidae) is an important pest of various crops in South Africa (du Plessis, 2000). It can cause up to 80 % stand loss in maize fields, forcing producers to replant (Smit, 1964). Larvae attacking crop seedlings are usually in the fourth and later instars of development (Blair, 1975). Pale western cutworm, *Agrotis orthogonia* L. and black cutworm, *Agrotis ipsilon* (Hufnagel) larvae feed on the above-ground parts of plants under wet conditions and below the soil surface in dry soil (Berry & Knacke, 1987; Hein *et al.*, 2000). Larvae remain below the soil surface during the day and emerge to sever seedlings on the soil surface at night. At the onset of winter, larvae of different sizes are present in fields (van den Berg *et al.*, 2000). They overwinter as slow developing larvae in the soil and below weeds. Cutworm moths may however occur throughout the winter and shelter under crop residues, winter weeds in fields and grasses in headlands (van den Berg *et al.*, 2000). Overwintering larvae remain active under winter weeds and develop into pupae from the beginning of August, causing a peak in moth numbers shortly afterwards.

Cutworm infestations early in the growing season are generally due to the presence of weeds in maize fields prior to planting of a crop (Bishara, 1932; Busching & Turpin, 1976). A weed-free field prior to planting therefore deprives cutworm larvae of food and moths of oviposition sites. The general recommendation for cutworm control in South Africa is to cultivate fields 35 days prior to planting (Drinkwater, 1980; du Plessis, 2000).

Survival of soil dwelling insects is primarily dependent on soil properties such as soil moisture, which is vital for the survival of insects that spend a part of their life cycle in the soil (Campbell, 1937; Kuhnelt, 1963; Youdeowei, 1977; Villani *et al.*, 1999). The aim of this study was to determine the influence of soil moisture on cutworm feeding and

survival in both the absence and presence of decaying food and whether the recommendation currently applied in practice would be sufficient in minimizing stand and crop losses due to cutworm damage.

## MATERIAL AND METHODS

### 1. Larval feeding under wet and dry soil conditions

A greenhouse experiment was conducted at 26<sup>0</sup> C and 14L:10D photoperiod to determine larval feeding under wet and dry soil conditions. Pots (12.5 cm in diameter) were filled with sandy loam soil. Treatments were maize planted in pots and the weeds, *C. carinatum* and *P. oleracea* transplanted from a field into pots. Inoculation with one fourth instar larvae per pot was done 12 days after planting to both wet and dry soil treatments. There were 30 replicates for each sub-treatment. Pots were covered with 2 l plastic bottles to prevent escape of larvae and evaporation. Six pots from each treatment were removed daily and damage under wet and dry conditions recorded for five consecutive days. Data was subjected to analysis of variance and means were separated using Tukey's test at the 95 % level of significance (Statgraphics Plus 5.0).

### 2. Effect of soil moisture on survival

Two experiments were conducted in pots (12.5 cm diameter), to determine the effect of soil moisture on cutworm survival in the absence and presence of decaying food. Experiments were conducted in a greenhouse at temperatures of 30<sup>0</sup> C during the day and 20<sup>0</sup> C at night with a photoperiod of 16L:8D. Neonate *A. segetum* larvae were obtained from a laboratory rearing colony maintained for one generation. Larvae were reared on an artificial diet originally developed for mass rearing of *Chilo partellus* Swinhoe (Lepidoptera: Crambidae) and modified for *Somaticus* species (Coleoptera: Tenebrionidae) (Drinkwater, 1994). Soil was collected at the ARC-Grain Crops Institute experimental farm, Potchefstroom (26<sup>0</sup>43'S, 27<sup>0</sup>06'E). Soil composition was 34.5 % clay,



17.5 % silt and 48 % sand with an in situ bulk density ( $\rho_b$ ) of  $1.55 \text{ g/cm}^3$ . The soil was dried at  $105^\circ \text{C}$  for 48 hours. Drained Upper Limit (DUL) of the soil was determined as a reference for soil moisture treatments, since moisture content levels above DUL rarely occur under field conditions (Prinsloo, personal communication).

Eight pots (12.5 cm diameter) were filled with soil to a predetermined level providing a soil volume of 800 ml. Soil mass was calculated as: volume of the soil  $\times \rho_b$  (i.e.  $800 \text{ ml} \times 1.55 \text{ g/cm}^3 = 1240 \text{ g}$ ). Soil with the calculated mass was added to the pots. Eight other pots were filled with water (assuming a water density of  $1 \text{ g/cm}^3$ ) up to the predetermined level. The mass of pots was determined and volume of the water ( $\text{cm}^3$ ) calculated. Eight pots with perforated bottoms were filled with 1240 g of soil and water of a known volume added. The soil was then compacted to the predetermined level to imitate field conditions of soil density and saturated with the rest of the known volume of water. Pots were covered with 2 l plastic bottles which were cut open at the base and sealed on top to prevent evaporation, and left for 48 hours to drain. After drainage ceased, each pot was weighed again and the mean mass or volume water at DUL calculated.

#### **(a) Absence of food**

To determine the effect of soil moisture on cutworm survival in the absence of food, pots were filled with soil and water added to obtain seven soil moisture levels i.e 0, 10, 20, 40, 60, 80 and 100 % of the water content at DUL. Fifty replicates were included for each treatment. Each pot was inoculated with one third instar larva and covered with a 2 l plastic bottle, cut open at the base. The bottles were sealed on top to prevent evaporation and escape of larvae. Eight pots from each treatment were removed daily and larval survival recorded for seven consecutive days.

### (b) Presence of decaying food

To determine the effect of soil moisture on larval survival in the presence of food, pots were filled with soil and water added to obtain three moisture levels, i.e 0, 10 and 80 % of the water content at DUL. Treatments consisted of the same weed species as in the previous experiment. One section of each plant species was buried separately in pots. Each pot, with soil at 0 % soil moisture level was inoculated with one third instar larvae at the onset of the trial. Pots with 10 and 80 % soil moisture levels were also inoculated with one third instar larvae three days after the onset of the trial to allow for drainage of water added. Pots were covered as in the previous experiment. Forty replications were included for each moisture treatment per plant species. Larval moulting and survival were recorded daily. Data was subjected to analysis of variance and means were separated using Tukey's test at the 95 % level of significance (Statgraphics Plus 5.0).

## RESULTS AND DISCUSSION

### 1. Larval feeding under wet and dry soil conditions

**Table 1:** Location of plant parts severed by *A. segetum* larvae under dry and wet soil conditions.

Treatment	Mean $\pm$ S.D	
	Dry soil	Wet soil
<i>C. carinatum</i> (below soil)	0 a	0 a
<i>P. olearacea</i> (below soil)	0 a	0 a
<i>Z. mays</i> (below soil)	0.03 $\pm$ 0.18 a	0.13 $\pm$ 0.35 b
<i>Z. mays</i> (above soil)	0.67 $\pm$ 0.48 b	0.63 $\pm$ 0.49 c
<i>C. carinatum</i> (above soil)	0.90 $\pm$ 0.31 c	1.00 $\pm$ 1.00 d
<i>P. olearacea</i> (above soil)	0.90 $\pm$ 0.31 c	1.00 $\pm$ 1.00 d

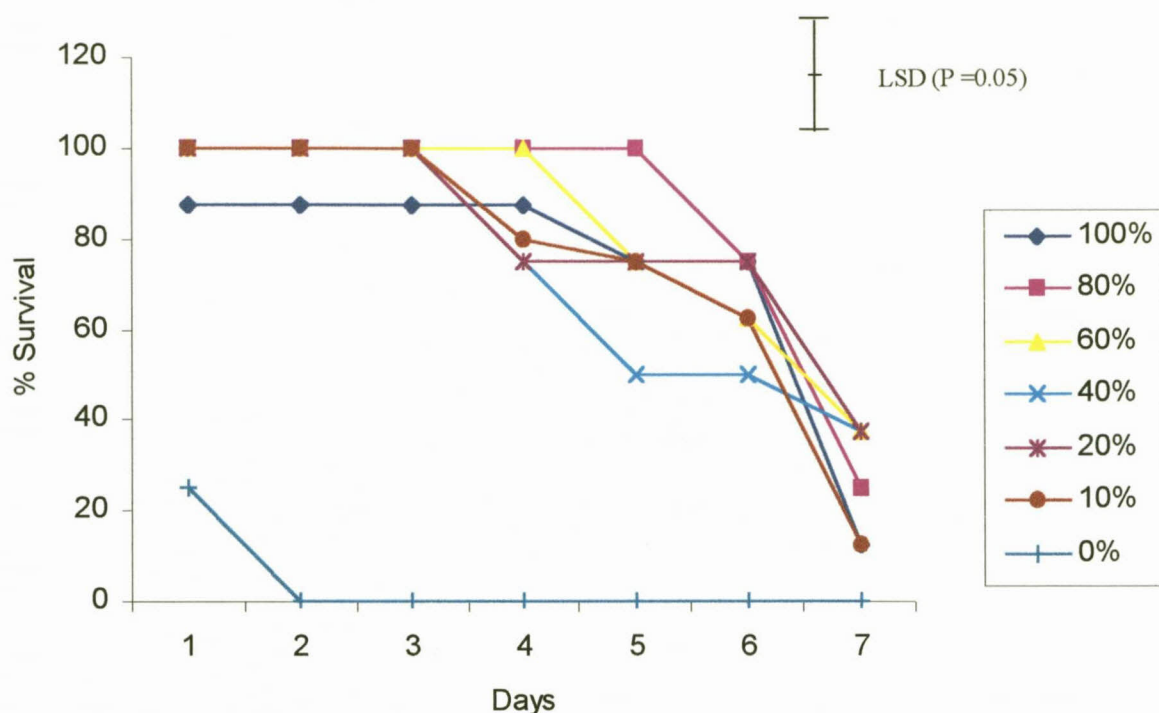
Means within columns followed by the same letter do not differ significantly at  $P = 0.05$ .

