New approach to improve livelihoods for poor farmers and pastoralist in Tanzania through monitoring and control of African armyworm, *Spodoptera exampta*

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Abstract

A new strategy to control African armyworm in Tanzania is reviewed, with the utilization of the natural disease of the armyworm, Spodoptera exempta nucleopolyhedrovirus (SpexNPV) for control of armyworm outbreaks in Tanzania serving as case- study. Also the opportunity of linking novel control methods with Community Based Armyworm Forecasting (CBAF) is reviewed.
Results from both ground and aerial application have shown that, SpexNPV is effective in controlling African armyworm if sprayed early in the outbreaks, with the mortality rate reaching 80% in 4days and >90% overall and could replace chemical insecticides in Tanzania. Further studies from the villages implementing CBAF, revealed that village forecasters achieved high level of forecasting accuracy; 75% of all positive forecasts had corresponding outbreaks, while only 25% had no outbreaks. Out of all the negative forecasts, 91% had no outbreaks while only 9% had outbreaks. This study has demonstrated that, not only SpexNPV has a potential of controlling armyworm outbreaks in Tanzania, but it also provide a mechanism for strategic control to this important migratory pest.

Key words: African armyworm; Spodoptera exempta; SpexNPV; Community Based Armyworm Forecasting (CBAF); Armyworm Related Cattle Poisoning (ARCP).

Introduction

The African armyworm, Spodoptera exempta (walker) (Lepidoptera: Noctuidae), is a serious outbreak pest of cereal crops and grasslands in Eastern and Southern Africa, devastating small scale subsistence farms and commercial production alike(Rose et 2000). Crop most frequently attacked are maize, sorghum, millet, wheat, and rice, and to a lesser extent teff, barley and sugar cane (Haggis, 1984). Indirect losses to livestock due to armyworm outbreaks in pastures are times severe and cattle deaths can occur when recently infested pastures are grazed, as some species of grass are cyanogenic when attacked by armyworms (Giorgiadis and McNaughton 1988); in one famous incident up to 100 cattle were killed (Rose et al., 2000) a phenomenon known as Armyworm Related cattle Poisoning (ARCP). Recently work by ourselves and others strongly suggest that these cattle deaths are probably due to Cyanide poisoning. This is because ARCP in East Africa is usually associated with armyworms feeding on grasses belonging to the genus *Cynodon. Cynodon* grasses are cyanogenic, which means that they liberated poisonous hydrogen cyanide (HCN) when the cyanogenic glycosides they produce are hydrolyzed by β-glucosidase enzymes (eg Brattsten et al 1983). Tanzania serve as a focal point for armyworm primary outbreaks, which goes on to cause new outbreaks else where in Eastern and Southern Africa. Their movements are largely governed by the seasonal progression of Inter -Tropical Convergence Zone (ITCZ) (Rose et all 2000). The survey carried out in 2002 in four armyworm high risk districts, showed clearly that the central armyworm forecast services as it was originally conceived (Odiyo, 1979, 1990) is not currently meeting the needs of the farmers who suffer from armyworm outbreaks. Less than 25% of all farmers interviewed could recall ever having received a forecast (Njuki, Mushobozi and Day, 2003)

The response to armyworm outbreaks has been to spray chemical insecticide, but there are major draws back with this control method. First insecticides are expensive and many poor farmers are unable to afford $10/ha chemical costs (Iles and Dewhurst, 2002), second spraying large areas of food crops and pastures with insecticides is undesirable, particularly where safety procedures are not well known and protective clothing is rarely used. Third pesticides are not always available when required particularly in subsistence cropping systems.

