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Research Paper

Modelling the control of African Armyworm (*Spodoptera exempta*) infestations in cereal crops by deploying naturally beneficial insects

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A solution was sought for control of *Spodoptera exempta* in cereal crops. The proposed solution enhanced a previous scheme since it provided control of the pest eggs and larvae and improved the quality of crop products by replacing pesticides. The scheme consists of a surveillance and monitoring system to activate a measured response to pest invasion. In the control phase naturally beneficial insects (NBIs) were deployed via an unmanned aerial vehicle (UAV) system to control the pest population; parasite egg wasps (*Trichogramma*) were combined with a larval parasite *Diptera* (*Tachinidae*) to achieve greater control of the life cycle stages of the African Armyworm – *Spodoptera exempta*.

1. Introduction

In West Africa most cereal crops such as maize, sorghum, rice, millet and grasses are susceptible to attack from the African Armyworm (AAW – *Spodoptera exempta*) (Scott, 1991). Major upsurges occur in seasons of sporadic rainstorms and long sunny periods, which promotes new growth of planted cereal crops and grasslands. The severity and extent of outbreaks are increased following the onset of the wet season when adult wind-borne migrations of moths are attracted to lay eggs which transform into larvae (caterpillars) within 2–5 days. The newly hatched caterpillars benefit from the flush of green vegetation resulting from the rain and develop rapidly over three weeks and outbreaks can have a very high density.

The AAW larvae are capable of creating severe plant damage, which can cover several thousand square kilometres

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Nomenclature

N_h, N_e, N_l, N_p	Population density of African Armyworm (AAW): moth, egg, larvae and pupae.
N_{ew}, N_{lw}	Population density of *Trichogramma* and *Tachinidae* parasitising: egg and larvae, respectively.
K_h	AAW moth carrying capacity of the field.
m_h, m_e, m_l, m_p	AAW: moth, egg, larvae and pupae – mortality rate, respectively.
p_{ew}, p_{lw}	*Trichogramma* and *Tachinidae* mortality rate, respectively.
ξ, ζ	Efficiencies of turning prey into *Trichogramma* and *Tachinidae* offspring.
a, b	Frequencies with which *Trichogramma* and *Tachinidae* parasitoid finds and parasitises a prey: eggs, and larvae, respectively.
β	Number of eggs per day from each moth
ε	Fraction of eggs hatching into larvae
λ	Fraction of larvae changing to pupae
ρ	Fraction of pupae turning into AAW moth
α	Leaf impact factor
δ	Leaf growth rate
γ	Fraction of leaves eaten by one larva per unit time
${}_iN_{lf}$	Initial population of leaves
N_{lf}	Population of leaves
μ	Effect of leaf population food supply on larva population

with a very high population density. Severe AAW outbreaks have long been reported to occur when rainstorms follow droughts (Brown, 1962). (Tucker, 1984) and (Harvey & Mallya, 1995) reported an armyworm outbreak, which started in Tanzania in 1970, from there it migrated to the nearby nations of Uganda, Ethiopia, Somalia (Achieng, 1999) and Kenya causing up to 90% losses in crops and pasture (Kenya Agricultural Research Institute, 1986). Outbreaks travelled over thousands of square kilometres to Malawi, Mozambique and Zambia (Rose, 1979). To understand these periodic outbreaks several research studies have been completed. Haggis (1996) and Tucker (1997) produced models based on weather patterns and estimated the dates of arrival of the moths from rainfall forecasting and larval counts from field inspections to predict possible outbreaks (DLCOEA, 2002).

The recent control measures used to mitigate the damaging effect of the armyworm includes: the treatment of larvae of the AWW moth (*S. exempta*) with insecticides including azadirachtin and aqueous neem seed extracts (Tanzubil & McCaffery, 1990) in which success was dose dependent and produced a range of undesirable adverse side effects on sensitive wildlife and human health. Tucker and Holt (1999) reported a decision tool to manage insect pest migration. Dixon (2004) used biological control for AAW and Grzywacz and Mushobozi (2004) used nuclear polyhedrosis virus (NPV), a naturally present disease that kills armyworm and helps control outbreaks. Faithpraise, Idung, Chatwin, Young, and Birch (2014) proposed the control of *S. exempta* using larval parasites to attack the larvae of the pest. This system was very reliable since 95% of the pest larvae were destroyed but the system was unable to reduce the pest eggs to a sufficiently low level to maintain control. This study gave rise to the idea of deploying both parasites to attack both the eggs and larvae of the pest. Grzywacz, Mushobozi, Parnell, Jolliffe, and Wilson (2008) demonstrated in the field the effect of *S. exempta* nucleopolyhedrovirus (SpexNPV) a disease virus for the control of African armyworm outbreak. Although there was successful control of 98% of the Armyworm from the resulting epidemics of NPV, natural disease outbreaks usually occur when major crop damage has already occurred (Rose, Dewhurst, & Page, 2000). The credibility of this system is therefore questionable and it is labour intensive (Mushobozi, Grzywacz, Museve, Kimani, & Wilson, 2005) since it depends on an existing AAW outbreak to enable the NPV to be harvested (Odindo, 1981, 1983). Also the long term effects of this microbial pesticide on livestock grazing, and even the labourers harvesting the diseased armyworm, has not been considered. The negative effects of the high cyanide levels induced in *Cynodon* grasses by AAW damage, or the ingestion of caterpillars or fungal mycotoxins on AAW faeces has also not been considered.

AAW outbreaks are frequently caused by moths transported by winds (Tucker, Mwandoto, & Pedgley, 1982). Over wintering pupae may likely be transformed into the adult moths when the conditions are favourable and the eggs laid by moths in the newly grown grassland. Pest outbreaks can occur over wide areas but especially in places where major cereal crops are being cultivated (Jahn, 1995) and (Odiyo, 1984).

To provide a solution to AAW outbreaks, this research proposes the early deployment of a combination of two species of naturally beneficial insects, *Trichogramma* the egg parasite wasp and *Tachinidae* a larval parasite *Diptera* used to control the activity of the egg and larval stages of the AAW. The early deployment of naturally occurring beneficial insects in any habitat is capable of holding down the population density of pests to an economically viable level as illustrated by Faithpraise, Idung, Chatwin, Young, and Birch (2013) thus preventing future outbreaks (Cheke & Tucker, 1995).

The goal of this research is to demonstrate preventive control by modelling the effect of parasites on the AAW population and to demonstrate the effectiveness of *Trichogramma* the egg parasite and *Tachinidae* a larval parasite for sustainable biological control.

2. Materials and operational strategy

To achieve realistic results a pest control experiment was simulated with the affected crop being sorghum, also known as "guinea corn," a cereal grain that originates from Africa (Kimber, 2000) and is eaten throughout most nations of the world. It is also milled into flour for making bread, porridge and pancakes (Hugo, Rooney, & Taylor, 2003). Because of its high resistance to drought, it is particularly appreciated in arid terrains (Jordan & Sullivan, 1982).