Both weed species were severed above the soil surface in both wet and dry soil. There was no significant difference in the mean number of plants severed below the soil surface between *C. carinatum*, *P. oleracea* and *Z. mays* in dry soil (Table 1). Significantly more maize seedlings were severed above the soil surface under dry and wet conditions, indicating that cutworms emerge on the soil surface in search for food. This is in contrast with the findings of Showers *et al.* (1983), that *A. ipsilon* larvae feed below the soil surface in dry soil. The current study was however conducted in a greenhouse and that of Showers under field conditions. Since the greenhouse study was conducted under controlled conditions, fluctuating environmental conditions were excluded. For example, larvae in the greenhouse experiment did not experience high soil surface temperatures during periods of drought under field conditions. This indicates the importance of a holistic approach of various factors in the understanding of insect behaviour.

## **2. Effect of soil moisture on survival**

### **(a) Absence of food**

There was a significant difference in the number of larvae surviving at the 0 % soil moisture level relative to the other soil moisture levels one day after inoculation. All larvae died within two days at 0 % soil moisture due to desiccation (Fig. 1). The high mortality at 0 % moisture level can also be attributed to inadequate humidity to support normal larval development. Cutworm larvae are therefore not able to survive without food and soil moisture, even for short periods. Generally, dry soils can impede larval movement and cause high larval mortality (Edwards, 2000). Sandy soil particles, particularly in dry soil may also scratch the insect's cuticle resulting in death due to desiccation (Brown, 1978). Furthermore, soft-bodied insects such as larvae tend to have comparatively large amounts of water in their tissues. When the limits of moisture tolerance are exceeded, many of an insect's activities are seriously impaired often resulting in death (Romoser & Stoffolano, 1981).



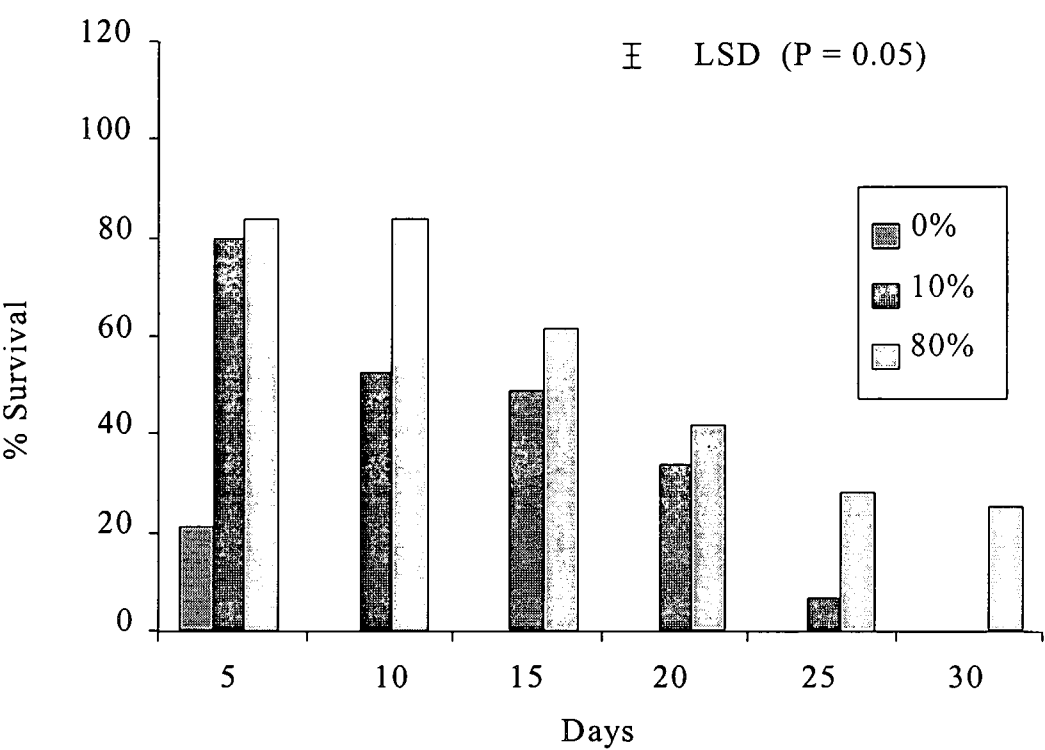
**Figure 1:** Percentage *A. segetum* larval survival at various moisture levels in the absence of food.

At soil moisture levels of 10-40 %, all cutworm larvae survived for three days in the absence of food. At 60 % and 80 % soil moisture levels all larvae survived for four and five days respectively. However, after six days a sharp decline in survival for soil moisture levels of 10-100 % was observed (Fig. 1). There was no significant difference in larval survival at soil moisture levels of 10 % and higher on day seven. Cutworm survival was therefore influenced by soil moisture in the absence of food. However, after a week, cutworms starved regardless of the soil moisture content.

Although the rate of soil aeration is directly influenced by soil moisture, the high level of larval survival in the absence of food was not attributed to soil moisture at 10-100 % levels since there was no significant difference in cutworm survival between the treatments. Soil organisms can only survive in moist soil when it is not highly saturated

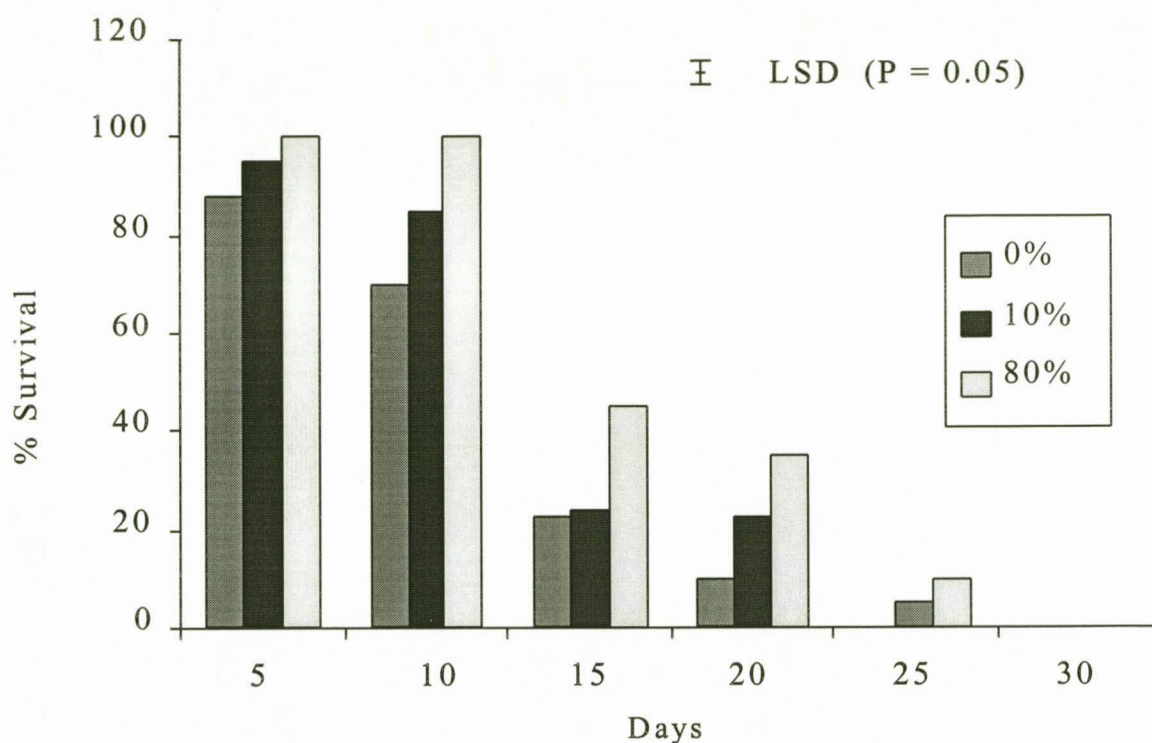
(Lapointe & Shapiro, 1999). In waterlogged soil, every pore space is filled with water to complete hydration, reducing oxygen supply in the soil (Villani & Wright, 1990). Exchange of gases between the soil and atmosphere through pore spaces is reduced since gaseous diffusion occurs slower through water (Edwards, 2000). However, cutworm larvae have the ability to move to the soil surface, escaping unfavourable conditions in the soil. They were therefore not fully dependent on oxygen supply in the soil.

**(b) Presence of decaying food**



**Figure 2:** Percentage survival of *A. segetum* larvae fed on *A. hybridus* at three soil moisture levels.





**Figure 3:** Percentage survival of *A. segetum* larvae fed on *P. oleracea* at three soil moisture levels.

In the presence of decaying *A. hybridus*, significantly more larvae survived at the 10 and 80 % soil moisture levels compared to dry soil. At 0 % soil moisture, all larvae died within 10 days when *A. hybridus* was provided as food (Fig. 2). However, *P. oleracea*, a highly succulent weed, supported a few larvae for up to 20 days at 0 % soil moisture (Fig. 3). Due to its large moisture reserves, *P. oleracea* can survive and retain moisture for some time even after being uprooted or broken (Bromilow, 1995). In general, there was no significant difference in cutworm survival between the two weed species. At 10 % soil moisture, which can be related to field conditions after rain in Hutton soils, a number of larvae survived for up to 25 days on both weed species. Although, not representative of field conditions, thirty percent of larvae were supported until pupation by *A. hybridus* at 80 % soil moisture levels.

Soil moisture was not the main factor determining cutworm survival. Depending on the plant species present, *A. segetum* larvae could survive even in dry soils. Larvae survived for a few days in the absence of food at moisture treatments of 10 % and higher (Fig. 1). Contrarily, larvae survived for up to 20 days at 0 % moisture level in the presence of food (Fig. 3). This suggests that the presence of certain species of buried weeds after cultivation can support cutworm survival regardless of soil moisture levels. Drinkwater (1980) reported as many as nine cutworm larvae underneath a single *Senecio consaguineus* DC. plant in a field prior to cultivation. Since many cutworms can be found under a single plant, a relatively small stand of a preferred plant species in fields can therefore support a number of cutworms. If cultivation of such a field takes place cutworms are provided with shelter and food. The presence of buried weeds in maize fields, either decaying or fresh can therefore increase the potential of cutworm infestations.