Against this background, a research project has been initiated in Tanzania to explore alternative non-chemical control for armyworm, including a naturally occurring pathogen of armyworm, nucleopolyhedrovirus (NPV) (Browne and Swaine, 1965), which is cheap, safe and can be produced locally and at the same time develop armyworm forecast and decision tools appropriate for rural communities. The Community Based Armyworm Forecasting is expected to overcome most communication difficulties because the forecast would be made by the same community that uses it. The SpexNPV virus occurs widely during major outbreaks of armyworm but normally it appears too late in the pest cycle to prevent serious damage to crops and rangeland. Small scale field trials in 2001 and 2002 showed that SpexNPV can be as effective as chemical insecticide in controlling armyworm outbreaks when applied early to outbreaks of larvae. Application of $1x10^{12}$ occlusion bodies of SpexNPV per hectare using standard ground application equipment to armyworm outbreaks on pasture initiate major outbreaks of NPV disease and population collapses within 4-5 days. Trials in 2004 repeated the successful ground trials and also completed successful aerial application trials on pasture. The data from these trials indicate that NPV can be used to control armyworm outbreaks and could be a viable replacement for the use of chemical insecticides in Tanzania and other parts of Eastern and Southern Africa. This paper reports on field trials undertaken to evaluate SpexNPV as a control for armyworm outbreaks in Tanzania. The trials involved evaluating the use of NPV against both the standard chemical insecticides and several neem formulations that are being assessed as alternatives to chemical pesticide.

Materials and Method
The Community Based Armyworm Forecasting (CBAF)

A total of 20 villages from 3 districts, Hai ,Kilosa and Moshi participated in the implementation of CBAF in year 2002,2003 and 2004. The villages and districts were selected based on criteria of high risks of armyworm outbreaks. A meeting was held in each village to provide an overview of CBAF and discuss the forecast communication strategy. Each village democratically elected two farmers one lead forecaster and an assistant who would attend a 2days training workshop accompanied by the village extension officer and the village government executive officer (**Plate 1**). At the end of the training workshop each village was presented with a forecasting pack (pheromone trap, pheromone lures and a can of pesticide, rain gauge, and file with record sheets) and operator's manual for rain gauge and trap, farmers were then left on their own to set-up a trap and make a weekly forecast in their village respectively (**Plate 2**). Mid- season assessment and end of season evaluation were carried out to:
1. Determine the performance of the forecasters.
2. Assess the effectiveness of forecasting information flow among the stakeholders, i.e. forecasters, farmers, village government, extension officers and the district authorities.
3. Assess the farmers' response to forecasts and perceptions about community forecasting.

The monitoring indicators included the following:
- Forecasters making correct forecasts
- Positive forecasts with outbreaks
- Negative forecasts without outbreak
- Proportion of farmers monitoring and controlling

Plate 1. **Farmers casting secrete ballot to elect village armyworm forecaster**

Plate 2. **Village forecaster collecting moth data from community trap**

The evaluation was executed using questionnaires for individual farmer interviews and checklists for the focus group discussions with farmers and discussions with the other stakeholders. One hundred farmers were interviewed individually and focus group discussions were conducted with 78 farmers in all the five villages designated for the evaluation.

The virus

The SpexNPV was a multiply enveloped NPV isolate (#0045) one of a number collected originally from wild S.exempta in Tanzania and Kenya in 1974. The virus was mass produced in third instar larvae using methods previously reported (Cherry et al 1997). After mass production the virus was counted using standard counting protocol (Wigley 1980) then freeze dried and stored at -30°C as a powder.

The field Trials

The field trials were carried out during the 2002 and 2004 armyworm seasons at several sites around Arusha Tanzania, no trials took place in 2003 as there was a prolonged drought and no significant armyworm outbreaks occurred that year. All trials were on pasture land that consisted of mixed grass species though the dominant grasses in quadrats (40%) were star grass (*Cynodon nlemfuensis*) with nutgrass species (*Cyperus spp*.) less common but important the remainder were a mixture of other species including *Chloris spp*. *Agrostis spp*. and *Segteria*. The 2002 trials reported here were carried out at M'ringa (S 03 20 25 0 E36 37 24 5) and in 2004 at a site at Tengeru ( ) and M'ringa.