**Table 2:** Number of surviving *A. segetum* larvae in the presence of food at various moisture treatments.

Treatment	Instar 4	Instar 5	Instar 6	% surviving to pupae
<i>A. hybridus</i> (0 %)	0 a	0 a	0 a	0 a
<i>P. oleracea</i> (0 %)	0.63 ± 0.49 b	0.13 ± 0.33 ab	0 a	0 a
<i>A. hybridus</i> (10 %)	0.40 ± 0.50 c	0.00 ± 0.00 a	0 a	0 a
<i>P. oleracea</i> (10 %)	0.75 ± 0.44 cd	0.25 ± 0.44 b	0 a	0 a
<i>A. hybridus</i> (80 %)	0.88 ± 0.33 de	0.75 ± 0.44 c	0.65 ± 0.48 c	40 b
<i>P. oleracea</i> (80 %)	1.00 ± 0.00 e	0.25 ± 0.44 b	0.13 ± 0.33 b	0 a

Means within columns followed by the same letter do not differ significantly at P = 0.05.

About 25 % of the larvae that were fed on *A. hybridus* did not develop beyond the third instar (Fig. 2). There was a significant difference in fourth instar larval survival at different soil moisture levels when the same plant species was provided as food (Table 2). Within plant species, significantly more fourth instar larvae survived with increasing

soil moisture levels. *Portulaca oleracea* supported some larvae to the fifth instar at all three soil moisture levels evaluated, with no significant difference between moisture levels (Table 2). In the presence of decaying *A. hybridus* and *P. oleracea*, cutworm larvae developed to the fifth instar at the 80 % soil moisture level only.

Some larvae provided with *P. oleracea* developed to the fifth instar at the 0 % soil moisture level. Although some larvae reached the sixth instar in the presence of decaying *P. oleracea*, only larvae fed on *A. hybridus* at 80 % soil moisture survived until pupation. This result is in contrast with the findings of Archer, Musick & Murray (1980) who found that black cutworm, *Agrotis ipsilon* (Hufnagel) larvae prefer to pupate on soil at 10 % soil moisture. High soil moisture and plant moisture levels were suspected to have resulted in deaths of larvae on *P. oleracea* at the 80 % moisture level. Due to succulence, *P. oleracea* could not lose moisture to the soil since the soil moisture was also high. Excessive water in the soil can easily immobilize insects due to surface tension or it can enter into their cuticles by endosmosis. At high soil moisture levels, cutworms may experience difficulty in moving and prevent them from reaching the soil surface. Reduced oxygen in the soil could have also resulted in high larval mortality. Cutworm larvae which died at high plant and soil moisture levels in this study were soft and colour changes were also observed. The colour of the larvae changed from grey to dull black.

Under field conditions, the saturated water content is generally between 40 and 60 percent of the soil volume (Rowell, 1994). Results of the present study are therefore not applicable to field conditions, since soil moisture levels of 80 % for periods long enough to support larval development until pupation do not occur in the maize production areas of South Africa.



## CONCLUSION

Development of cutworm larvae seems to be influenced by soil moisture in the absence and presence of food. Larvae could survive in dry soil without food. However, succulent plant species could support larvae in dry soils for a longer period. Larvae died prior to pupation under conditions of high soil moisture levels. Contrarily, high moisture levels and a non-succulent food plant could support larval development until pupation since the plant can absorb moisture from the soil.

Cultivation of fields is performed under various soil moisture conditions. Various weed species and volunteer plant species are often buried and may serve as a food source for cutworm larvae which survived cultivation. Severity of cutworm infestation of crops may therefore be favoured by moisture conditions and weed species suitable for survival. Although fields may appear weed-free above the soil surface, cutworm larvae can still be provided with food below the soil surface for prolonged periods prior to planting. The cultural control recommendation to cultivate fields 35 days prior to planting seems to be sufficient in reducing larval survival effectively and to protect the crops against cutworm damage.

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# CHAPTER 4

# SUITABILITY OF VARIOUS PLANT SPECIES FOR OVIPOSITION AND DEVELOPMENT OF *AGROTIS SEGETUM* (DENIS & SCHIFFERMÜLLER) (LEPIDOPTERA: NOCTUIDAE)<sup>2</sup>

## ABSTRACT

Oviposition preference of *Agrotis segetum* (Denis & Schiffermüller) moths was studied in cages in two multi-choice greenhouse experiments. Mass gain and survival of first instar larvae as well as larval development were studied in laboratory no-choice experiments. Oviposition preference was evaluated in a multi-choice test with five weed species viz. *Amaranthus hybridus* L., *Chenopodium album* L., *Datura stramonium* L., *Ipomoea purpurea* (L.) Roth., *Portulaca oleracea* L. and *Zea mays* L.. Choice tests were also conducted with the grasses, *Pennisetum purpureum* (K.) Schumach., *Vetiveria zizanioides* (L.) Nash. and *Z. mays* in a separate experiment. In the weed multi-choice experiment, most eggs were laid on *A. hybridus*, *I. purpurea* and *P. oleracea*. Significantly more eggs were laid on stems than on leaves. There was no significant difference in oviposition among the three grasses, but significantly more eggs were laid on dead plant material. Survival and mass gain of first instar larvae fed on *A. hybridus* and *C. album* was significantly higher than on the other host plants, while survival was significantly lower when fed on *V. zizanioides* and *P. purpureum*. The highest percentage of larvae completed their life cycle on *C. album*. However, larvae that fed on *A. hybridus* and *I. purpurea* developed significantly faster. Leaf pubescence was studied as a possible explanation for these results. Types and densities of trichomes could, however, not account for the observed differences.

**Key words:** development, grasses, mass gain, oviposition, survival, trichomes, weed species.

2. *African Entomology*, Submitted 2001.

## INTRODUCTION

The common cutworm, *Agrotis segetum* (Denis & Schiffermüller) can survive on a variety of plant species due to its polyphagous feeding (Smit, 1964; Metcalfe & Metcalfe, 1964). Cutworm moths oviposit on various host plants ranging from crops to weeds and grasses (Busching & Turpin, 1977). Selection of an oviposition site is a critical stage in host plant selection for most plant-feeding insects (Singer, 1984). This is more important when newly hatched offspring are not capable of searching for additional hosts until they have fed on the plant they hatched on. Since many neonate Lepidoptera are incapable of moving long distances to locate potential food plants, the ability of females to locate and select host plants on which their offspring will develop normally is critical to survival of the larvae (Ng *et al.*, 1990). Newly hatched larvae, due to their small size, have a narrow movement range which minimises their selection of food plants and forces them to feed on the plant species available (Busching & Turpin, 1977). However females do not always oviposit on hosts appropriate for larval survival and newly emerged larvae may reject the plant on which they hatch (Bernays & Chapman, 1994). After hatching, first instar *A. segetum* larvae remain and feed on the plants selected by the female (du Plessis, 2000). Oviposition on host plants suitable to support first instar larvae is therefore important for survival and development of *A. segetum* larvae.

Leaves of many plant species are covered with trichomes which may impede or even prevent larvae from feeding on a particular plant. Trichomes also prevent some insect species from ovipositing on plants, while others prefer leaves with trichomes (Johnson, 1975; Lambert *et al.*, 1992). *Heliothis zea* (Boddie) (Lepidoptera: Noctuidae), lays more eggs on hairy surfaces partly because the female is able to hold on to the hairs (Bernays & Chapman, 1994). Tobacco budworm, *Heliothis virescens* Fabricius (Lepidoptera: Noctuidae) also prefer to oviposit on leaves of pubescent cotton (Ramalho *et al.*, 1984). However, in general, pubescence interferes with oviposition, attachment of eggs to plant surfaces, feeding and ingestion of many insects (Ramalho *et al.*, 1984). There is a

negative correlation between trichome density on the plant surface and insect feeding in numerous plant species (Sosa, 1988). No information concerning factors that inhibit or favour feeding of first instar *A. segetum* larvae on its host plants is available.

Cutworms are attracted to weedy fields for oviposition (Busching & Turpin, 1977). Oviposition preference for certain host plants and the ability of newly emerged cutworms to survive on various weeds and grasses as well as the associated rate of development may be important to predict seasonal outbreaks and potential damage. The objectives of this study were to determine oviposition preference, survival of newly hatched larvae and larval development of *A. segetum* on various host plants. A possible relationship between trichome density and the number of eggs laid on various plant species was investigated as well as survival and mass gain of newly emerged larvae on the plant species evaluated.

## MATERIALS AND METHODS

### 1. Oviposition

Moths were obtained from larvae reared in the laboratory on artificial diet. The artificial diet was originally developed for mass rearing of *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) and modified for rearing of *Somaticus* species (Coleoptera: Tenebrionidae) (Drinkwater, 1994).

All studies were conducted in a greenhouse where a temperature of  $25 \pm 1^{\circ}\text{C}$  and a 14 hour photoperiod were maintained. Weed species (Table 1) were selected according to their relative abundance in maize fields. The weeds were transplanted from fields into pots (30 cm in diameter).



#### **(a) Multi-choice experiment: weeds and maize**

Five different weed species, viz. *Amaranthus hybridus*, *Chenopodium album*, *Ipomoea purpurea*, *Portulaca oleracea* and *Datura stramonium* and maize, *Zea mays* were evaluated (Table 1). One potted plant of each plant species was placed in gauze-covered cages (65 x 100 x 100 cm) in a randomized complete block design. The experiment was repeated six times and the plant positions alternated in each replication to allow for each plant species to occupy all six demarcated positions within the cage. Ten female and ten male moths were released into each cage within 24 hours of eclosion from pupae and left for three days to allow for mating, ovary maturation, photoperiod adjustment and oviposition. Cotton balls, saturated with 20 % sugar-water solution were provided as food. Number and location of eggs on the plants as well as eggs laid elsewhere in cages were recorded. Data was subjected to analysis of variance and the means were separated using Tukey's test at the 95% confidence level (Statgraphics Plus 5.0).