Tengeru ground NPV spray trial 2004

This trial was conducted on pasture land adjacent to the research station at Tengeru. Following high moth catches in late January an infestation of young larvae (2-3 days old) were found at the paddocks at high densities (>200 larvae per m^{2}) on the 9th Febuary. Quadrat vegetation counts showed the dominant grasses in quadrats (40%) were star grass (Cynodon nlemfuensis) , 25% were mixed Cynodon and others, 10% were nutgrass species (Cyperus spp.) the remainder were a mixture of other species including Chloris spp. Agrostis spp. and Segteria ssp.

The SpexNPV was again applied at 1 x10^{12} occlusion bodies (OB) ha^{-1} ha with 0.1% triton. Other treatments were fresh neem leaf extract at 50% w/v, neem seed extract at 5% at w/v, a chemical insecticide control Diazinon applied at the recommended rate of 100 ml of ???? per ha and finally

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an untreated control. The treatment applications were made by motorized mist blower (Solo 412 aster) with an application rate of 50litres/ha with the nozzle 30-50 cm from the canopy and a swath width of 8 meters was employed. All plots were sprayed on February 12th, starting at 1530h on plot B (neem leaf), followed by plots C (neem seed), F (*Diazinon*) and E (*Spex*NPV). Spaying finished at 1800h. Throughout this period, it was hot (24-32 deg C), sunny with a clear sky and a light breeze (<2m per second). The larvae were approximately 5 days old when the grassland plots were sprayed. No rainfall occurred during the 5 days post spraying. A total of 30 quadrat armyworm counts were made the day before application and at 1, 3, 5, 7 and 9 days post application. Quadrat size was 0.25 m^2.

Plate 3.**Spraying SpexNPV at the Tengeru paddocksite, 2004**

Aerial NPV application trial 2004

The site of the trial was pastureland on the M'ringa estate a mixed farm and coffee plantation some 5 km west of Arusha. Reports from a pheromone had indicated a sudden increase in moth numbers (>200 per night) during the week beginning Monday 8th March. Newly hatched armyworms were found at densities of over 200 per m^2. The pasture was predominantly star grass (*Cynodon spp.*) with some nut grass (*Cyperus* sp.) and some clumps of non graminacious weeds and the vegetation was 3-10cm in height.

NPV treatment was applied to a 5 ha block of the pasture. An adjacent upwind block of pasture of 3 ha on the western border of the sprayed site was used for control counts. This area had similar vegetation composition and armyworm counts showed that this control area had armyworm infestation numbers not significantly different to those in the sprayed plot. Aerial spraying was carried out by a Cessna 188 plane fitted with hydraulic Cooper Pegler nozzles set on finest setting. NPV was made up in 165 litres of water with 0.02% triton surfactant to aid dispersion and applied as a 20-metre swath (GPS guided) at 20 litres per ha. Counts of the armyworm were made two days before the application then one, four, six and eight days afterwards using standard quadrat counts replicated 30 times on each plot. Ambient conditions during the trial were overcast to sunny with a temperature range of 18-34 deg C.
On the date of application larvae were in the 1st and 2nd instars and extensive windowing was already apparent in the grass due to their feeding.
All the data from trials was entered onto an excel spreadsheets. Graphs were prepared from these master spreadsheets using Sigmaplot 2001 package. Data on NPV counts was analysed and found to be non normal in distribution .This count data was analyzed using Moods median test and Mann-Witney procedure using minitab statistical package. Proportionality data (dead/alive) was analyzed for significance using Chi square tests in minitab.

Results and discussion

The Community Based Armyworm Forecasting (CBAF)

The results presented here are from the evaluation carried out in July, 2004 in five villages in Moshi district. Table 1.shows the performance of the Mabogini village forecaster and accuracy of the forecasting rules.

Table 1: Mabogini village forecaster's records

Week		Number of Moths	Rainfall (days having > 5mm)	Vege-tation	Farmers' Forecast	Correct Forecast	Out-break
No.	Date						
1	31/1 – 6/2/2004	38	2	Yes	Positive	Positive	Yes
2	7/2 – 13/2/2004	25	0	Yes	Negative	Positive	Yes
3	14/2 – 20/2/2004	43	1	Yes	Positive	Positive	Yes
4	21/2 – 27/2/2004	138	1	Yes	Positive	Positive	Yes
5	28/2 – 5/3/2004	178	1	Yes	Positive	Positive	Yes
6	6/3 – 12/3/2004	198	1	Yes	Positive	Positive	Yes
7	13/3 – 19/3/2004	386	1	Yes	Positive	Positive	Yes
8	20/3 – 26/3/2004	121	3	Yes	Positive	Positive	Yes
9	27/3 – 2/4/2004	79	3	Yes	Positive	Positive	Yes
10	3/4 – 9/4/2004	93	3	Yes	Positive	Positive	Yes
11	10/4 – 16/4/2004	281	3	Yes	Positive	Positive	No
12	17/4 – 23/4/2004	21	0	Yes	Positive	Positive	Yes
13	24/4 – 30/4/2004	2	2	Yes	Negative	Negative	No
14	1/5 – 7/5/2004	0	0	Yes	Negative	Negative	No
15	8/5 – 14/5/2004	3	1	Yes	Negative	Negative	No
16	15/5 – 21/5/2004	0	2	Yes	Negative	Negative	No
17	22/5 – 28/5/2004	7	0	Yes	Negative	Negative	No

Overall the evaluation revealed that the forecasters were dedicated to their duties. The forecasters' records were accurate and generally consistent with the forecasting rules. The forecasters reported that they would prefer to continue with the forecasting duties. This was because they had benefited as farmers and also obtained skills and knowledge about what causes the armyworms, their occurrence and how they could be forecasted.

There were variations with respect to the adherence to the forecasting rules and the accuracy of the forecasting rules (Table 2 and 3). Adherence to the forecasting rules was established by comparing the forecasts made by the village forecasters and what those forecasts would have been according to the forecasting rules (Table 2). This was meant to assess how well the forecasters understood and followed the forecasting rules.

Table 2: Adherence to the forecast rules

Correct Forecasts	Farmer Forecasts	
	Positive	Negative
Positive	25	5
Negative	0	55

Farmers never forecasted positive when they should have forecast negative. Only on 5 occasions was a negative forecast issued when according to the forecasting rules a positive forecast should have been issued. This was because the current week's data did not indicate a positive forecast but the previous week's did. However, there was only one outbreak on these occasions.

Accuracy of the forecasting rules was established by cross checking the forecasting information/records with the actual outbreaks as reported by the farmers on weekly basis. Farmers were asked to provide information on whether or not there had been any outbreaks and the weeks

during which there had been outbreaks. The farmers' information was tallied with the forecasters' records and assessed (Table 3).

Table 3: Accuracy of the forecasts

Correct Forecasts	Outbreaks	
	No	Yes
Positive	8	23
Negative	52	2

Seventy four per cent of all positive forecasts had corresponding outbreaks, while 26% had no outbreaks. Out of all negative outbreaks 96.3% had no outbreaks while only 3.7% of all the negative forecasts had an outbreak.

Table 4: compares the situation before the start of the CBAF that is baseline information about farmer perceptions and the changes attributed to the CBAF, which is after the implementation.

Table 4: Farmer perceptions change due to community based armyworm forecasting (%)

Characteristic/ attribute	Before	After
Moths are a precursor for armyworms	36	90
Knowledge of armyworm forecasting	48	80
Access to forecast information	28	64
Farmers monitoring fields	48	92
Farmers attempting control with various methods	28	77
Control at stages (instars) i & ii	20	61

Conclusion

Community Based Armyworm Forecasting proved to be effective way of warning the farmers against the impeding armyworm outbreaks. Farmers trusted the forecast information because they found a direct correspondence between the forecast and the appearance of armyworms. Seventy four percent of the positive forecasts were followed by armyworm outbreaks. Farmers appreciated early warning information because forecasting was being done at the local level which gave them time for timely control thereby reducing the level of crop damage.

Results and Discussion

Tengeru ground NPV spray trial 2004 Treatment effects

The results of the quadrat counts made on each of the 5 plots over the 11 days of the trial are shown in Figure 1, and percentage changes in the number of larvae in each plot (relative to day –1) are shown in Figure 2.