#### **(b) Multi-choice experiment: grasses**

Oviposition preference between the grasses *Vetiveria zizanioides*, *Pennisetum purpureum* and *Z. mays* was evaluated (Table 1). One potted plant of each grass species was placed in gauze-covered cages (60 x 50 x 80 cm). Plants of *P. purpureum* and *V. zizanioides* comprised of fresh and dead leaf tissue. No dead leaves were present on maize plants. Five female and five male *A. segetum* moths were released into each cage within 24 hours of eclosion from pupae. The experiment was repeated six times and position of the pots was alternated for each replication. Oviposition preference was determined by counting the number of eggs laid on the host plants. Data was subjected to analysis of variance and the means were separated using Tukey's test at the 95% confidence level (Statgraphics Plus 5.0). Although a number of eggs were encountered on the cage frame and gauze, these were not included in the analysis.

**Table 1:** Plant species evaluated in choice and no-choice experiments.

Family	Plant species	Common name
Amaranthaceae	<i>Amaranthus hybridus</i> L.	Common pigweed
Chenopodiaceae	<i>Chenopodium album</i> L.	White goosefoot
Convulvulaceae	<i>Ipomoea purpurea</i> (L.) Roth	Common morning glory
Gramineae	<i>Pennisetum purpureum</i> (K.) Schumach	Napier grass
	<i>Vetiveria zizanioides</i> (L.) Nash	Vetiver grass
	<i>Zea mays</i> L.	Maize
Portulacaceae	<i>Portulaca oleracea</i> L.	Pigweed
Solanaceae	<i>Datura stramonium</i> L.	Common thorn-apple

## **2. Larvae**

### **(a) Survival and mass gain of newly emerged larvae**

To determine mass gain and larval survival, neonate larvae were fed an artificial diet and different host plants (Table 1). Second generation *A. segetum* larvae reared for one generation on artificial diet under laboratory conditions, were used in this study. Ten newly hatched larvae that had not yet fed, each weighing between 0.09 and 0.12 mg were transferred to separate containers and the mean mass per container recorded. The agar lined containers (7 cm in diameter) contained fresh leaf sections of one host plant in abundance. In one treatment, artificial diet was provided instead of plant material. There were 10 replicates for each treatment. Containers were sealed with plastic lids with small holes, which allowed air movement and reduced condensation. After five days, mean mass of larvae and mortality in each container were again recorded. Data was subjected to analysis of variance and the means were separated using Tukey's test at the 95% confidence level (Statgraphics Plus 5.0).

### **(b) Larval development**

Newly hatched *A. segetum* larvae that had not yet fed were transferred to plastic containers (7 cm in diameter). In each container, fresh leaf sections of one host plant were provided. The host plants were *A. hybridus*, *C. album*, *D. stramonium*, *I. purpurea*, *P. oleracea*, *P. purpureum* and *V. zizanioides*. Containers with treatments that contained

*P. purpureum* and *V. zizanioides* leaf sections were lined with an agar base to prevent leaf turgor. There were 10 replicates for each treatment. Containers were sealed as in the previous experiment. Larvae in each container were monitored daily for development and mortality recorded. Food was replenished every second day. Data was subjected to analysis of variance and the means were separated using Tukey's test at the 95% confidence level (Statgraphics Plus 5.0).

### **3. Trichome density**

Leaves from each of the eight plant species were individually placed in containers and immersed in 70 % alcohol for 24 hours. Transfer to 80 % alcohol dehydrated the leaves for 30 minutes followed by 90 % alcohol for 30 minutes and 100 % alcohol for 12 hours. Adaxial and abaxial leaf sections from each leaf were then excised, immersed in acetone and critical point dried for 45 minutes. The excised sections were 1 cm<sup>2</sup>. After drying the sections were mounted on stubs, sputter coated with gold / palladium for 15 minutes and recoated for an additional 10 minutes. Coated leaf sections were examined under a scanning electron microscope for the presence and types of trichomes on the abaxial and adaxial leaf surfaces. The number of trichomes / cm<sup>2</sup> on the abaxial and adaxial surfaces were determined from SEM micrographs. Data was subjected to analysis of variance and the means were separated using Tukey's test at the 95% confidence level (Statgraphics Plus 5.0).

## RESULTS

### 1. Oviposition

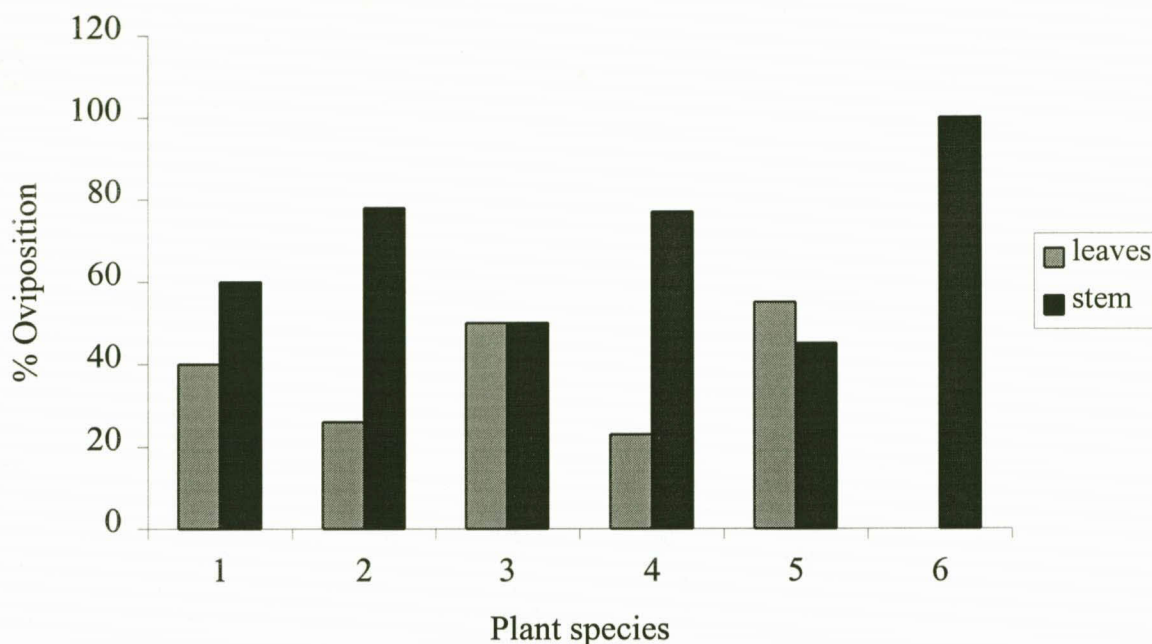
#### (a) Multi-choice experiment: weeds and maize

**Table 2:** Number of eggs laid by *A. segetum* and trichome density on leaves of various plant species.

Plant species	Mean no. of eggs $\pm$ S.D	Trichomes/cm <sup>2</sup> (abaxial)	Trichomes/cm <sup>2</sup> (adaxial)
<i>C. album</i>	6.0 $\pm$ 14.7 a	60	180
<i>D. stramonium</i>	6.3 $\pm$ 15.5 a	0	0
<i>Z. mays</i>	6.3 $\pm$ 15.5 a	600	120
<i>P. oleracea</i>	18.7 $\pm$ 30.2 ab	0	0
<i>A. hybridus</i>	53.7 $\pm$ 42.9 b	0	0
<i>I. purpurea</i>	61.7 $\pm$ 75.8 b	70	130

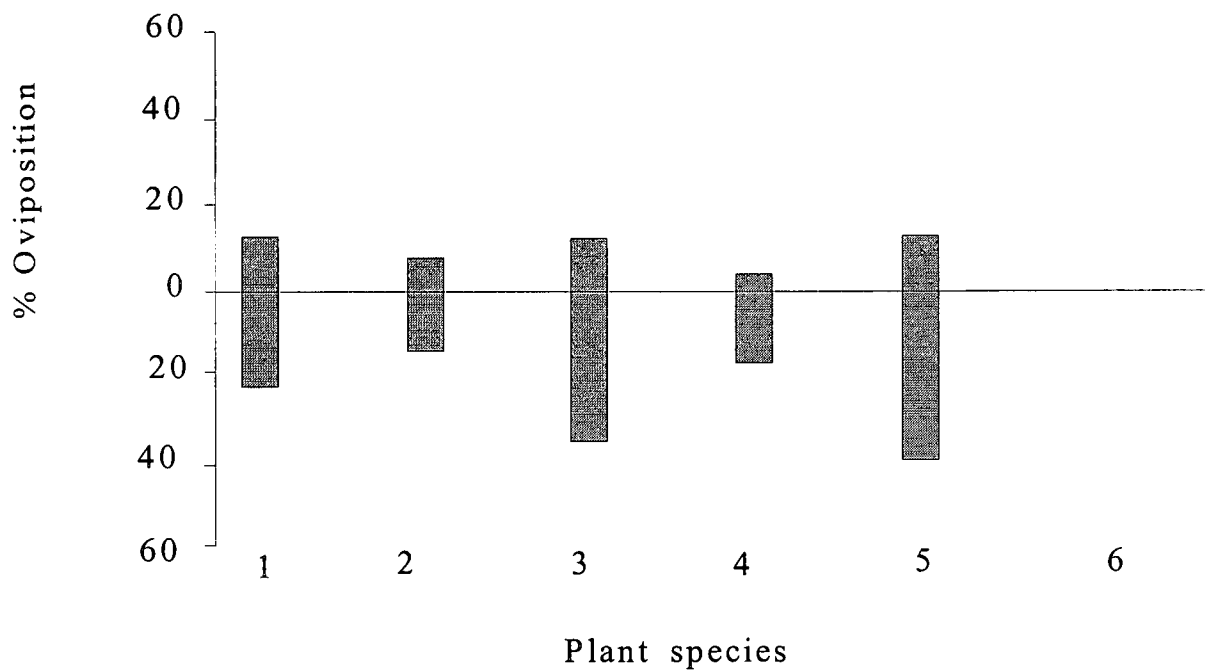
Means within columns followed by the same letter do not differ significantly at  $P = 0.05$ .

*Agrotis segetum* moths oviposited on all plant species, but significant differences in number of eggs were observed (Table 2). Oviposition was significantly higher on *A. hybridus* and *I. purpurea*. It did however not differ significantly from the number of eggs laid on *P. oleracea*. There was no significant difference between the number eggs laid on *C. album*, *D. stramonium*, *P. oleracea* and *Z. mays*.