Over the duration of the trial (from day –1 to day +9), the Control plot (A) maintained a consistently high density of larvae (25-50 larvae per quadrat or 100-200 larvae per m^2). Relative to day –1, larval counts fluctuated by around $\pm$ 35% over the 9 days post-spraying (Figure 2).

The Neem Leaf (plot B) and Neem Seed (plot C) treatments exhibited similar trends to each other over the first 3-5 days of the trial (Figure 1): one day prior to, and following, spraying, larval densities were similar (indicating that neem had no immediate 'knock-down' effect). However, by day +3 larval densities were approximately half of their pre-treatment levels (Figure 2). In the case of the Neem Leaf treatment, there appeared to be relatively little subsequent mortality (and final densities were around 80 larvae per m^2), whereas in the Neem Seed treatment, numbers continued to decline, such that final larval densities on day +9 were around 50 larvae per m^2. Neem seed

seems to produce lower mortality than neem leaf extracts. This may be related to the different chemistry of neem seed and leaf extracts. In Neem seed there is a high proportion of relatively stable azardaractin.

While in neem leaf much of the insecticidal activity is in the form of smaller more volatile compounds that are likely to disappear from plant surfaces more rapidly in the field.
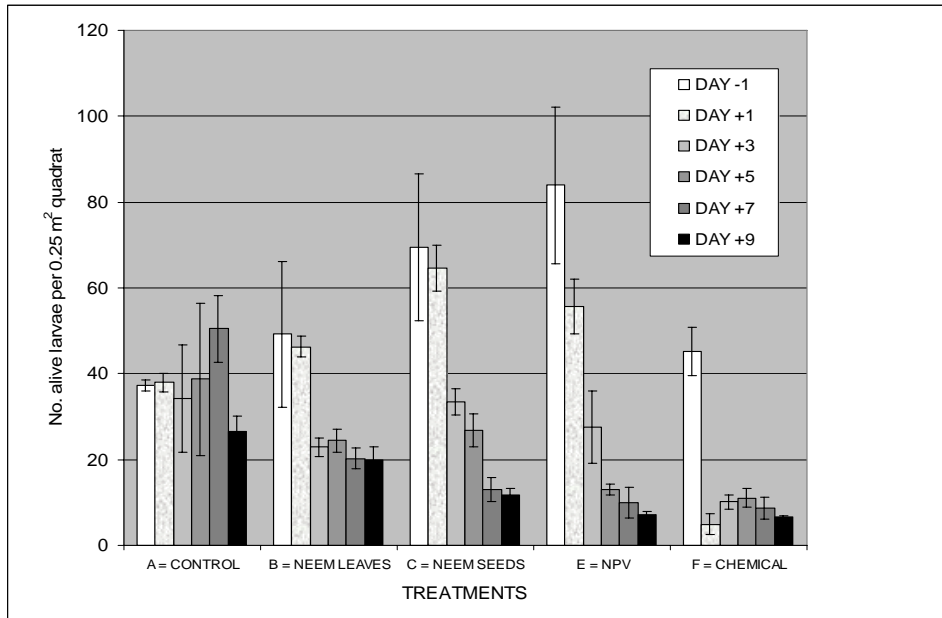

Figure 1: Densities of armyworm larvae in each plot following treatment with various insecticidal sprays (mean number of larvae per 0.25m² quadrat ± s.e.).