**Figure 1:** Percentage eggs laid by *A. segetum* moths on leaves and stems of various plant species. 1: *A. hybridus*, 2: *C. album*, 3: *D. stramonium*, 4: *I. purpurea*, 5: *P. oleracea*, 6: *Z. mays*.

Eggs were laid singly and in clusters. Most of the eggs were laid on the fleshy stem on all weed species evaluated with the exception of *P. oleracea* where most of the eggs were laid on leaves and *D. stramonium* where a similar percentage of eggs was laid on the leaves and stems (Fig. 1). The hairy stem of *I. purpurea* was a highly preferred oviposition surface by *A. segetum* moths (Fig. 1). When laid on leaves, the abaxial was preferred over the adaxial surface of *A. hybridus*, *C. album*, *D. stramonium*, *I. purpurea* and *P. oleracea* (Fig. 2).



**Figure 2:** Percentage egg distribution on leaves of various plant species. Percentages above and below zero indicate the number of eggs on the adaxial and abaxial leaf surfaces respectively. 1: *A. hybridus*, 2: *C. album*, 3: *D. stramonium*, 4: *I. purpurea*, 5: *P. oleracea*, 6: *Z. mays*.

#### (b) Multi-choice experiment: grasses

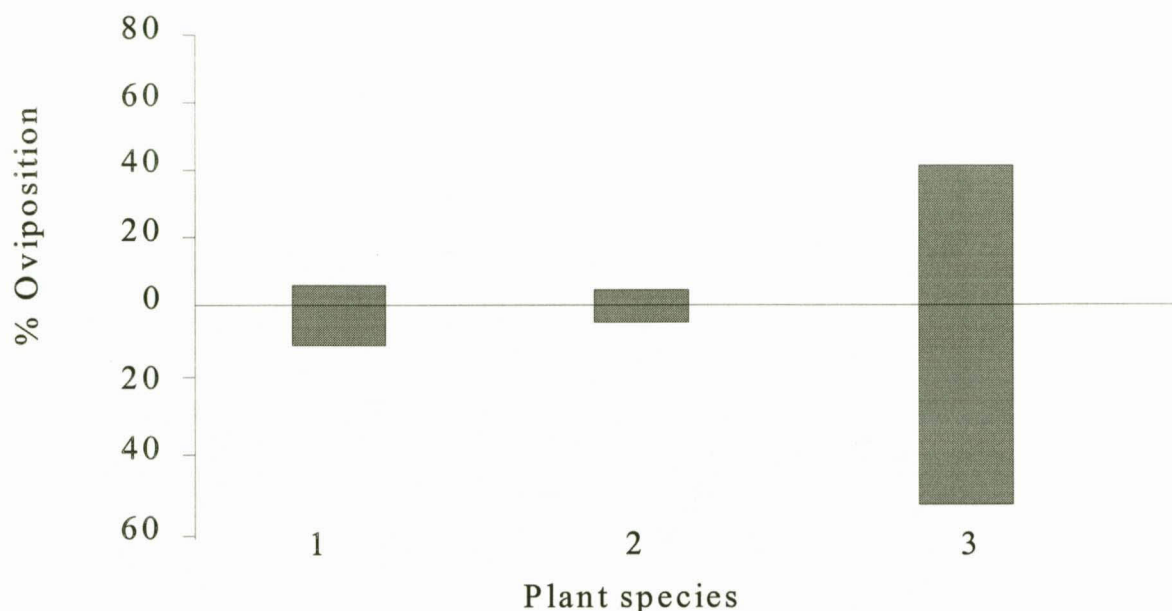
**Table 3:** Number of eggs laid by *A. segetum* moths and trichome density on leaves of various plant species.

Plant species	Mean no. of eggs $\pm$ S.D	Trichomes/cm <sup>2</sup> (abaxial)	Trichomes/cm <sup>2</sup> (adaxial)
<i>P. purpureum</i>	28.5 $\pm$ 42.8 a	17640	400
<i>V. zizanioides</i>	7.5 $\pm$ 18.4 a	90	20
<i>Z. mays</i>	20.5 $\pm$ 25.1 a	600	120

Means within columns followed by the same letter do not differ significantly at  $P = 0.05$ .

There was no significant difference between the numbers of eggs laid on the three grass species, although more eggs were laid on *P. purpureum* followed by *Z. mays* (Table 3). Eggs laid on dead plant material constituted 82 % and 90 % of the total laid on *P.*

*purpureum* and *V. zizanioides*, respectively. On fresh leaves, the abaxial was preferred over the adaxial surface for oviposition (Fig. 3).



**Figure 3:** Percentage of egg distribution on leaves of three plant species. Percentages above and below zero indicate adaxial and abaxial leaf surfaces respectively. 1: *P. purpureum*, 2: *V. zizanioides* 3: *Z. mays*.

## 2. Larvae

### (a) Survival and mass gain of newly emerged larvae

The highest number of larvae survived on *A. hybridus* and *C. album* with no significant difference between the two weeds (Table 4). Significantly less larvae survived on *V. zizanioides* and *P. purpureum* than on any of the other treatments (Table 4).

**Table 4:** Leaf pubescence, larval mass and number of surviving larvae after five days.

Treatment	Mean mass (mg) ± S.D	Mean no. alive ± S.D	Trichomes/cm <sup>2</sup> (adaxial)	Trichomes/cm <sup>2</sup> (abaxial)
<i>V. zizanioides</i>	0.5 ± 0.4 a	2.5 ± 1.2a	20	90
<i>P. purpureum</i>	0.5 ± 0.4 a	2.6 ± 0.9a	400	17640
<i>P. oleracea</i>	4.7 ± 3.4 a	5.0 ± 2.1 b	0	0
Artificial diet	5.7 ± 3.9 a	5.1 ± 2.5 b	-	-
<i>Z. mays</i>	13.5 ± 6.7 b	6.3 ± 2.6 bc	120	600
<i>D. stramonium</i>	15.6 ± 10.3 bc	6.4 ± 2.0 bc	0	0
<i>I. purpurea</i>	20.0 ± 6.1 c	6.9 ± 2.0 cd	130	70
<i>C. album</i>	41.0 ± 9.7 d	8.4 ± 1.6d e	180	60
<i>A. hybridus</i>	46.9 ± 12.9 d	8.6 ± 0.09 e	0	0

Means within columns followed by same letter do not differ significantly at P = 0.05.

Larvae fed on *V. zizanioides*, *P. purpureum*, *P. oleracea* and artificial diet gained significantly less mass than those fed on other plant species (Table 4). There was no significant difference in mass gained by larvae fed on *I. purpurea* and *D. stramonium*. *Amaranthus hybridus* and *C. album* fed larvae were approximately ten times bigger than those fed on *V. zizanioides* and *P. purpureum* and differed significantly from the other treatments.



### 3. Larval development

**Table 5:** Development and survival of *A. segetum* larvae on various host plants.

Treatment	Mean mass (mg) ± S.D	Mean no. alive ± S.D	Trichomes/cm <sup>2</sup> (adaxial)	Trichomes/cm <sup>2</sup> (abaxial)
<i>V. zizanioides</i>	0.5 ± 0.4 a	2.5 ± 1.2 a	20	90
<i>P. purpureum</i>	0.5 ± 0.4 a	2.6 ± 0.9 a	400	17640
<i>P. oleracea</i>	4.7 ± 3.4 a	5.0 ± 2.1 b	0	0
Artificial diet	5.7 ± 3.9 a	5.1 ± 2.5 b	-	-
<i>Z. mays</i>	13.5 ± 6.7 b	6.3 ± 2.6 bc	120	600
<i>D. stramonium</i>	15.6 ± 10.3 bc	6.4 ± 2.0 bc	0	0
<i>I. purpurea</i>	20.0 ± 6.1 c	6.9 ± 2.0 cd	130	70
<i>C. album</i>	41.0 ± 9.7 d	8.4 ± 1.6d e	180	60
<i>A. hybridus</i>	46.9 ± 12.9 d	8.6 ± 0.09 e	0	0

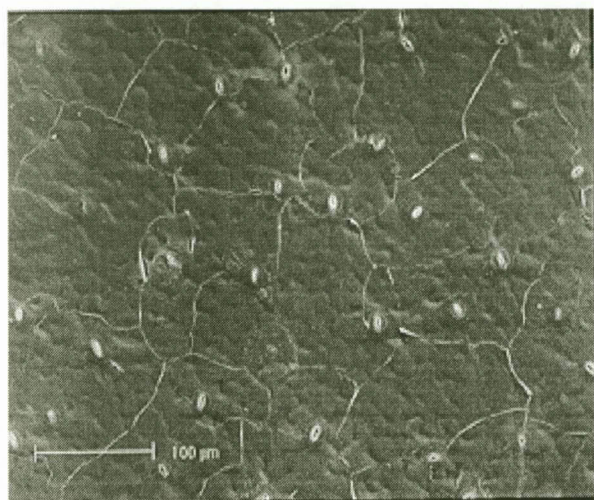
Means within columns followed by the same letter do not differ significantly at P = 0.05.

*Agrotis segetum* larvae completed their development on all plant species except on *P. purpureum* and *V. zizanioides* where larvae died while in the first instar (Table 5). Eighty five percent of larvae fed on *C. album* completed their life cycle. Larvae fed on *A. hybridus* and *I. purpurea* developed significantly faster than larvae fed on *C. album*, *D. stramonium* and *P. oleracea*. The duration of the larval period did not differ significantly between the latter three treatments. There was no significant difference in duration of the pupal period of larvae fed on *A. hybridus*, *C. album*, *D. stramonium* and *I. purpurea*. Larval and pupal development times were similar for larvae fed on *C. album* and *D. stramonium* though the percentage surviving to adults was significantly different (Table 5).

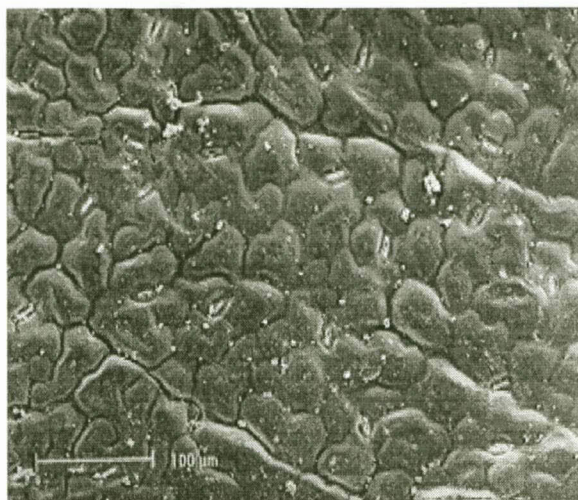
### 4. Trichome density

Trichomes were absent on leaf surfaces of *A. hybridus*, *D. stramonium* and *P. oleracea* and present on *C. album*, *Z. mays* and *I. purpurea* (Table 5). *Pennisetum purpureum* had the most trichomes and *V. zizanioides* the least.

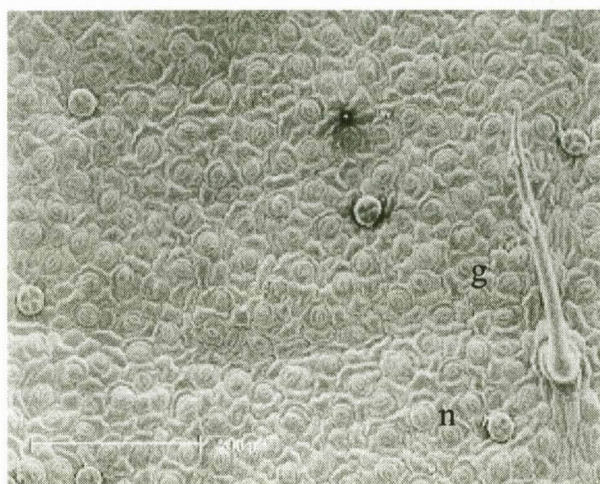
Adaxial surface



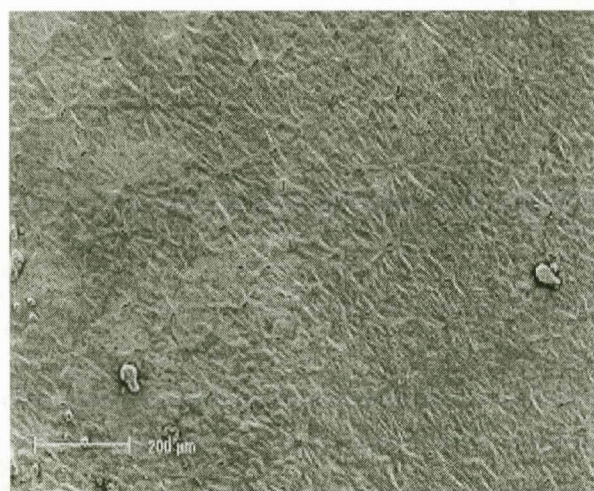
Abaxial surface



*A. hybridus*



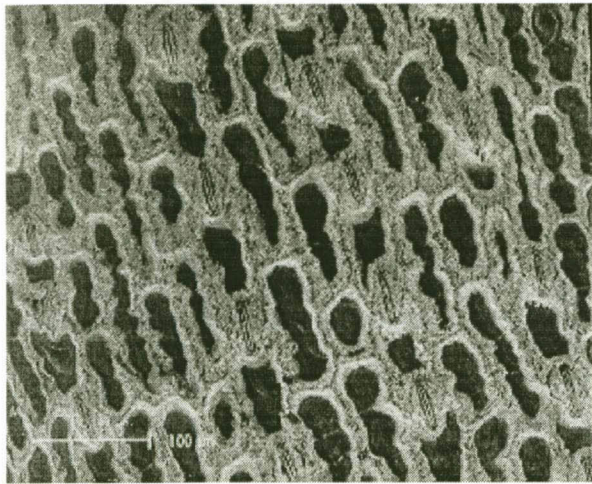
*C. album*



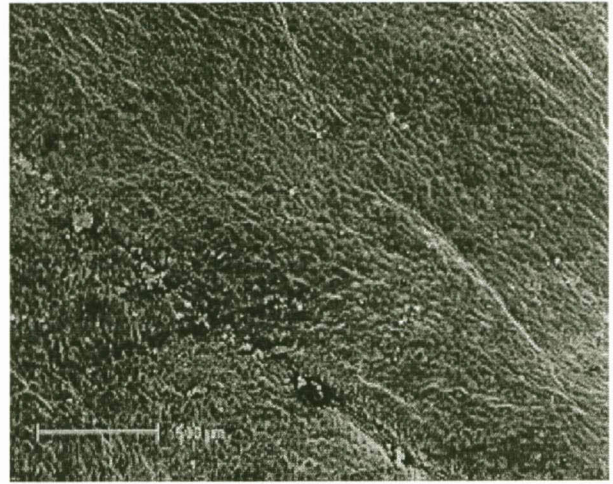
*D. stramonium*



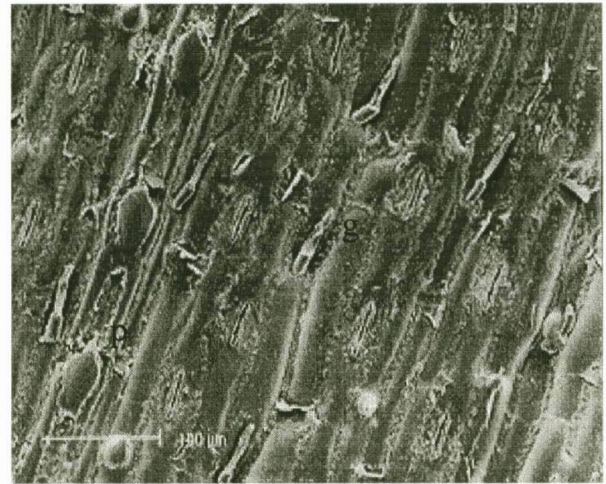
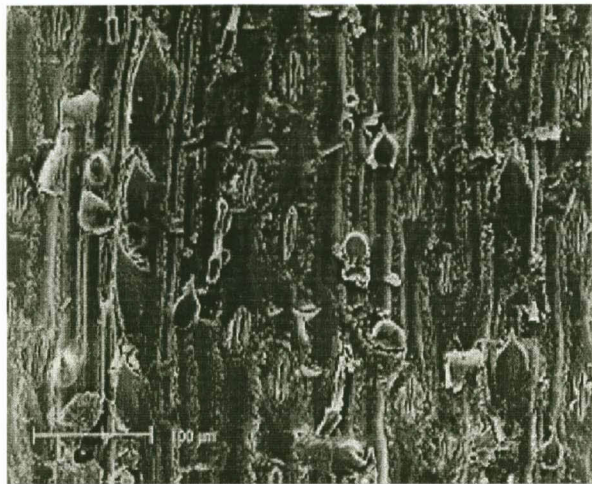
Adaxial surface



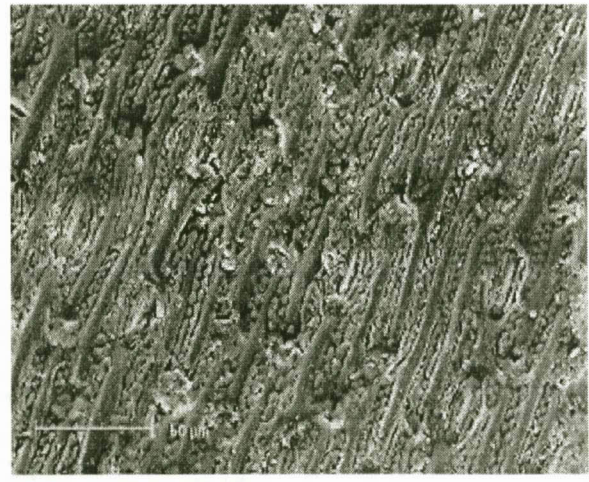
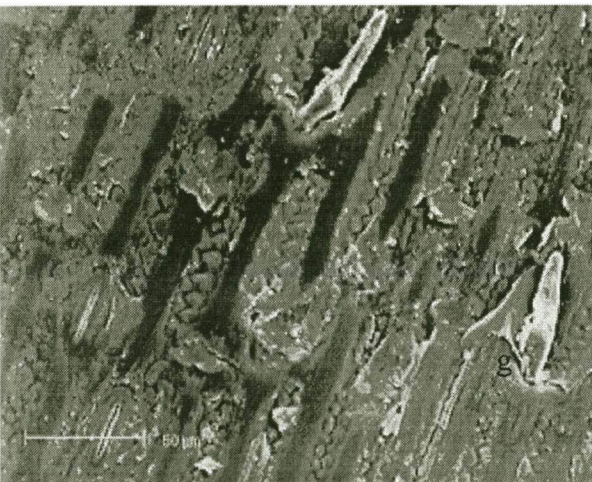
Abaxial surface