Results of ground application of neem and NPV on armyworm populations presented as percentage of initial populations in each treatment
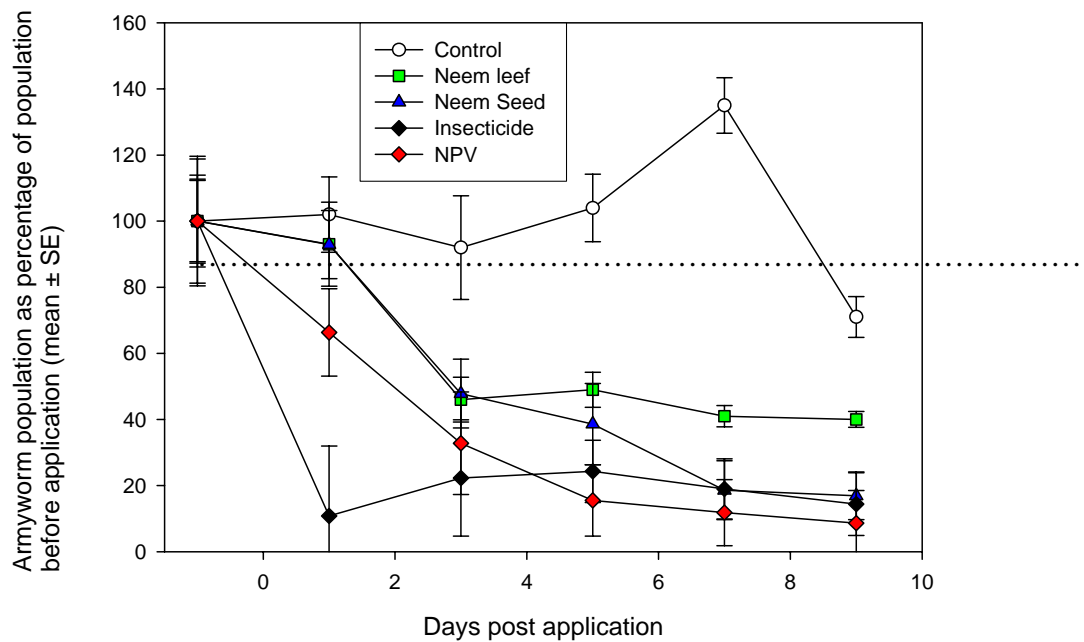
Figure 2: Results of ground application of neem and SpexNPV on armyworm populations presented as a percentage of initial populations in each treatment.

As expected, the chemical insecticide, *Diazanon* (plot F), rapidly reduced larval densities, such that 1 day post-spraying, larval densities were approximately 10% of their pre-treatment levels, and they remained low until the end of the trial, when they were c. 25 larvae per m^2 (Figures 1 and 2).

The *Spex*NPV treatment (plot E) showed a steady decline in armyworm numbers from day +1 (Figure 1). From a starting point of around 340 larvae per m^2, larval densities declined to approximately two-thirds of their pre-treatment levels by day +1 post-treatment and, by day +3, they had reduced to about one-third of their initial levels. By the end of the trial (day +9), larval densities were down to less than 30 larvae per m^2 (indicating a 10-fold reduction in larval densities). Thus, *Spex*NPV appears to reduce armyworm numbers more rapidly than either of the neem preparations. The decline in numbers on day +1 was unexpected and was not associated with the appearance of overt NPV-infected larvae (Figure 3). At present, it is not known whether the decline in armyworm numbers on day +1 was due to NPV or to some other factor, such as larval dispersal.

A small proportion of larvae in the *Spex*NPV-treated plot were observed to have died from NPV infection on day +3, but significant numbers of dead larvae were not observed until day +5 (Figure 3). The maximum proportion of NPV-infected larvae was seen on day +9, when 23% of larvae were exhibiting symptoms of overt NPV infection. There were virtually no NPV deaths observed in other non NPV sprayed plots with recorded NPV deaths in other plots ranging from 0 to a single maximum of 3 % suggesting that there was little natural background SpexNPV infection in the non NPV sprayed plots.
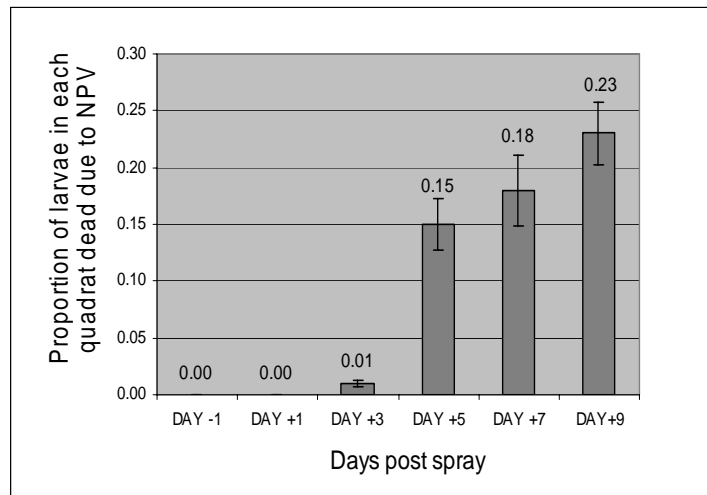