*P. oleraceae*



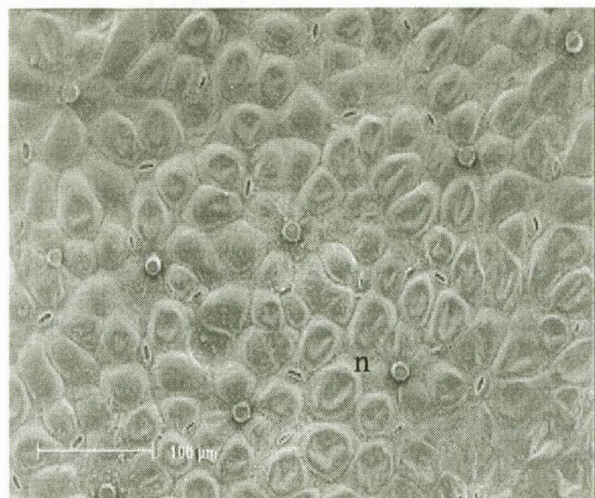
*P. purpureum*



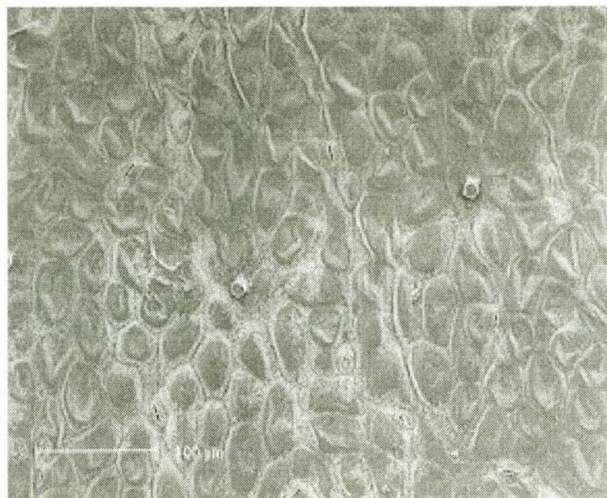
*I. purpurea*



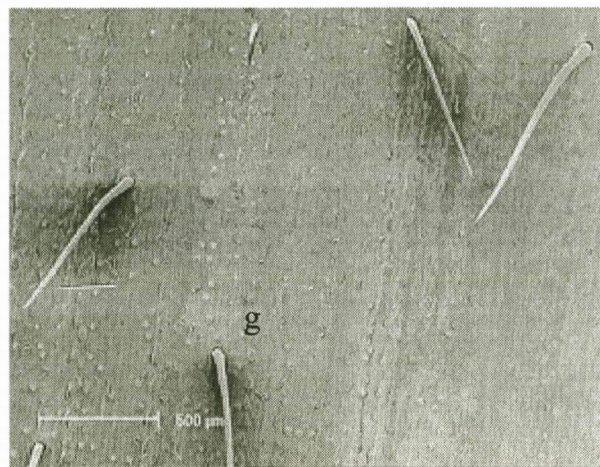
Adaxial surface



Abaxial surface



*V. zizanioides*



*Z. mays*

**Figure 4:** SEM micrographs of the adaxial and abaxial leaf surfaces of various plant species. n: non-glandular trichome, g: glandular trichome, p: prickly hair.

*Vetiveria zizanioides* contained only non-glandular and *Z. mays* only glandular trichomes, while *C. album* and *P. purpureum* contain both types of trichomes (Fig. 4). A significant relationship did not exist between trichome density and number of eggs laid ( $r = -0.32$ ).

The presence of trichomes on leaf surfaces had no effect on oviposition (Table 2 and Table 3) and on survival of first instar larvae (Table 4). A different type of non-glandular trichome, prickly hairs, was also present on *P. purpureum* and could have contributed to the low larval survival of *A. segetum* (Kruger, personal communication) (Fig. 4).

*Amaranthus hybridus* and *I. purpurea* were the most preferred for oviposition, while *C. album* and *D. stramonium* were least preferred. However, *C. album* is a more suitable host plant for development of *A. segetum* larvae. The high survival on *A. hybridus* and *I. purpurea* indicated that they were more suitable for development. *Portulaca oleracea*, *P. purpureum*, and *V. zizanioides* were unsuitable for cutworm development. Larval development was only partially corresponding with oviposition preference and this could mean that *A. segetum* females oviposited on some hosts that were relatively poor and unsuitable for larval survival. No significant relationship was established between trichome density and percentage larval survival ( $r = -0.53$ ).

## DISCUSSION

When a number of potential host plants are available, a female insect will lay most eggs on the preferred plant species (or plant part), fewer eggs on her next preferred plant and so on (Thompson & Pellmyr, 1991). Since some ovipositing insects are unable to sample the inner contents of leaves it may be expected that they would make particular use of features of the leaf surface (Sosa, 1988). Plant surface texture is crucial in the evaluation of potential oviposition sites in moths (Ramaswamy, 1988). The majority of moth species seems to prefer hairy or rough surfaces (Pedigo, 1971; Ramaswamy, 1988; Lambert *et al.*, 1992). Hairy surfaces allow the female to maintain a footing on the plant during oviposition and may retain eggs better than smooth surfaces (Renwick & Chew, 1994). However, pubescence has been reported to deter oviposition of the stem borer, *C. partellus* on leaves of different maize cultivars (Kumar, 1992). Oviposition by *A. segetum*

moths occurred on weed and grass species regardless of the presence or absence of trichomes and was not inhibited or stimulated by it. Trichome density did not act as an oviposition cue for *A. segetum* moths. The type rather than density of trichomes may therefore be inhibitory to oviposition and larval survival. Tactile, chemical and other physical factors could be responsible for stimulating the oviposition behaviour of *A. segetum* moths.

Eggs were however not laid on the host plants only, but also on the wooden frames and gauze of the cages, soil and pots. Soil moisture might partially explain soil as a preferred oviposition site, since ovipositing *Agrotis ipsilon* Rott. (Lepidoptera: Noctuidae) moths prefer soil with a fair degree of moisture (Bishara, 1932). Wet soil also accelerates germination of weeds and grasses which may be attractive to ovipositing moths (Busching & Turpin, 1977). The tendency of ovipositing on the soil in close proximity to the host plant was also documented for *Anartia fatima* Fabricius (Lepidoptera: Papilionidae) (Siberglied, 1983) and other Papilionidae species (Young, 1979). Under field conditions, this strategy protects eggs from predators that search for eggs using visual or phytochemical cues of the host plants.

*Agrotis segetum* preferred certain weeds for oviposition compared to maize. Egg laying in clusters or singly may be advantageous under field conditions. Offspring from eggs deposited singly can avoid predators and competing herbivores. In contrast egg clustering is advantageous where host plants have a patchy distribution and insures that newly hatched larvae locate siblings and remain together (Stamp, 1980). Dry matter was preferred over fresh plant material of the grass species, *P. purpureum* and *V. zizanioides* for oviposition. This result is in accordance with observations made on the stemborer, *C. partellus* which lays its eggs on sorghum plants close to the ground, often on old dry leaves (Bernays & Chapman, 1994).

Most of the eggs laid by *A. segetum* moths were on the fleshy stems of all weed species and on dead plant material of the grasses. On fresh leaves, the abaxial was preferred over the adaxial surface for oviposition. This is in accordance with the findings of Beck (1974), that oviposition by insects is not typically confined to selected plants, but also to selected plant parts.

Smaller features of the host plant are also important oviposition cues (Renwick & Chew, 1994). In some insect species it has been shown that the visual shape of leaves is a dominant cue in selecting a proper oviposition site. Neotropical heliconiid butterflies locate oviposition sites solely by visual cues (Autrum, 1981). A positive oviposition response to shorter wavelengths of light from plants of darker colour compared to lighter colours has been reported in *H. zea* moths (Pitre *et al.*, 1983). Leaf size and shape can possibly explain oviposition preference for *I. purpurea* by *A. segetum* moths, since *I. purpurea* leaves were relatively wider than the other plant species evaluated. Wider leaf surfaces furthermore constitute a larger surface area for oviposition. However, studies need to be conducted to support this speculation.

Most insects select specific host plants and manifest appropriate oviposition behaviour to ensure their survival (Hall, 1986). *Amaranthus hybridus* was one of the most and *C. album* the least preferred plants for oviposition among the weed species evaluated. However, survival of first instar *A. segetum* larvae was high on both the species, as was larval development. Oviposition preference and development on some plant species has been observed to have a close relationship (Singer *et al.*, 1988). The relationship therefore exists for *A. hybridus*, but not for *C. album*. Larval development of *A. segetum* was only partially corresponding with oviposition preference females therefore oviposit on some hosts that are relatively poor and unsuitable for larval survival.

It would be expected that larval survival would be highest on leaf surfaces with a few or no trichomes since trichomes are known to deter insect feeding (Mauseth, 1988).

Survival of *A. segetum* larvae on *A. hybridus* and *C. album* was high regardless of the presence of trichomes. *Agrotis segetum* larvae were therefore able to feed on leaves with trichomes. *Vetiveria zizanioides* had comparatively few trichomes and supported few larvae.

Polyphagous insects grow faster, live longer and reproduce better on some plant species than on others (Snyder, 1954). First instar larvae fed on *A. hybridus* and *C. album* gained more than twice the mass of larvae fed on *I. purpurea* and were approximately ten times bigger than those fed on *V. zizanioides* and *P. purpureum*. This indicated significantly higher leaf consumption by larvae on the two plant species. Sufficient nutrients or nutrient balances required by first instar cutworm larvae were therefore provided. Some instances of resistance might be attributed to the complete absence of specific stimulating nutrients required by the insect for survival and development (Painter, 1953) and may explain the differences in survival and mass gain of *A. segetum* between the plant species evaluated as well as the artificial diet. *Datura stramonium* were regarded as a poor host since few eggs were laid on the plant species while development and survival of larvae were average. The three grass species, *P. purpureum*, *V. zizanioides* and *Z. mays* were found to be suitable for oviposition but are poor hosts and did not sustain larval growth and development. Choice of oviposition site may therefore be a choice for egg survival rather than a suitable host for larvae (Straatman, 1962). The host plant significantly affected larval and pupal development times. Larval survival and development of *A. segetum* on the various plant species could be attributed to other factors such as plant nutrition, host odours, physical factors and leaf anatomy.

Physical form and tissue structure of plants influence their utilization by their insect hosts (Beck, 1965). Physical factors include tissue toughness and presence of trichomes. Small insects are sometimes inhibited to feed on certain plant species because the leaf is too tough (Miller & Miller, 1986). This resulted in resistance of rice to the larvae of the rice stemborer, *Chilo suppressalis* Walker (Lepidoptera: Crambidae) (Sasamoto, 1958).



Tissue toughness may explain the low larval survival on *V. zizanioides* since the leaves are rather thick and may inhibit larval feeding. Furthermore, plants of the Gramineae family have generally been found to possess a high silica content which contributes to tissue toughness (Sasamoto, 1958; Metcalfe, 1960). Nitrogen and silica content in grasses influenced the survival of the lepidopteran stem borer, *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae) with decreased nitrogen and increased silica inhibiting survival (Setamou *et al.*, 1993).

Other factors that could explain the differences found are plant biochemicals and surface waxes. Biochemicals released by the plant may also have adverse effects on insect feeding and survival (Beck, 1965). Plant biochemicals that have a deterrent effect on feeding may reduce survival of first instar larvae which are incapable of selecting their host plant. Many insects are known to respond to the chemical composition of wax on leaf surfaces or some of the chemicals occurring in it (Miller & Miller, 1986; Smith *et al.*, 1994). It may affect the establishment and feeding behaviour of insects on a plant, e.g aphids, planthoppers, grasshoppers and caterpillars (Beck, 1965). Similarly, factors such as lignification of cell walls, tissue sclerotization and arrangement as well as number of vascular bundles affect the feeding and establishment of insects on plants (Smith *et al.*, 1994). Tough vascular bundles have been reported to make larval feeding difficult (Mauseth, 1988).

Moisture content of the host plant may also have an effect on larval development. *Portulaca oleracea* is a highly succulent plant (Bromilow, 1995). Compared to other plant species which sustained larval growth, larvae fed on *P. oleracea* gained more mass and a low percentage survived to moths. This is in accordance with the findings of Barnes (1955) who found that food of high moisture content tended to produce larger grasshoppers.

It is evident from this study that *A. segetum*, a highly polyphagous insect oviposit on a wide range of plant species which are not necessarily suitable for larval development.

## CONCLUSION

*Agrotis segetum* moths oviposit on all plant species provided in this study regardless of the suitability of the plants for larval development. *Amaranthus hybridus* and *C. album* supported high larval survival suggesting that the two plant species could be considered as important host plants for newly emerged, *A. segetum* larvae. Various other factors may influence oviposition choice, larval survival and development of *A. segetum*. Field studies to verify what visual and phytochemical cues stimulate and deter oviposition and feeding of newly emerged larvae remain to be explored.

Not all weed species occurring in maize fields are suitable for larval development. *Chenopodium album* is a suitable host plant for *A. segetum* development. Abundance of this plant species in the field can therefore significantly contribute to high population levels. Removal of weeds therefore remains the best strategy to reduce population density of *A. segetum* larvae in fields.

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## SUMMARY

The objectives of this study were to investigate the effect of light, soil moisture and host plants on behaviour of *Agrotis segetum* (Denis & Schiffermüller). A marking technique for larvae was developed to study behaviour at night. The marker consisted of a 1:1 mixture of Humbrol paint and fluorescent powder. It had no adverse effect on larval behaviour and survival. Dusting of larvae with fluorescent powder also proved useful in tracking movement for short range studies. Powder trails could be detected for a distance of up to two meters.

The effect of illumination with different light sources i.e incandescent, infrared and UV light on activity of larvae was evaluated. Larvae were starved for 24, 48, 72 and 96 hours. Significantly more larvae that had been starved for 72 and 96 hours remained on the soil surface in search of food after an hour of illumination with infrared and UV light. Light and dark adaptation periods of 24, 48 and 72 hours had an effect on larval activity. Phototaxis of *A. segetum* was therefore influenced by their degree of starvation and dark adaptation. Larvae moved towards the light source when illuminated with UV light under field conditions possibly perceiving it as a sign of open space.

To evaluate the feeding behaviour of *A. segetum* larvae under wet and dry conditions, a greenhouse trial with *Chenopodium carinatum* R. Br., *Portulaca oleracea* L. and *Zea mays* L. was conducted. Significantly more above ground plant sections of all the three plant species were damaged under both dry and wet soil conditions. Larvae survived for approximately one week at soil moisture levels 10, 20, 40, 60, 80 and 100 % in the absence of food. To evaluate survival in the presence of food at various moisture levels, *Amaranthus hybridus* L. and *P. oleracea* were buried in separate pots at soil moisture levels 0, 10 and 80 %. All larvae remained alive for up to 10 days at the 80 % moisture level for each weed species. Larval survival was lowest at 0 % soil moisture in both the absence and presence of food. Larval development was supported until pupation on *A. hybridus* at 80 % soil moisture.



*Agrotis segetum* moths were given a choice between six plant species for oviposition. Eggs were laid on all plant species. Oviposition was however significantly higher on *A. hybridus* and *I. purpurea*. Significantly more eggs were laid on stems than on the leaves. When laid on leaves, the abaxial was preferred over the adaxial surface. There was no significant difference in the number of eggs laid when given a choice between *Vetiveria zizanioides* (L.) Nash and *Pennisetum purpureum* (K.) Schumach. Dry leaves of *P. purpureum* and *V. zizanioides* were more preferred for oviposition than fresh plant sections.

Plants selected by moths for oviposition are not always appropriate hosts for newly emerged larvae. Larval survival was low on some of the plants preferred for oviposition. First instar larvae were not able to feed on the grasses, *P. purpureum*, *V. zizanioides* and *Z. mays* and died while in the first instar. Survival and mass gain of first instar larvae fed on *A. hybridus* and *C. album* was significantly higher than on the rest of the plant species. Presence of these plant species in uncultivated maize fields seems to contribute to high population levels due to their suitability as hosts. Leaf trichome density on the plant species evaluated could however not account for the differences in survival and development of *A. segetum* larvae. The type rather than density of trichomes could be inhibitory or stimulatory to oviposition and larval survival of *A. segetum*.

**Key words:** development, grasses, light, marker, moisture, oviposition, starvation, survival, trichomes, weeds.

## OPSOMMING

Die doel van hierdie studie was om die effek van lig, grondvog en verskillende gasheerplante op die gedrag van die gewone snywurm, *Agrotis segetum* (Denis & Schifferrmüller) te ondersoek. 'n Tegniek is ontwikkel om larwes te merk om hul gedrag gedurende die nag te bestudeer. Die merker bestaan uit 'n 1:1 mengsel van Humbrol verf en fluoresserende poeier en het geen nadelige effek op die larwes se gedrag en oorlewing gehad nie. Larwes wat in fluoresserende poeier gerol is, het 'n poeier-spoor agtergelaat tydens beweging, wat dit moontlik gemaak het om bewegings snags oor kort afstande te monitor. Poeiermerke kon vir afstande van tot twee meter gevolg word.

Die effek van lig uit verskillende bronne op die aktiwiteit van larwes is geëvalueer. Larwes is uitgehonger vir 24, 48, 72 en 96 uur en belig met onderskeidelik 'n gloeilamp, infrarooi en ultraviolet lig. Na 'n uur van beligting met infrarooi en UV-lig het die aantal larwes wat uitgehonger is vir 72 en 96 uur betekenisvol meer op die grondoppervlak gebly opsoek na kos as dié wat vir 24 en 48 uur uitgehonger is. Fototaksis van die larwes is dus onderdruk deur hul graad van uithongering te verhoog. Die duur van periodes vir lig-aanpassing (24, 48 en 72 uur onderskeidelik), het ook invloed op die aktiwiteit van die larwes gehad. Onder veldtoestande het larwes in die rigting van die UV-ligbron beweeg en het dit moontlik as 'n oop ruimte waargeneem.

Om die voedingsgedrag van *A. segetum* larwes onder nat en droë toestande te evalueer, is 'n glashuisproef gedoen met die gasheerplante *Chenopodium carinatum* R. Br., *Portulaca oleracea* L. asook *Zea mays* L. Betekenisvol meer bo- as ondergrondse dele van al drie plantspesies is beskadig onder beide nat en droë toestande. In die afwesigheid van kos, het larwes vir ongeveer 'n week oorleef by grondvogvlakke van 10, 20, 40, 60, 80 en 100 %. Om oorlewing in die teenwoordigheid van kos by verskillende vlakke van grondvog te evalueer, is *Amaranthus hybridus* L. en *P. oleracea* in afsonderlike potte begrawe by grondvogvlakke 0, 10 en 80 %. Alle larwes het by 80 % grondvog tot 10 dae

oorleef op beide *A. hybridus* en *P. oleracea*. Oorlewing van larwes was die laagste by 0 % grondvog in beide die teenwoordigheid en afwesigheid van kos. Larwale ontwikkeling tot papiewording het slegs plaasgevind op *A. hybridus* by 80 % grondvog.

In 'n keuse-proef is *Agrotis segetum* motte toegelaat om te kies tussen ses plantspesies, naamlik *Amaranthus hybridus* L., *Chenopodium album* L., *Datura stramonium* L., *Ipomoea purpurea* (L.) Roth., *P. oleracea* and *Z. mays* vir eierlegging. Eiers is op al die plantspesies gelê, maar eierlegging was betekenisvol hoër op *A. hybridus* en *I. purpurea*. Meer eiers is op die stamme as die blare van plante gelê. Die abaksiale is bó die adaksiale blaaroppervlak gekies vir eierlegging. In 'n keuse-toets vir eierlegging tussen die grasse, *Pennisetum purpureum* (K.) Schumach, *Vetiveria zizanioides* (L.) en *Z. mays*, was daar was geen betekenisvolle verskil in die aantal eiers wat per plantspesie gelê is nie. Droë blare van *P. purpureum* en *V. zizanioides* is verkies bo vars plantdele.

Plante wat deur motte vir eierlegging verkies word, is nie altyd geskikte gashere vir pas uitgebroeide larwes nie. Eerste-instar larwes was nie instaat om op die grasse, *P. purpureum* en *V. zizanioides* te voed nie en het as eerste-instar larwes doodgegaan. Oorlewing en massa toename van eerste instar larwes wat op *A. hybridus* en *C. album* gevoed het, was betekenisvol hoër as op die res van die plantspesies. Indien *A. hybridus* en *C. album* plante in onbewerkte mielielande voorkom, kan hulle dus bydra tot hoë populasievlakke van *A. segetum* as gevolg van hul geskiktheid as gasheerplante. Die digtheid van trigome op blare, kon nie 'n verklaring bied vir die verskille in oorlewing en ontwikkeling van *A. segetum* larwes op verskillende gasheerplante nie. Die tipe, eerder as die digtheid van die trigome kan onderdrukkend of stimulerend vir eierlegging en larwale oorlewing van *A. segetum* larwes wees.

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