Figure 3: Proportion of armyworm larvae in each quadrat dead from NPV in the NPV-treated plot (plot E).

A recorded maximum of SpexNPV mortality rate of 23% may seems low to account for the observed population decline. However when larvae die in the field the corpses may nor be obvious or eaten by some predators making an exact correlation between observed kill and population decline difficult to obtain.

Conclusions
1) *Spex*NPV again proved effective in controlling armyworms, with mortality after 5 days in excess of 80% and >90% overall.
2) Extracts of neem leaf, and especially neem seed, have the potential to be used as alternative biopesticides to control African armyworm in Tanzania
3) *Spex*NPV reduced armyworm numbers faster than either of the neem extracts

Results and discussion
Aerial NPV application trial 2004

Spray coverage of the plot was good with an average of 45.6 drops per cm^2 and individual papers recording in the range 17.5- 84.5 drops per cm^2. This was despite the site being bounded on the south side by overhead power cables along the farm road and on the west by a belt of trees that made low level flying a problem.


Plate 4: **Spraying NPV at M'ringa site 17th March 2004**

Plate 5: **Dead and dying larvae in NPV sprayed plot hanging from the grasses**

The results of quadrat counts of numbers of larvae at both the sprayed and unsprayed sites are shown in Figure 4.

It can be seen clearly that the armyworm population in the NPV plot increased after initial scouting as larvae continued to hatch out. By the forth day after application the population of live larvae in the NPV plot fell dramatically and then continued to decline until by day 6 the outbreak declined to nearly zero in the sprayed area. In the control plot the population also declined as larvae matured but remained by day 6 at greater than 100 per m^2 a sufficient level to produce heavy damage to the pasture. Counts in the control were significantly higher than for the NPV plot on day 4 (Chi sq. = 48.65, df = 1, P=<0.0001) and day 6 (Chi sq. = 60 df=1. p = <0.0001).

Figure 4 Counts of live armyworm in untreated control and NPV sprayed plots at at M'ringa Estate NPV trial 17-27th March 2003.
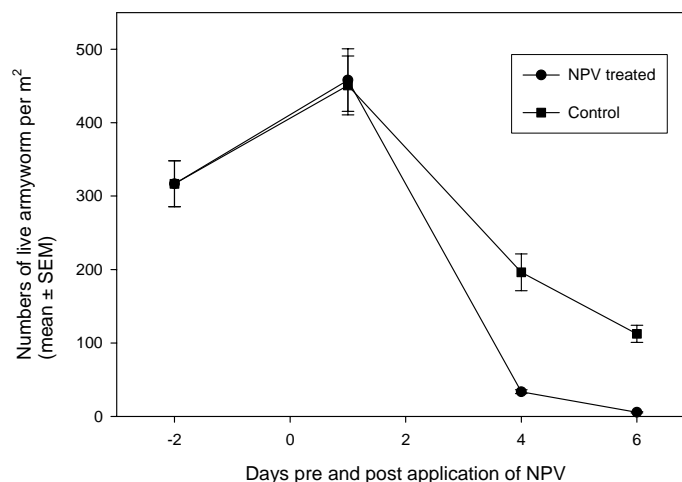
In the NPV sprayed plot the decline in live insects was accompanied by the appearance of many NPV infected and killed larvae hanging from grass stems and on the ground (see plate 5). The graph in Figure 5 shows that by day 3 over 70% of larvae counted in quadrats were dead of NPV and this rose to more than 80% by day 4.

Fig 5 Numbers of dead larvae per metre^2 in NPV and control plots in aerial trials of NPV at M'ringa 2004

Numbers of dead larvae per m2 counted in NPV sprayed and unsprayed control plots in NPV aerial spray trials M'ringa 2004

Days pre/post application of NPV
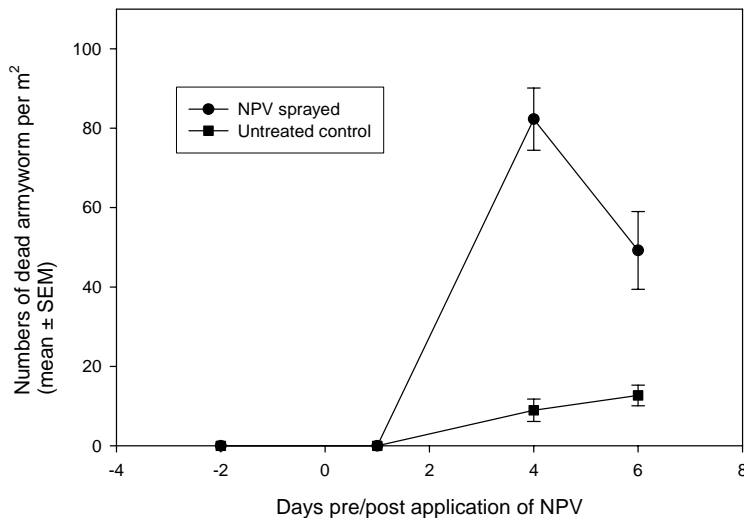
The damage in NPV sprayed area was ceased within a few days of application. The farm manager noticed that as early as the third day after spraying larvae in the NPV sprayed plot were observed to be "sickly". It is likely that this early appearance corresponded to the widespread onset of NPV infection and suggests that larval feeding would have ceased in the majority of larvae by day 3 after application. The appearance of disease symptoms by day three and high mortality by day four is encouraging as slow speed of action is often cited as major disadvantage of microbial biopesticides. This observation provides an interesting contrast with the field performance of the fungal biological pesticide "Green Muscle" on brown locusts and some grasshopper. Infected grasshoppers actively "sunbathe" to raise their body temperature and slow infection. Here the sunbathing of infected locusts produces a "fever response" that impedes the development of the disease delaying death and the markedly reducing the effectiveness of the control (Thomas and Blandford 2003).

The appearance and course of the NPV infection in the control areas was however different from that in the sprayed areas. Deaths from NPV did not become pronounced in the population of armyworms in the unsprayed areas until 27th of March, 10 days after NPV application in the trial plots. The NPV disease in unsprayed pastured occurred among dense populations (500-700 m^2) of large larvae (IV-Vth instars) that had swarmed and marched from their breeding pastures after having consumed the pastures in which they hatched. The origin of these SpexNPV infections in unsprayed plot could have arisen naturally without any connection to the NPV aerial application. Our studies have shown that *sub-lethally* infected parents are capable of passing on *lethal* infections to their offspring via vertical transmission of the virus through the ova (L. Vilaplana, E.M. Redman, K. Wilson & J.S. Cory, in prep.; see also Swaine 1966), which may trigger new virus epizootics

What is interesting here is that, the events demonstrate epidemic outbreaks of SpexNPV disease is a natural occurrence, but that it's unaided its spread is too slow to prevent larvae reaching the late stages of the V-VIth instar which is when they do 90% of their feeding and the most crop damage (see plate 6).

Plate 6. **Armyworm larvae V- VI instar in untreated plot damaging pasture**

Conclusion
 1) The effectiveness of SpexNPV in killing armyworm and preventing damage has been clearly demonstrated provided it can be applied early enough during the early larval stages.
2) The trial shows that SpexNPV can be successfully applied by aerial application to control armyworm outbreaks on pastureland in Tanzania.
3) NPV though acting more slowly than most broad spectrum chemicals can act fast enough, 3-4 days after application, to prevent serious damage to pasture crops.

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